The Cyclicality in Norwegian Farmed Atlantic Salmon Market – the approach of cobweb model.

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ABSTRACT

In this article, I estimate the cobweb model for Norwegian farmed Atlantic salmon market that allows me to verify the cyclicality of the market, and the simulations that based on the estimation indicates the evaluation of the model's explanatory ability for the cyclicality. By using annual panel data from 1994 to 2011, I found that the cobweb structure explains some part of the cyclicality. This result makes a contribution to understand about the market and make a policy for reducing the cyclicality that deteriorate the profitability of supplier in long-term.

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1 Introduction

In 1970 to 80's, aquaculture technology revolution occurred and this revolution allows us to produce gigantic amount of production in aquaculture. According to the FAO statistics (Figure1), the catch of wild fish become stable around 90million tonnes after 1990, contrast to the aquaculture production is constantly growing from 1970's. Figure2 shows that the share of aquaculture in total seafood supplies. Production quantity of aquaculture was around 3.5million tonnes that is 5% of whole seafood production in 1970, and it is increased until 83 million tonnes that is 47% of total seafood production in 2011. Basically, the aquaculture is getting larger role in supplying seafood today.

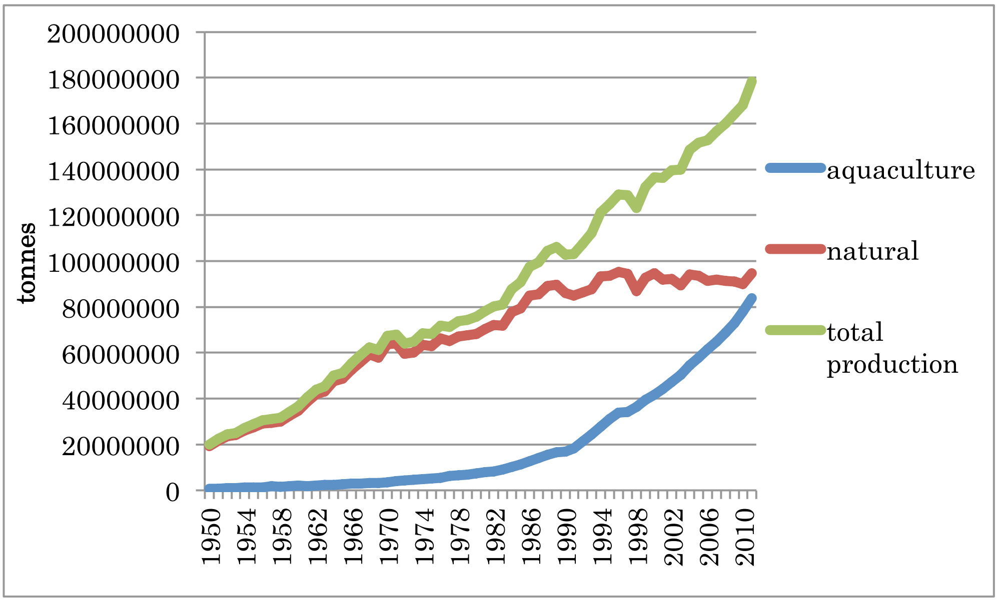

Figure 1[1]

[1] Data source: FAO Fishery Statistical Collections Global Production,

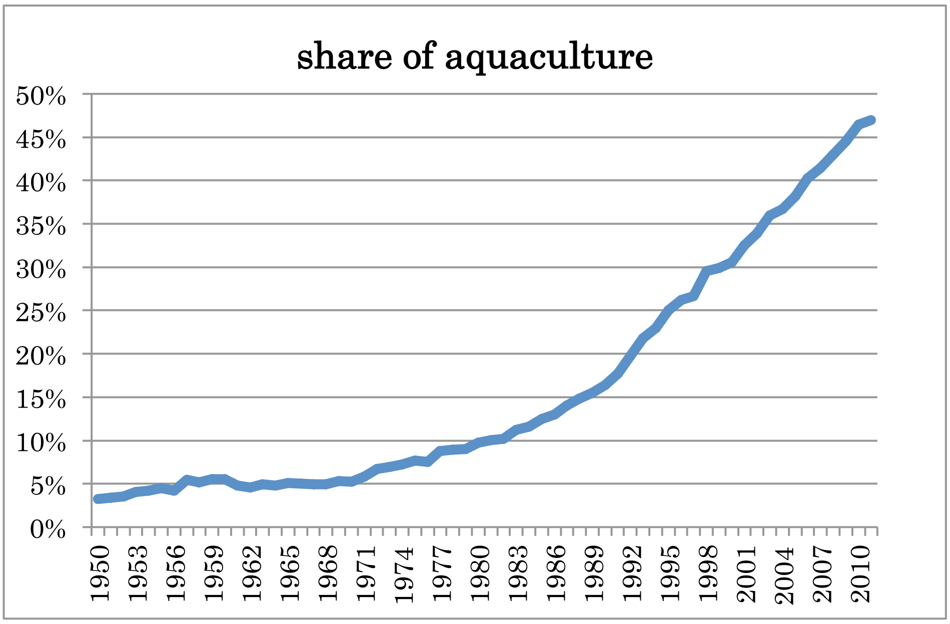

Figure 2

Atlantic salmon is the leading species of aquaculture production today, and its consumed quantity is in the top five species in most seafood markets such as EU, the U.S and Japan. Actually, share of farmed Atlantic salmon in aquaculture production quantity is just about 2 %, but the share in aquaculture production value is around 7 % in 2011. (Figure3) This indicates that salmon is highly valued product enough to attract some technological advance. In the 80's, the production of farmed Atlantic salmon was just around five thousand tonnes, and it increased to 1.7 million tonnes in 2011. Beside the whole aquaculture growth that is about 2000% of increase in the production weight from 1970 to 2011, the salmon aquaculture industry experienced about 580000% of growth in the production weight in the same period (Figure4). Norway was the leading country of this tremendous growth and it produces around 1 million tonnes in 2011, although the production quantity was almost nothing in the beginning of 1980's.

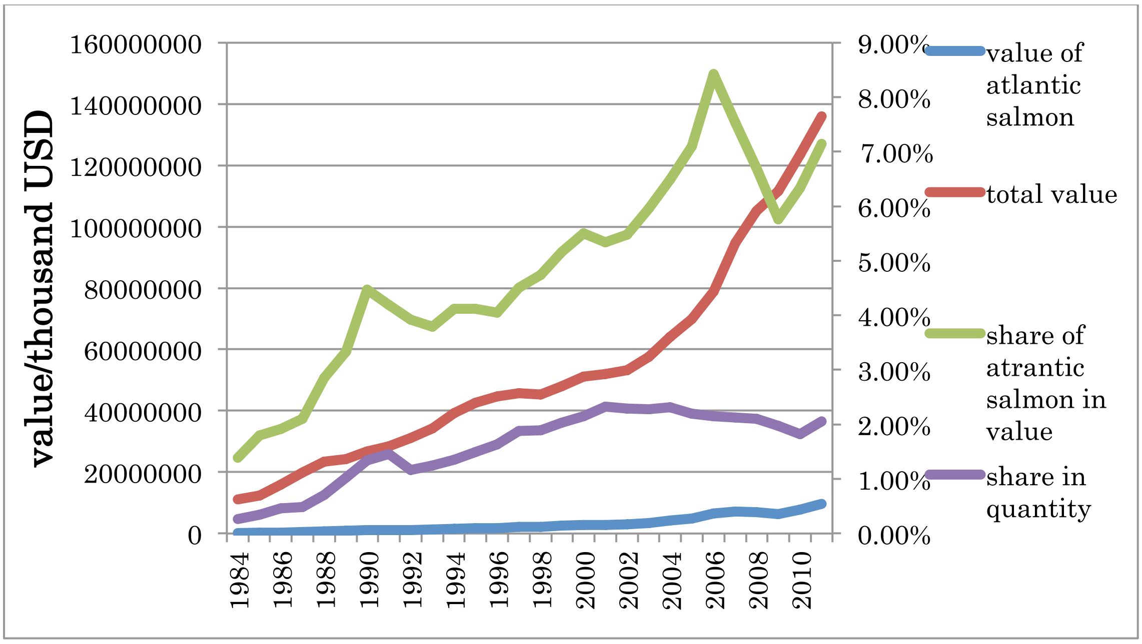

Figure 3[2]

This growth rate of Atlantic salmon production simply shows us that the advancement in salmon aquaculture was extraordinary and rapid in this era. This amazing rapid growth of production is sustained by the technological revolution that provides the opportunity of controlling the production and leads the reduction of cost. Not only the aquaculture technology itself, also the advancements of logistics system for transporting harvested farmed salmon in this period are of significance for reducing the cost. (Ashe, Roll, and Tveteras 2007)

[2] Data source: FAO Cultured Aquatic Species Information Programme, http://www.fao.org/fishery/culturedspecies/Salmo_salar/en

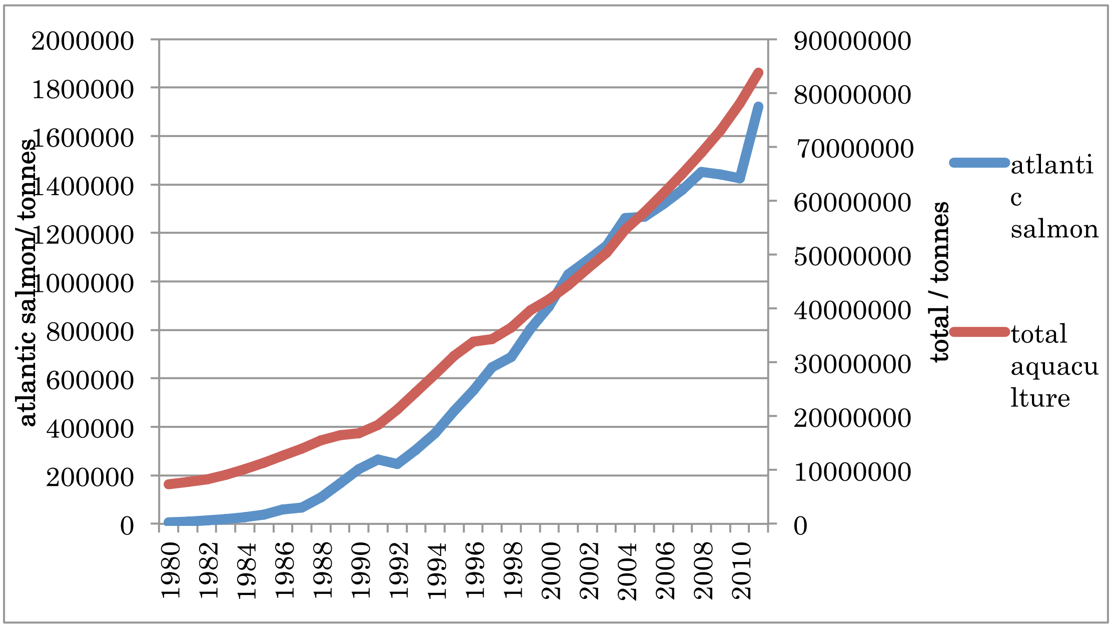

Figure 4[3]

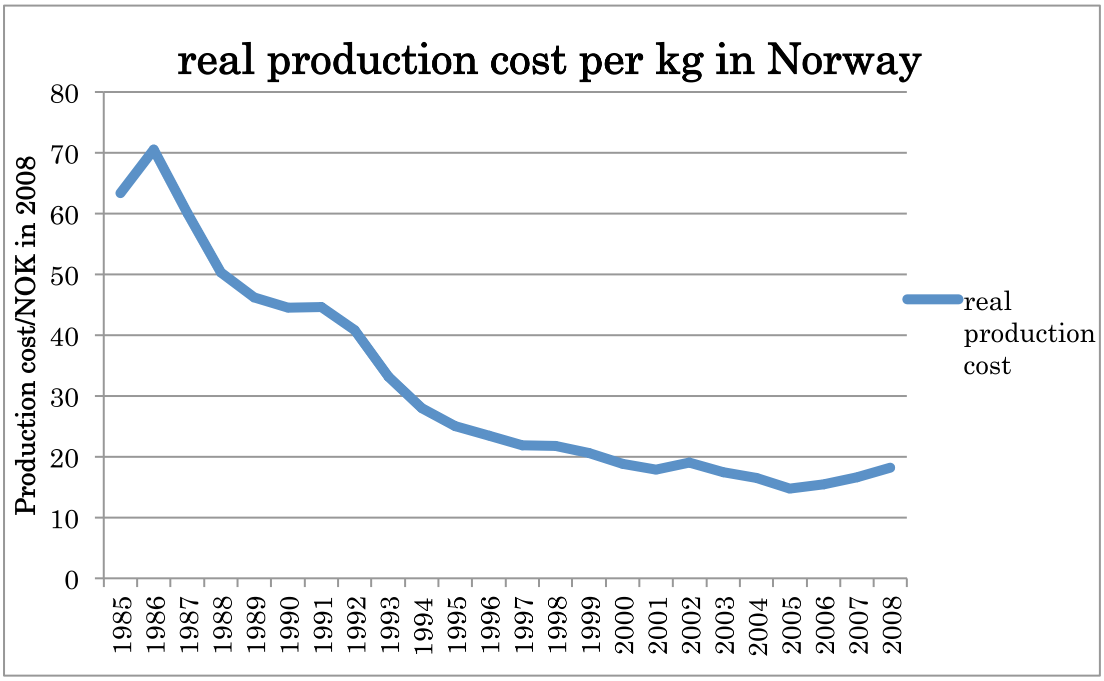

Figure 5[4]

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3 Data source: FAO Fishery Statistical Collections Global Aquaculture Production, http://www.fao.org/fishery/statistics/global-aquaculture-production/en

4 Data source: Ashe(2011) table4.1, Statistics Norway Consumer Price Index http://www.ssb.no/en/priser-og-prisindekser/statistikker/kpi/maaned/2013-06-10

Figure5 shows that the real production cost in Norway from 1985 to 2008 and there is strong time trend of declining of the production cost. The real production cost in 2008 was 28% of the cost in 1985. As a result of the cost reduction, Norwegian farmer get much higher value compared with fisherman. This profitability fascinated many suppliers to increase the production, so that the quantity of production was going up over time in this period, and price was decreasing on the other hand. As a result, compared with the price in 80's, currently the price is around 1/3. Since the price reduction attracted more customers, this supply growth was consumed by the increased demand. Ashe (2008) concluded that the substantial demand growth amplified the tremendous productivity growth. Consequently, the farmed salmon market experienced growing production and reducing price since 1980's until today, and this trend might be continued if the cost reduction keeps going.

Although the industry is getting higher productivity year by year in this era, they experienced the strong cyclicality in the price and profitability around this long-run trend. Ashe (2011) stated that this cyclicality reduces the profitability of this industry in long run. To reduce this problem from cyclicality of the market, we need to comprehend about the cycle. Therefore, the mechanism that makes this cyclicality needed to be understood. In order to approach this cyclicality we need to capture the demand and supply in long-term.

Short-term supply decision may have limited ability to explain this cycle, since the reaction for the price change will be late. On the other hand, long-term supply decision may capture this cyclicality, as it is possible to include the gap between supply decision and actual supply.

So far, most study about salmon aquaculture was focused only on supply side, especially in the innovation in many areas that made a contribution to increase productivity and reduce the unit production cost, such as Asche, Roll and Tveteras & Battese (2006) and Vassdal & Sorensen (2011). Some researches focus on the price itself. For instance, Asche and Guttormsen(2001) investigated the relationship between price and weight classes, and Oglend and Sikveland (2008) researched about the volatility of the price. Basically, most researches in this area are focusing on the single factor of the market such as price and supply side and not trying to capture the whole market that includes both supply and demand side, therefore those research did not discuss about the structure of the cyclicality mainly. One exception is the research of Asheim, Dahl, Kumbhakar, Oglend and Tveteras (2011). Their research captured both supply and demand side and estimated short and long run elasticity in both supply and demand, and then they showed that price of farmed salmon has a limited effect on supplied quantity in short term and get significant effect in long term. Since they analyzed the unique monthly dataset in order to focusing on the short-term price and supply, they did not show the analysis of the whole market in long-term, although they mentioned the possibility of cyclicality from the obtained result.

The object of this article is finding cyclicality in the Norwegian farmed Atlantic salmon market. To verify this, I am going to use the annual dataset to examine whether the cobweb structure that explains the cyclicality exists in the farmed Atlantic salmon market or not. The structure of this article is following. The next section introduces the production process of farmed salmon. In the third section, the cobweb model that explains the market cyclicality will be introduced then I am going to apply this model into the salmon farming. Section4 describes about the dataset and the issue in the estimation, then show the result of the estimation. Section5 shows the results of some simulation based on the result in section4, and discuss the evaluation of the model. Finally, I am going to provide a summary and conclusion.

2 Farming process and Cyclicality

2.1 Farming process

The biological process in salmon farming consists of the following 4 processes in Figure6 based on the life cycle of wild salmon. First process is the production of bloodstock and roe. Eggs are taken from salmon, fertilized artificially and then transported to a hatchery. Larvae hatches after an incubation period that takes about two months. Second process is the production of fry. The fry reach the fingerling phase and start developing the shape of salmon after they grow to 5g. Third process is the production of smolts. When the fingerlings become large enough, the process of smoltification begin and the fish are adapted to salt water. Fourth step is the production of farmed fish, this process is called grow up phase. The released smolt grow up to 2 – 8kg and harvested in order to supply to the market.

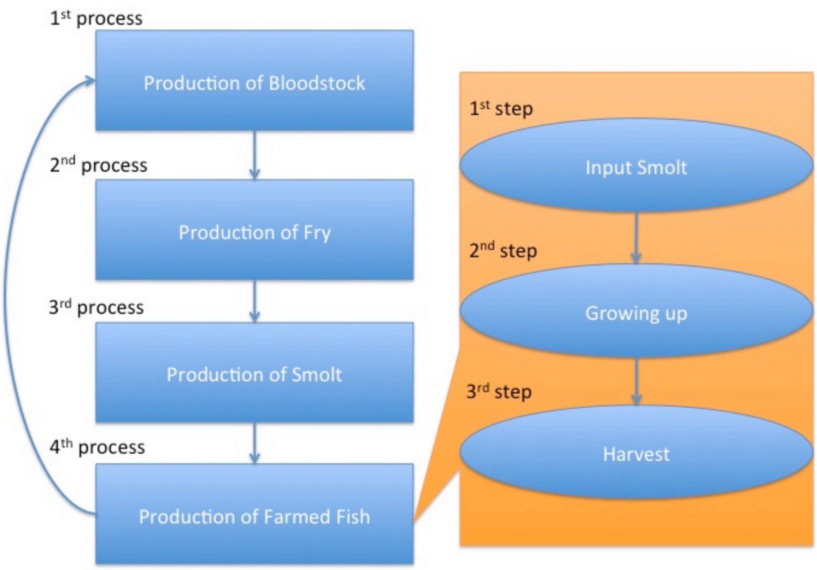

Figure 6

In the wild salmon case, the matured salmon reproduce the first step after the final step by spawning eggs. On the other hand, the salmon aquaculture does not have a renewable connection between those steps, since all farmed salmon is going to be harvested in order to supply for the consumer, and there is a separated process for just reproducing the bloodstock. As other studies, this research is going to focus on the last process, because most market related decisions are taken in the production of farmed fish process.

The production of farmed fish process can be separated into the following three steps. Firstly, release smolt that is baby fish of salmon into the fish pen. Secondly, feed those smolt until they become ready to supply to the market. Thirdly, harvest grown salmon from fish pens and supply to the market.

First step can be taken only from May to October, since smolt grows up slowly in the cold water. Because they grows faster if released in May, most smolts are released in May. Atlantic salmon through the second sequence in two years then reach weights of 2-8kg. On the other hand, Atlantic salmon become sexually matured in one year in natural. Once they get mature, they start to enter the spawning process and produce some eggs, and then deteriorate the quality as a product by losing nutrition from their body. It is possible to postpone harvesting for one year to retain the quality, but this option is not practical because the additional cost for keeping those matured salmon for 1 year make the production unprofitable. Moreover, occupied production site may lose the opportunity for putting new smolts that derive the profit in the future. Thus, farmer is required to use some technique for controlling the sexual maturity of salmon, such as an artificial light. After salmon become ready to be supplied, farmer starts to harvest those salmon and supply to the market as the third step. To sum, farmer buy smolt as an input and feed them with controlling the biological factors, then harvest when they growth.

In these processes, there are two economic decisions that are related to the market for the farmer. The long-term supply decision decides the number of smolts that is going to be released in to the fish pen. The other decision is the harvest determination that decides the timing of the transaction. In the log-term supply decision, there are two questions, how and when does the farmer decide the supply quantity, smolt input in other words. “How to decide the supply amount” is quite simple question if we assume that the supplier predict the price by using the price of when the decision is taken.

On the other hand, it is difficult to make one single answer for the question about “when does the supplier make the decision” for following reasons, although the model has to capture this factor. Smolt is usually released in May, as the growth speed is faster than other timing. However, the period when smolts are transferred to sea is slowly being extended, and an increased proportion of smolts have been transferred to sea during autumn not only in spring, especially from late 1990’s. (Ashe 2011) Hence, there are two seasons for releasing smolt into the fish pen. Moreover, different supplier may make the contract for buying smolt in different timing. Consequently, this is going to be an issue in making models and selecting data especially if we use short-term data such as monthly or weekly.

The harvest determination is recognized as short-term supply determination. The long-term supply decision determines the stock of supply in the future. Then suppliers need to decide when do they harvest and sell those stocks that derived from long-term decision. To sum, the long-term supply decision form the constraint that is the stock size to the short-term supply decision of the future. Although this is not the main focus of this research, understanding about this decision-making is of significance. Consequently, the model that is going to be formed in next section need to captures these supplier's decision-makings.

2.2 Cyclicality

Under the above-explained process, the market has cyclicality by following mechanism. When the price is higher than the equilibrium for some reason such as environmental factor, higher price makes higher predicted price then it makes some incentives to increase the production for suppliers. However, this decision makes quite ironic outcome. Because most suppliers make the same decision if the reason of higher price is global, the market is going to have large supply so that the farmers are going to get lower price and profit.

In the next step, supplier reacts to the lower price by reducing the production. As the case of higher price, most suppliers make the identical decision that reduce the production, thus the price goes up. As a result, the supplier increase the amount of smolt input, and it makes higher supply and lower price in the future and so on.

In other words, there is cyclicality in this market because of individual but identical supply decision-making that based on the simple price forecast.

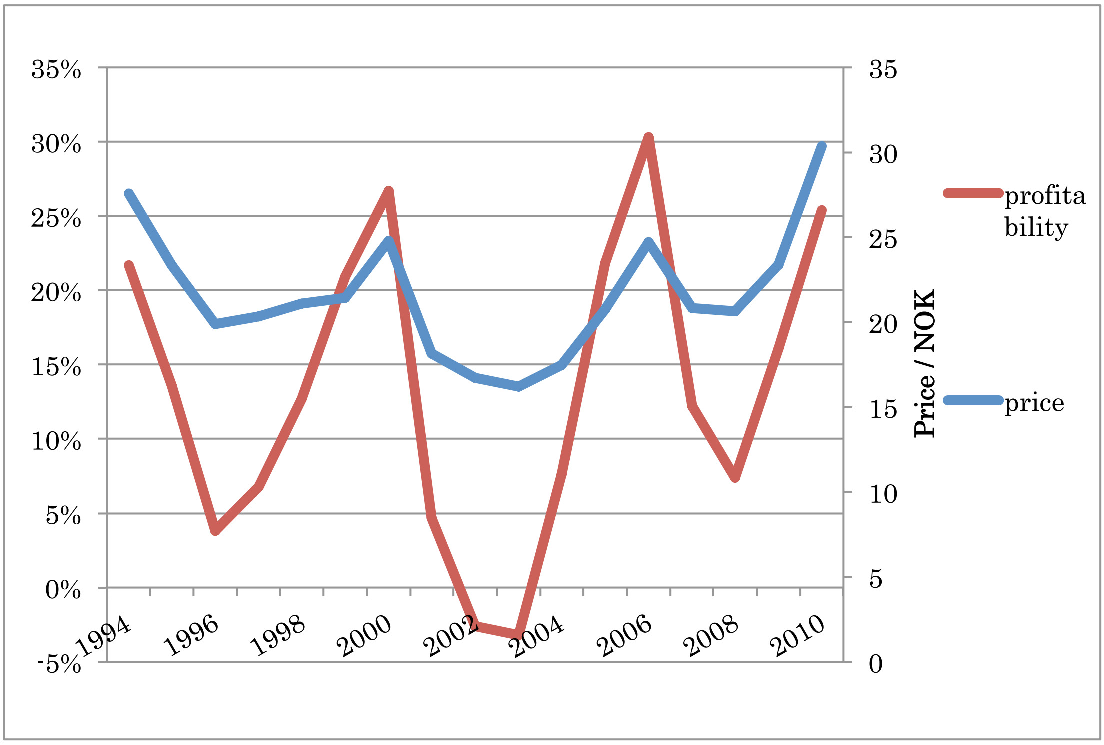

Figure 7[5]

In the real data, we are able to observe the cyclicality both in profitability and export price per kg. Figure7 indicates there is strong correlation between price and profitability and there is cyclicality. The cycle of price and profitability has the same pattern and we are able to see that the profitability risk is mainly derived from

[5] Data Source: Lønnsomhetsundersøkelse for matfiskproduksjon Laks og Regnbueørret 1994-2010, http://www.fiskeridir.no/statistikk/akvakultur/statistiske-publikasjoner/loennsomhetsundersoekelser-laks-og-regnbueoerret/loennsomhet-settefisk-laks-og-regnbueoerret

the price risk. Figure8 shows the exported quantity of Norwegian Atlantic salmon from 1990 to 2011. Although the profitability and price show the strong cycle, but the quantity seems not having strong cyclicality and it has strong trend, since the increasing trend of production quantity is strong.

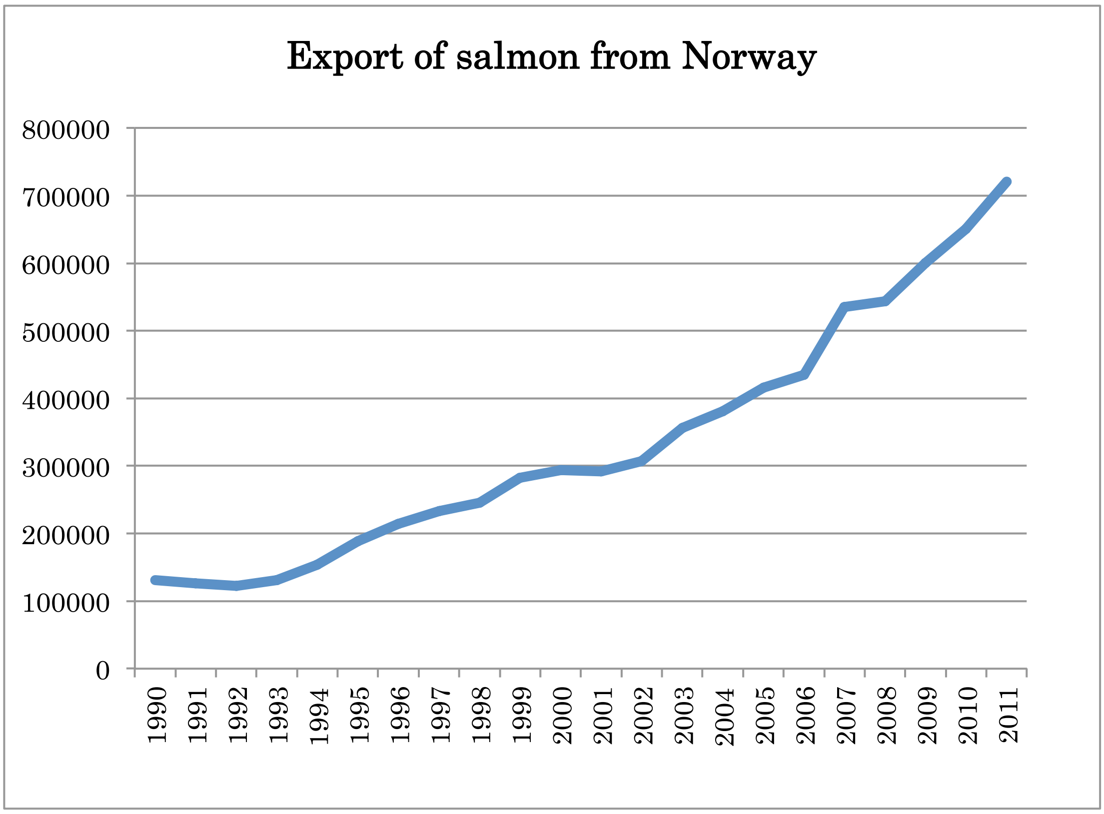

Figure 8

Then the question is going to be "how much does the above-described process explain this cyclicality on the data?". To verify this question, it is necessary to make a model that captures these supply decision system.

3 Modeling

3.1 Cobweb model

Cobweb model is well-known model to explain the time delay between the supply decision and actual supply to the market. Emile Cheysson introduced the cobweb model as economic theory for the first time in 1887. Then Ezekiel (1938) showed the dynamics in price and quantity of the cobweb model with linear supply and demand. After those works, the cobweb model has been one of the benchmark models for explaining the economic dynamics. The cobweb model describes the behavior of the price in a single market with the good that is not storable and taking at least one unit of time to produce. We are able to see some applications of cobweb model in many markets, especially in primitive goods market. For instance, the cycle that is produced by the cobweb structure in the market of pig is called hog cycle. Moreover, Richard B Freeman (1975 and 1976) explained there is such cycle in labor market especially for the market of labor that has specialty such as Engineer and lawyer. Both pig and specialized labor cannot be preserved until next year because of the cost, and these goods require long time to be supplied because of feeding and education. Therefore, cobweb model works to explain the cyclicality in those markets.

In this part, I am going to introduce the simple linear cobweb model and explain the behavior of the price that is produced from the model, and then the application in the farmed Atlantic salmon market is going to be introduce in next part.

Now we assume there are usual linear supply and demand curve, but production takes time let's say 1 year in here. This is the reason why Quantity is depending on the Predicted price ($price_t^*$) that is equal to the Price in t-1. Moreover, this good cannot be stored or it is expensive to hold for 1 year. So that the cobweb model is explained in following equations.

Supply function

$$Quantity_t = a_1 + a_2 * Price_t^*$$

Demand function

$$Price_t = b_1 + b_2 * Quantity_t$$

Price prediction

$$Price_t^* = Price_{t-1}$$

At some year, the price of the goods was higher than usual for some reason (P1 in the figure9). Suppliers produce the quantity of Q1 when the price is equal to P1. However, to let the consumer demands Q1, the price of the product has to be P2. Therefore, produces have to admit the price P2, because they are not able to preserve goods for next year. This price reduction creates some incentive to decrease the supply quantity for supplier in order to save their profit, so they decide to produce Q2. As a result, the price goes up till P3 for consuming Q2.

Then increased price lead the supply increase that makes the lower price and so on.

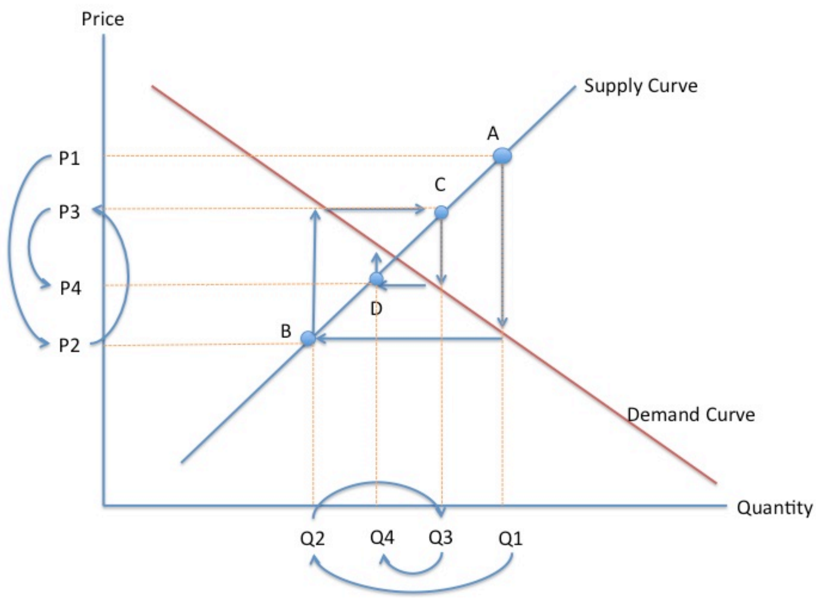

Figure 9

To sum, Price and Quantity make a cyclicality by delay of supply decision and good's characteristic that it is impossible to be preserved for next year. The outcome of the cyclicality depends on slopes of those demand and supply curve. If the slope of the supply curve is steeper than the slope of the demand curve, price and quantity are going to converge to the market equilibrium as the case of Figure9. On the other hand, if the slope of supply curve is weaker than the one of demand curve, the size of the cyclicality in the price and quantity is going to get higher and diverse away as a consequence.

3.2 Cobweb model for farmed Atlantic salmon market

The salmon farming process can be explained by this cobweb process for two reasons. Firstly, the production takes about 2 years. Basically, there is the gap between supply decision and actual supply, so that the supplier is not able to adjust the supply amount immediately. Secondly, it is expensive to preserve matured salmon for next year, since suppliers have to feed them to keep those salmons alive and sustain the quality as a product. Moreover, it is more profitable if they put new smolt instead of matured salmon for preservation purpose. As a consequence, suppliers do not have strong incentive to keep matured salmon until next year, so that they want to sell salmon before the season of smolt input. If the salmon is possible to be preserved, the supplier put those excess salmon into the cage and wait with controlling the supply quantity then the cyclicality will not show up in the market.

There are three steps in production of farmed salmon process as explained in section2. First step is input determination. In here, supplier decides the production size that is the number of individual smolt, based on the price prediction ($Price_t^*$). Therefore, the input determination is described in following model.

Input determination based on the price prediction

$$Smolt_t = a_1 + a_2 * Price_t^*$$

Second step is growing up process. Basically, this equation describes that how much does the smolt grow after two years. The most common weight when the farmer harvest those salmon is 3-5kg (Ashe and Guttormsen 2002), so that I expect the coefficient will be in this range when the model is level-level model. These two equations explain the supply side of the market in combination.

Grow up equation

$$Quantity_t = c_2 * Smolt_{t-2}$$

Third step is the phase of the market. In other word, price determination. The following model describes the demand function, so the price may low if quantity is high and vice versa.

Demand equation(price determination)

$$Price_t = b_1 + b_2 * Quantity_t$$

Salmon farming has one additional equation for growing up process compared with simple cobweb model. Furthermore, supply decision is taken as the smolt input decision. By these three equations, the cycle sequence that is explained in section 2 can be reproduced on the theory such as the case in Figure9.

However, this simple cobweb model is not able to explain the cyclicality in the data well, because there is other factors that has significant role in explaining demand and supply. Therefore, econometric model that includes some other explanatory variables is required to specify the cyclicality. In the next section, I am going to modify this simple cobweb model and solve some issues in extracting the cyclicality from the data.

4 Empirical estimation

4.1 Dataset

In this paper, cyclicality is going to be estimated with annual data for following reasons. Firstly, Leif, Roy, Subal C, Atle and Ragnar (2011) showed that price of salmon has limited effect on its supply in the short term, since the supply is largely determined by other effect such as existing stock of live salmon in the fish pen and exogenous factors in the market. By contrast, the suppliers have ability to adjust their capital and smolt input in long term, so that the price is strong incentive to change its supply in annual base. In other word, annual data has better potential to explain the influence of the price on supply quantity more than monthly data. Since cobweb model’s ability of explaining the cyclicality is based on the elasticity of demand and supply curve, estimation in long term is indispensable. Secondly, some key variables are not available on monthly basis. For instance, the number of input of smolt is obviously indispensable variable in this analysis in terms of forming the long-term supply decision model. However, this data is corrected in Norway annually, since the producer input smolt only in the limited seasons. In other word, capturing the smolt input process by making a model that based on monthly data is impossible. Consequently, if the cyclicality mechanism is based on the price prediction and the delay of supply decision, annual data is preferred rather than monthly data.

One shortage of using annual dataset is the relatively small sample size.

Compared with monthly dataset, the sample size is about 1/12 in simple calculation, so that the accuracy of the statistical estimation will be lower. In order to mitigate this issue, I am going to use annual panel dataset that individual dimension is Norwegian County. The export price and county local prices are not identical, but the gaps between those prices are roughly constant over time. (Figure10) This constant gap might the revenue of agents that take part of supply chain. Therefore, the county base price can be a good proxy of exporting price.

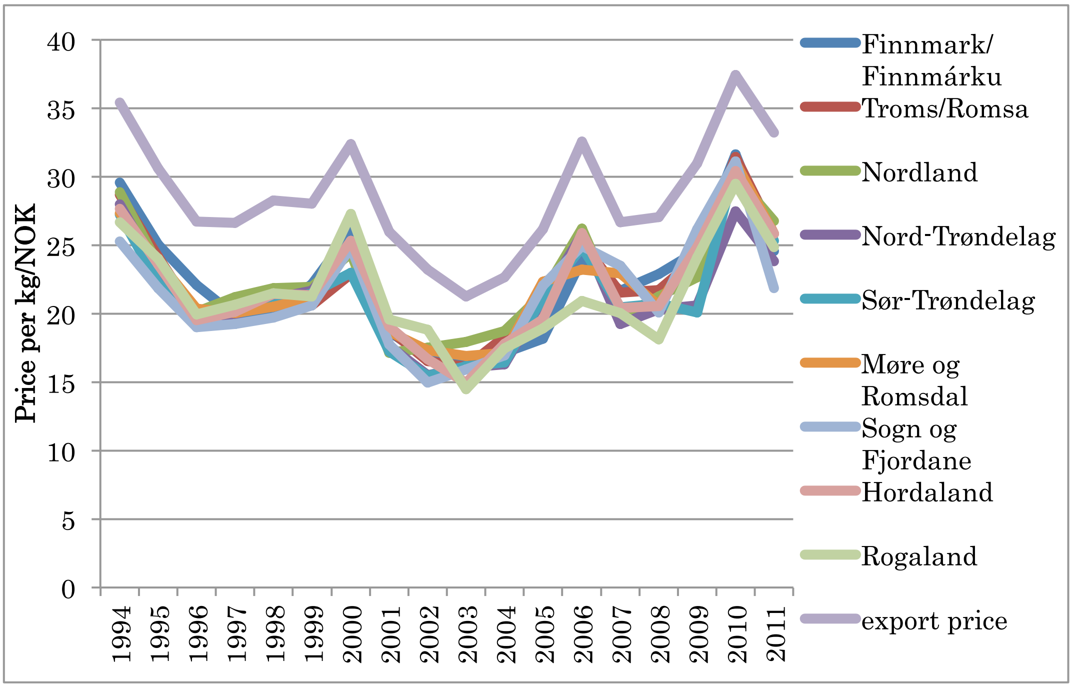

Figure 10

The annual panel dataset that I am going to analyze has been collected by FISKERIDIREKTORATET (Norwegian Directorate of Fisheries), NORGES BANK and French National Institute of Statistics and Economic Studies. The duration of the data set is 1994 to 2011. Total observations are 162. The detailed definition of each variable is explained in Appendix.

4.2 modeling

In this part, it will be shown that the model of farmed salmon market for econometrical estimation with annual panel dataset.

Equation1: Long-term Supply determination model

$$\log\left(\frac{input_{it}}{license_{it}}\right) = \alpha_0 + \alpha_1 * \log(price_{it}^{*}) + \alpha_2 * T + a_i + u_{it}$$

Long-term supply determination (input decision) is specified with log of input per license ($\log\left(\frac{input_{it}}{license_{it}}\right)$) as the dependent variable. The independent variable is log of annual average price in the last year ($\log(price_{it-1})$) and the time trend (T). In this equation, smolt input is depends on the sales price at farm gate. Since the input amount is divided by the number of license and the growth of industry is diminished, the trend capture only effect of untied biomass regulation and technological advancement. Unspecific individual effect is captured by a_i, and it may include geographical characteristics. As discussed in section2, it is difficult to capture the supplier's decision for smolt input precisely, since they might use different information. Some farmer may use the price of August in last year, contrast to some other farmer use the price of January in this year. To make a model of this decision-making, it is required to have a reasonable simplification. Thus, I made the following 12 regression models for checking the effect of each particular month's effect on the long-term supply determination. Table1 is the result of regressions that regress price of each month on the size of smolt release. All month's price except for January, are not statistically significant. This shows that the supplier does not determine the production size from the price of the current year.

$$\log\left(\frac{input_t}{license_t}\right) = \alpha_0 + \alpha_1 * \log\left(price_{january,t}\right) + \alpha_2 * T + u_t$$

$$\log\left(\frac{input_t}{license_t}\right) = \alpha_0 + \alpha_1 * \log\left(price_{February,t}\right) + \alpha_2 * T + u_t$$

$$\vdots$$

$$\log\left(\frac{input_t}{license_t}\right) = \alpha_0 + \alpha_1 * \log\left(price_{December,t}\right) + \alpha_2 * T + u_t$$

To check the effect of the price in last year, I regressed the same equations but used log of lagged particular month's price instead of the current particular month's price. Table2 is the result of those regressions. All month's prices are statistically significant in here. Because of the lack of information about long-term supply decision process, it is difficult to determine which one of those significant prices is the best for making the model of long-term supply decision. Therefore, the annual price that may capture those all month's effect is going to be used. Moreover, the annual price of current year include many non-significant month's effect, so that the annual price of last year ($price_{it-1}$) is going to be used in here.

	January input	February input	March input	April input	May input	June input	July input	August input	Septemb input	October input	Novembe input	Decembe input
trend	0.0533***	0.0528***	0.0523***	0.0527***	0.0528***	0.0532***	0.0526***	0.0527***	0.0532***	0.0536***	0.0532***	0.0530***
	-19.83	-18.13	-17.73	-17.37	-17.58	-17.86	-17.67	-17.74	-17.82	-17.43	-17.74	-17.19
jan	0.217*											
	-2.22											
feb		0.15										
		-1.49										
mar			0.156									
			-1.54									
april				0.0938								
				-1.04								
may					0.0924							
					-1.12							
jun						0.0833						
						-1.12						
jul							0.094					
							-1.29					
aug								0.112				
								-1.29				
sep									0.116			
									-1.06			
oct										0.0819		
										-0.7		
nov											0.113	
											-1	
dec												0.0723
												-0.7
_cons	-102.2***	-101.0***	-100.1***	-100.8***	-100.9***	-101.6***	-100.6***	-100.8***	-101.8***	-102.4***	-101.8***	-101.1***
	(-18.98)	(-17.42)	(-17.14)	(-16.70)	(-16.87)	(-17.05)	(-16.96)	(-17.04)	(-17.01)	(-16.47)	(-16.94)	(-16.50)
N	18	18	18	18	18	18	18	18	18	18	18	18

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1

	January input	*February* input	*March* input	*April* input	*May* input	*June* input	*July* input	*August* input	*September* input	*October* input	*November* input	*December* input
year	0.0554***	0.0534***	0.0519***	0.0522***	0.0519***	0.0520***	0.0508***	0.0506***	0.0515***	0.0522***	0.0514***	0.0506***
	-25.57	-23.32	-21.56	-20.07	-18.74	-19.46	-18.97	-19.31	-19.59	-19.28	-20.75	-18.78
L.jan	0.448***											
	-4.89											
L.feb		0.375**										
		-4.12										
L.march			0.336**									
			-3.64									
L.april				0.254**								
				-3.07								
L.may					0.193*							
					-2.58							
L.jun						0.177*						
						-2.86						
L.jul							0.177*					
							-2.92					
L.aug								0.219**				
								-3.11				
L.sep									0.264**			
									-2.98			
L.oct										0.267*		
										-2.76		
L.nov											0.297**	
											-3.45	
L.dec												0.241*
												-2.9
_cons	-107.3***	-103.1***	-100.00***	-100.2***	-99.38***	-99.56***	-97.15***	-96.85***	-98.92***	-100.3***	-98.73***	-96.94***
	(-24.11)	(-22.18)	(-20.66)	(-19.17)	(-17.91)	(-18.58)	(-18.20)	(-18.58)	(-18.79)	(-18.41)	(-19.93)	(-18.10)
N	17	17	17	17	17	17	17	17	17	17	17	17

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2

In addition, in the purpose of forming the cobweb mechanism, annual price is more convenient unless the annual price fail to capture the farmer's decision. Therefore, in this model it is assumed that the price prediction is equal to the annual price in the last year. ($Price_{it}^{*} = Price_{it-1}$)

Equation2: Growth equation

$$\log\left(\frac{supply_{it}}{license_{it}}\right) = \beta_0 + \beta_1 * \log\left(\frac{input_{it-2}}{license_{it-2}}\right) + b_i + e_{it}$$

Growth equation (equation2) has log of supply quantity per license as the dependent variable. Independent variable is log of the smolt input per license of two years before. Basically this equation describes that how many percentage of salmon is going to be produced when the smolt input is increased by 1%. Combining these above two equations, it is possible to see the effect of the price of farmed salmon in year t-3 on the supply quantity in year t.

Equation3: Demand equation (price determination) model

$$\log(price_{it}) = \gamma_0 * \log(supply_{it}) + \gamma_1 * \log\,(currency_t) + \gamma_2 * T + c_i + \varepsilon_{it}$$

Demand equation (equation3) has price of farmed salmon as the dependent variable. Explanatory variable is supply quantity, currency rate and time trend. Since the price is determined by total supply in the market, the total supply amount is used in here instead of supply per license. Currency rate is the real rate between France and Norway. Because France is the biggest importer of Norwegian Farmed salmon over time, the demand of France has significant effect on the price determination. Hence, this currency rate between France and Norway ought to have significant effect on the price. Because the price and supply quantity are determined jointly, there is a simultaneity problem in estimating this model, and it means that one of the explanatory variables in a regression model is endogenous. As a conclusion the OLS estimator is biased and inconsistent in here. Next part is going to discuss more about this problem and the solution for this problem.

4.3 Simultaneity Problem

Since there is simultaneity problem in price determination process, Instrumental Variable Method is going to be used in here. The price determination model indicates that the price is derived by the quantity. However, this relation can be reversed in reality. The producers want to sell their salmon when the price is higher than usual. In the other side, large supply quantity makes lower price. Thus, quantity can be explained in following simple model.

$$Quantity_t = b_1 + b_2 * Price_t$$

To sum, there is simultaneity problem like other market. However, there is one thing different in here. Simultaneity caused only in short-term and not in long-term supply decision. Long-term decision determines the limit of short-term supply of two years later and is determined by the price of one year before the input. But the current price is determined by the current short-term supply and not input of this year. Therefore, there is no simultaneity problem in long term supply decision as there is delay between supply and supply decision.

To eliminate the simultaneity problem in short term supply decision, I am going to use the excess stock per license from last year as an instrumental variable in estimating. There are two requirements for valid Instrumental Variable. Firstly, Instrumental Variable has to be correlated to the variable that has simultaneity problem. Secondly, Instrumental Variable has to be uncorrelated to the dependent variable. Consequently, the variable that is not correlated to the price and correlated to the quantity is required in order to estimate the short-term demand model. Excess stock per license from last year satisfies these two indispensable characteristics. When the farmer has large amount of excess stock from last year, the farmer has to sell it before smolt input anyway. Thus, the amount of excess stock from last year has an effect on the supply quantity in this year. On the other hand, the ratio of excess stock is small compared with total supply, so the effect on the price may small. Furthermore, since the excess stock has to be sold in the limited period before smolt input, the effect on price is small in long-term. Therefore, I am able to expect that the excess stock does not have significant effect on Price but is correlated to the annual supply quantity.

4.4 Result

	input fe	*input re*	*grow fe*	*grow re*
	ln(input/license)	ln(input/license)	ln(harvest/license)	ln(harvest/license)
L.ln(price)	0.186*	0.182*		
	-2.45	-2.39		
trend	0.0503***	0.0503***		
	-18.69	-18.6		
L2.ln(input/license)			1.023***	1.029***
			-25.09	-25.9
constant	4.201***	4.212***	1.208***	1.180***
	-18.08	-17.65	-5.77	-5.72
N	153	153	144	144

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3

The result of Hausman-test for input determination model has 0.89 of P-value and for growth model has 0.55 of P-value, so that these test results indicates that the estimator of random effect and fixed effect are not significantly different in these models. As a consequence, Random effect is preferred in both models. In the result of input decision model, log of lagged price, time trend and constant term are statistically significant. The coefficient of the lagged price states that 1% of additional price in previous year makes 0.18% of additional smolt input amount. The coefficient of the time trend was 0.05, so the smolt input growth 5% every year.

This result may capture the technology advance and mitigating regulation on the biomass.

Long-term supply determination model

$$\log\left(\frac{input_{it}}{license_{it}}\right) = 4.212 + 0.182 * \log(price_{it-1}) + 0.0503 * T + a_i + u_{it}$$

In the result of growth model, 2year lagged input amount per license and constant term are significant. The coefficient of log of input per license indicates that 1% of additional smolt input makes 1% of additional supply amount. Since the farmer cannot harvest more than they input and the growth of the smolts depends on the duration of the growing process and not on how many are put, so that this result makes sense.

Growth equation

$$\log\left(\frac{supply_{it}}{license_{it}}\right) = 1.18 + 1.029 * \log\left(\frac{input_{it-2}}{license_{it-2}}\right) + a_i + u_{it}$$

By combining these two results, we are able to state that 1% of additional price increase the supply quantity by 0.18%.

	Fixed	*Random*	*Fixed IV*	*Rnadom IV*
	log(price)	log(price)	log(price)	log(price)
log(supply per licence)	-0.141*	-0.0214	-0.246**	-0.108*
	(-2.46)	(-0.86)	(-2.98)	(-2.54)
log(currency rate)	2.226***	2.229***	2.000***	1.971***
	-5.11	-5.12	-4.68	-4.58
time trend	0.0612***	0.0504***	0.0710***	0.0585***
	-5.92	-5.47	-6.18	-6.11
constant	-0.525	-1.726	0.984	-0.342
	(-0.46)	(-1.72)	-0.79	(-0.33)
N	162	162	153	153

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4

The result of Hausman-test for usual Fixed effect and Random effect is Prob>Chi2 = 0.09 and for Fixed effect and Random by Instrumental Variable method is Prob>Chi2 =0.28, so that these test results indicates that the estimator of random effect and fixed effect are not significantly different. Moreover, the price determination might follow the same mechanism, so that the individual specific effect may not have correlation with the error term. In the random effect estimation result, the supply quantity does not have significant effect on the price. This result may be occurred by the simultaneity problem. On the other hand, this problem is solved in the result of Instrumental Variable Method. The coefficient of log of supply amount per license is -0.108. In other word, 1% of additional supply reduces the price by 0.1%. Log of currency rate has 1.971 of coefficient in here, and time trend indicates the price goes up by 5.85% every year. Constant term is not statistically significant in here. Therefore, we estimated following model in here.

Demand equation (Price determination)

$$\log(price_{it}) = -0.108 * \log(supply_{it}) + 1.971 * \log(currency_t) + 0.0585 * year + a_i + u_{it}$$

Since it was confirmed in these above estimations that the effect of the price in long-term supply decision was positive and the supply quantity has negative effect in price determination, we are able to expect that there is the cobweb type cyclicality that is described in section3. The next section is going to show some simulation results based on the result in this section and evaluate the econometric model that is formed in this section.

5 Simulation of cobweb model

5.1 Deterministic model

The main purpose of running simulations is evaluating the estimated model in terms of the ability to explain the cyclicality in the Norwegian farmed salmon market. I am going to run three simulations and reproduce the price pattern and production quantity to evaluate the estimated model by comparing those simulations and actual data.

In this part, I am going to show the process of simulation and the result of deterministic model. The following figure is the sum of this simulation sequences.

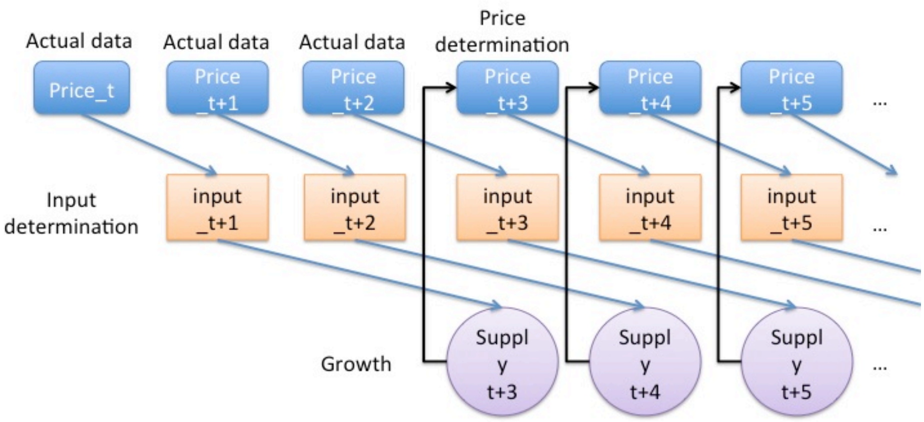

Figure 11

Basically, I am going to make two equations that calculate the price and supply in the future and insert the actual price for the first three years and see whether is produce the cyclicality. For simplicity, I am going to simulate the average annual price and total production amount among counties, since it is difficult to simulate for each county. Hence, instead of county level price ($price_{it}$), I used average price among counties $avgprice_t$.

Firstly, input determination model without stochastic term was inserted into the growth model to obtain the equation for calculating the current supply amount per license from the price in the past. Since the dependent variable of growth model is supply amount per license, it has to be multiplied by the number of licenses in order to insert into the price determination model. As a result, the equation for obtaining the current total supply amount from average price in 3 years before is obtained.

$$\log\left(\frac{supply_t}{license_t}\right) = 1.18 + 1.029 * (4.212 + 0.182 * \log(avgprice_{t-3}) + 0.0503 * T)$$

$$supply_t = license_t * exp\big(1.18 + 1.029 * (4.212 + 0.182 * \log(avgprice_{t-3}) + 0.0503 * T)\big)$$

Then, insert the estimated supply quantity into the price determination model. As a result, the following model was obtained. This equation allow to forecast the price in the future from the price in the past with other control variables. Consequently, those equations predict the price and supply quantity from the previous price.

$$\log(avgprice_t) = -0.108 * \log(supply_t) + 1.971 * \log(currency_t)$$

$$= -0.108 * log\Big(llicense_t$$

$$* exp\big(1.18 + 1.029 * (4.212 + 0.182 * \log(avgprice_{t-3}) + 0.0503 * T)\big)\Big)$$

$$+ 1.971 * \log(currency_t)$$

In order to calculate the price and quantity, I putted the actual data for the first three years price and other control variables. Then calculated prices afterward by the above equation. Figure12 and Figure13 are the result of the above deterministic cobweb model.

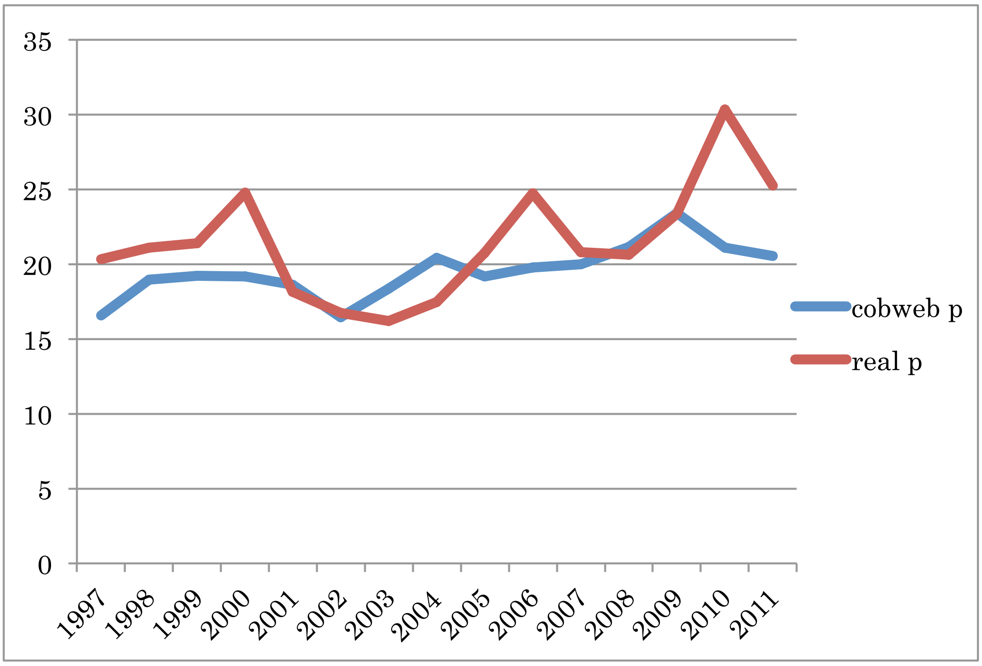

Figure 12

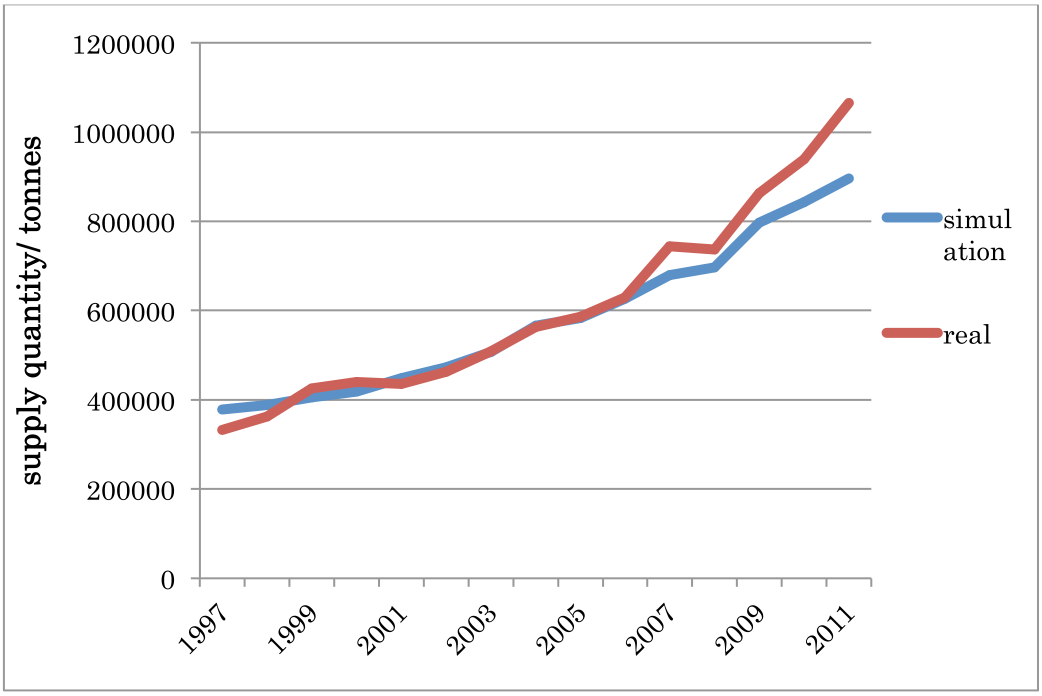

Figure 13

The deterministic model seems explain some part of the cycle in the Price well. However, there are two problems in this simulation result. Firstly, the fluctuation of the cycle is not large enough compared with actual data. Secondly, the trend in quantity is weaker than the data after year 2003, although the magnitude of the cycle seems very similar.

5.2 Stochastic model

The purpose of running the simulation of stochastic cobweb model is that checking the pattern of variability in Price that produced from the simulation and its magnitude are similar with the actual data. By contrast to the result of deterministic model, stochastic model is able to reproduce the magnitude of the cyclicality better both in price. To simulate the stochastic model, we need to include stochastic terms that are estimated residual in the econometric estimation.

$$\log\left(\frac{supply_t}{license_t}\right) = 1.18 + 1.029 * (4.212 + 0.182 * \log(avgprice_{t-3}) + 0.0503 * T + u_t) + e_t$$

$$supply_t = \mathrm{license_t} * \exp(1.18 + 1.029 * (4.212 + 0.182 * \log(avgprice_{t-3}) + 0.0503 * T + u_t) + e_t)$$

Then, insert the supply quantity into the price determination model. As a result, the following model was obtained.

$$\log(avgprice_t) = -0.108 * log(license_t * exp(1.18 + 1.029 * (4.212 + 0.182 * \log(avgprice_{t-2}) + 0.0503 * T + u_t) + 1.971 * \log(currency_t) + \varepsilon_t$$

Where

$$u_t = N(0, \sigma = 0.16)$$

$$e_t = N(0, \sigma = 0.148)$$

$$\varepsilon_t = N(0, \sigma = 0.157)$$

Then input the first three years price as the simulation of deterministic model. Figure14 shows two results of stochastic simulations and actual price from 1997 to 2011. Since the model includes stochastic term, results of the same simulation are different all the time.

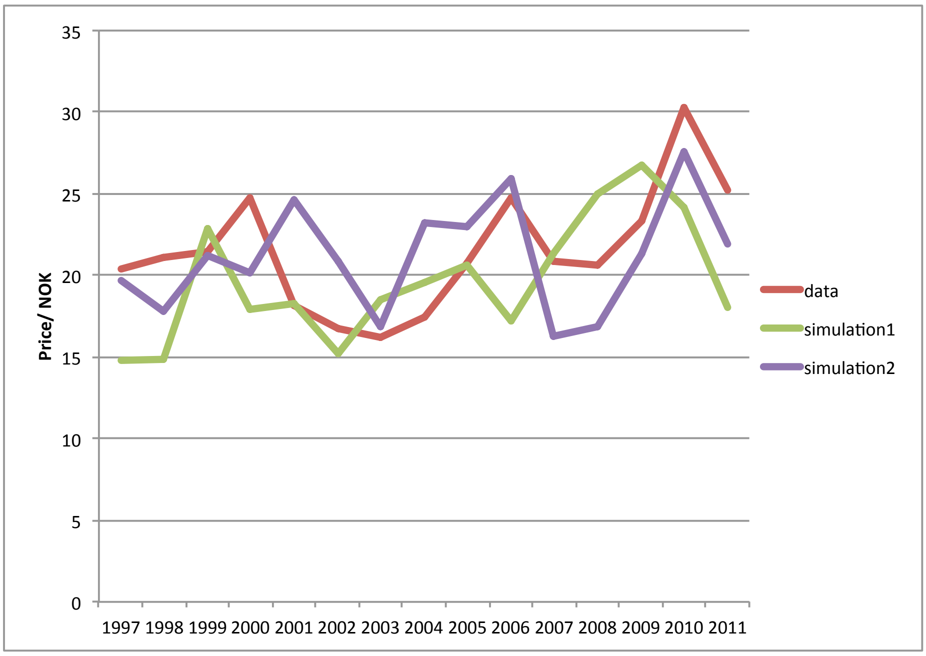

Figure 14

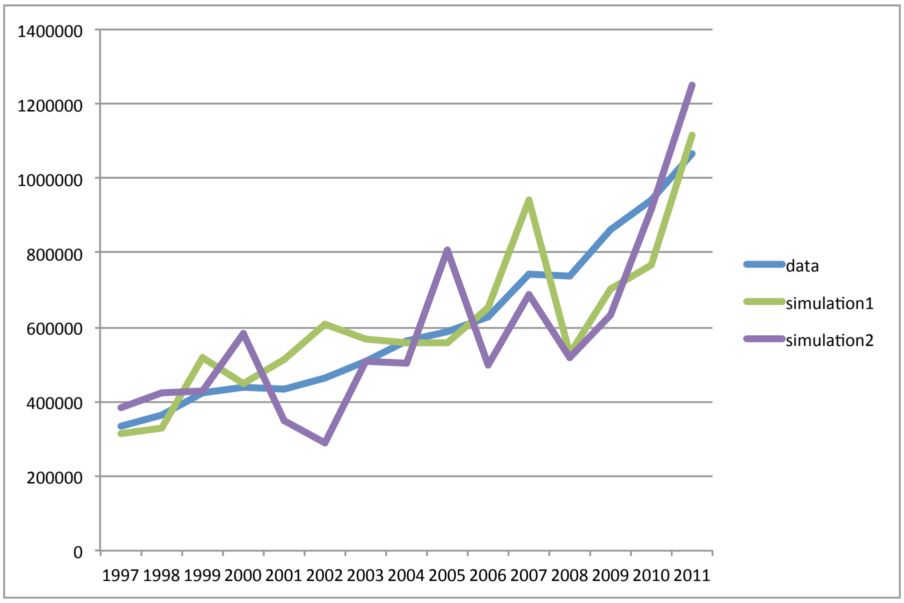

Figure 15

Of course these simulation results are not exactly the same with the real data too, as this data is also the result of some mechanism that include some stochastic process. In that sense, this figure indicates that this model has some ability to explain the cyclicality of farmed salmon price in annual term, since the size of the cycle and patter is also similar in here, though the price paths are not exactly the same with the data.

Figure15 shows the simulated supply quantity. By contrast to the simulated price, the simulated supply quantity has too strong cyclicality compared with the real data. This strong fluctuation is not be erased if the stochastic term is not excluded from both long-term supply decision model and grow up model.

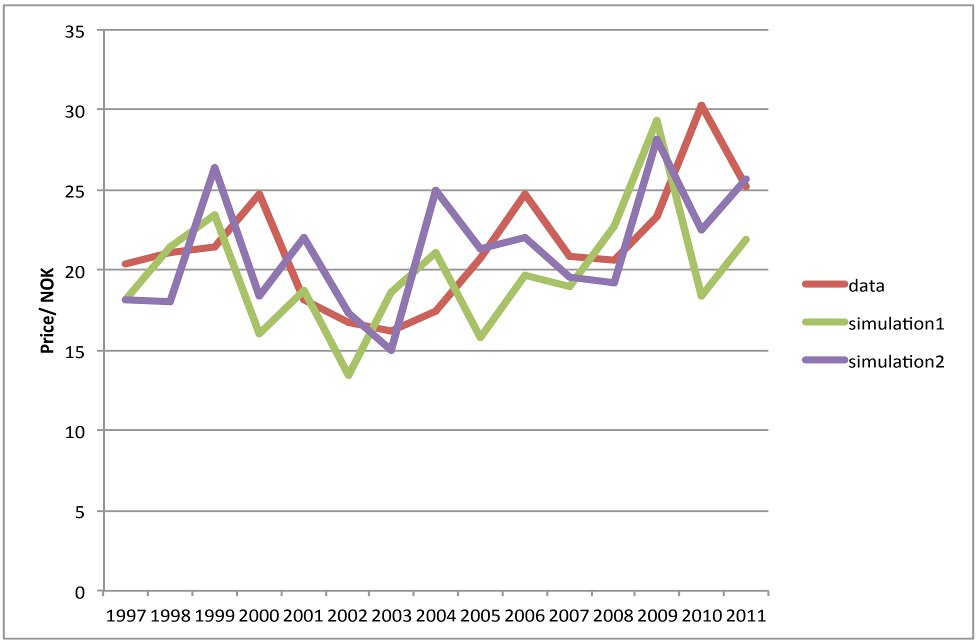

Figure 16

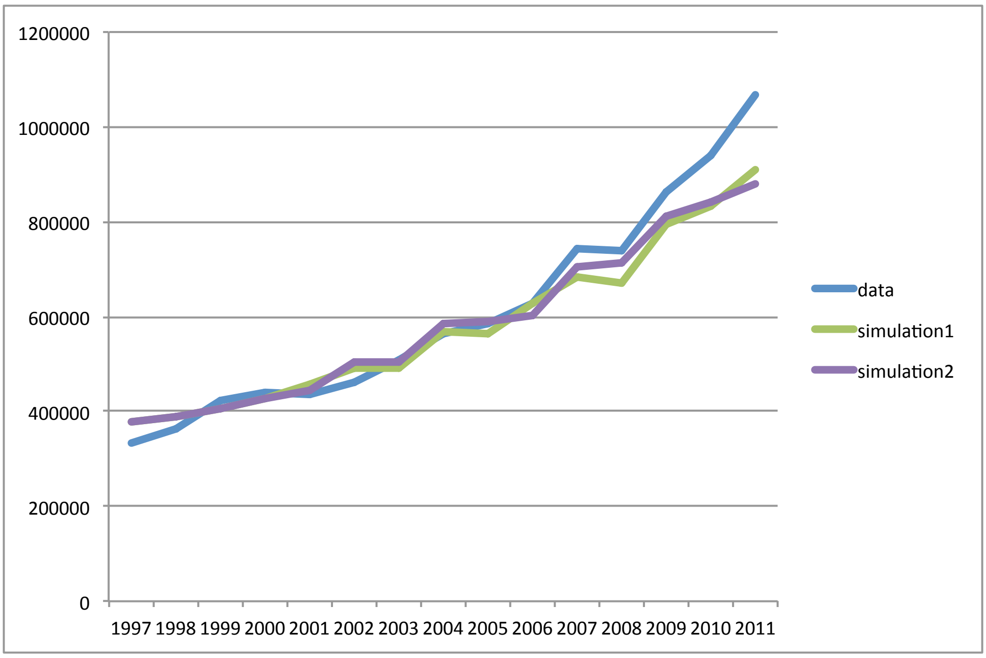

Figure 17

Figure16 and Figure17 are the result of the simulation that included the stochastic term only in price determination. The main difference of the result is magnitude of simulated quantities that is shown in Figure 17. The result seems reproducing the pattern in the data well, although the trend is still weak after 2007 and this patter did not change in other try. The price is also well reproduced in here.

From here, the input decision model and grow up process model should not have stochastic term in order to erase the too strong cyclicality of the quantity. It is comprehensible that the out put model is deterministic in logarithmic form, because 1% of additional input of smolt may make just 1% of additional supply. Moreover, long-term supply decision should follow some logic that the supplier has. In that sense, the supply decision model also should be deterministic in principle. However, the model that is used in this article may miss some diversity of supplier's decision mechanism by simplification. Hence, I expect that the volatility in the quantity may shrink by making better model to capture the diversity of the supply decision-making.

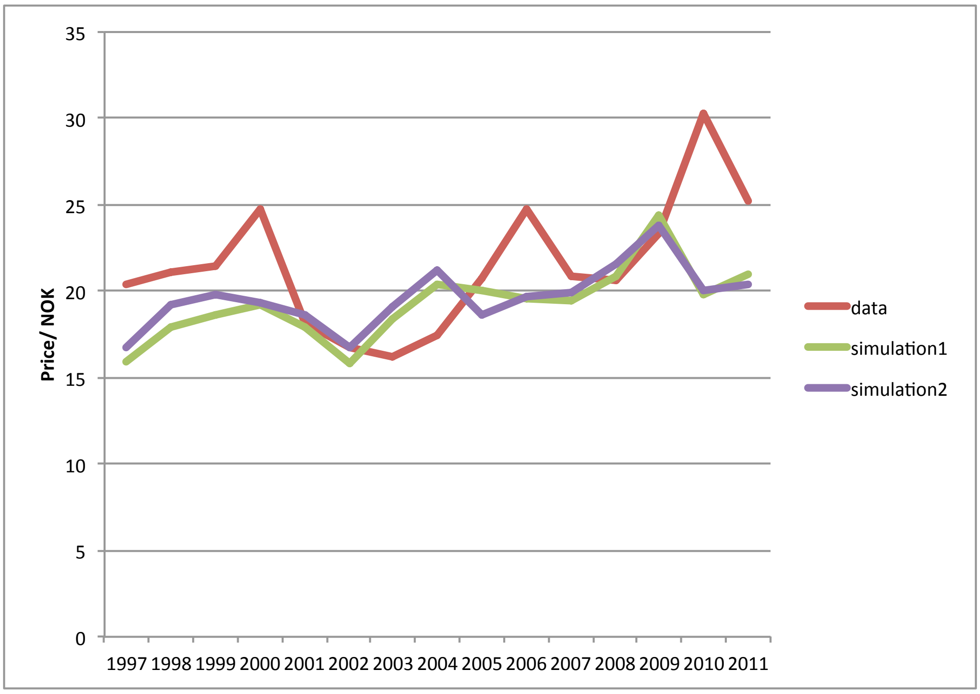

Figure 18

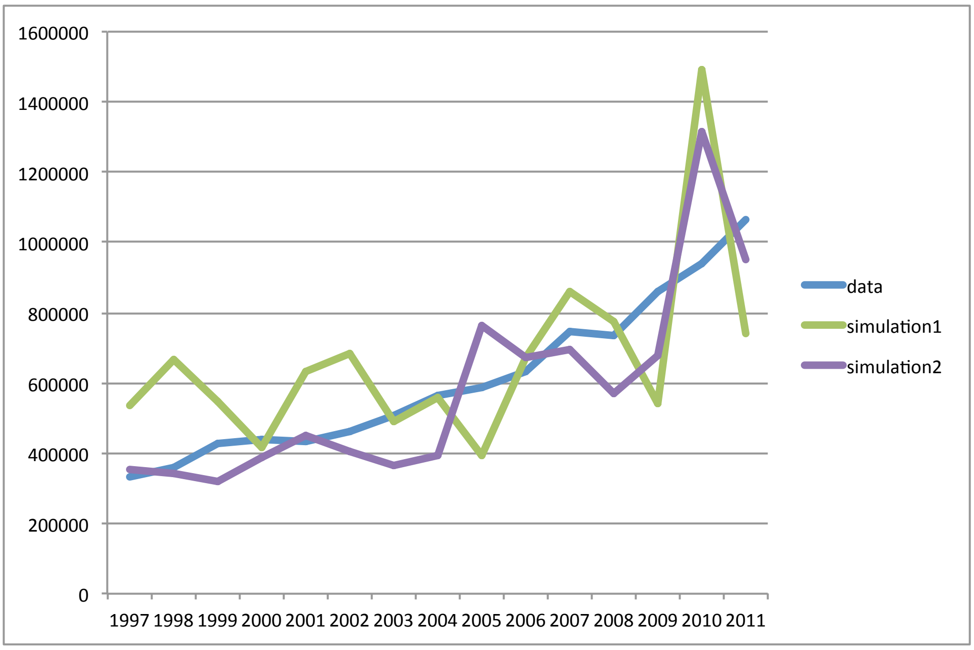

Figure 19

When stochastic term is not included in short-term supply model that is price determination, the magnitude of cyclicality is not enough and almost the same with deterministic model's result (Figure18). Thus, this result concludes that the stochastic term in price determination is of significance in order to reproduce the magnitude of the cyclicality in the Price. The size of stochastic term is taken from the result of econometric estimation. This means that the error term of the model is large. In other word, the error term in the short-term supply model contains some important factor so that the model can be improved by adding some control variable, or the stochastic process has a large effect in determining the price.

5.3 Indication from this simulation

The comparison between deterministic model and stochastic model shows several important indications in improving the model for estimating the mechanism of cyclicality in Norwegian farmed Atlantics salmon market.

Firstly, the deterministic model indicated that the cobweb model that is estimated in section4 explains some part of the cyclicality. However, the result did not reproduce the magnitude of the cyclicality.

Secondly, the stochastic model reproduced the price pattern and its magnitude well. However, it is required that excluding stochastic term from long-term supply determination model and grow up model in the simulation in order to erase the excess magnitude of the cyclicality in supply quantity. The supply determination process and growing out process may not have the large randomness, so this magnitude of stochastic term may come from unexplained factor in the model. This suggests that the improvement of those models is going to reduce the magnitude of the cyclicality in supply quantity when simulated.

Thirdly, the comparison between deterministic model and stochastic model showed that the stochastic term in price determination model is necessary to reproduce the magnitude of the price cycle. This indicates that the model is not developed enough to capture the cyclicality in the price. Also this might suggest that the random process has significant role in the price determination, since usually price is affected by some randomness. In order to check this statement, it is necessary to improve the model by correcting some other control variables that may have effect on the demand and supply.

Consequently, these simulation confirmed that the estimated cobweb model have some ability to explain the cyclicality of the farmed Atlantic salmon market. On the other hand, it is also true that this model is still simple that is not enough to explain the market well, so that we are able to expect that the improvement of the simulation result by modifying the cobweb model.

6 Conclusion

The global supply of Atlantic salmon has increased from almost nothing in the early 1980s to a current level of about 1.7million metric tonnes, with a sales value of 9.7 billion USD. Since the salmon aquaculture may be grow in the future as well by increasing the production per site and some country may join the market as supplier, this cyclicality is going to be remained.

The cycle itself may not a critical issue if the farmer is able to retain the lost profit at the bottom of the cycle when the cycle reaches the top. This means that the real issue is the average profitability in long-term. However, Ashe (2011) reported that many owners do not retain earnings in the cycle as other primary industries. Moreover, the cyclicality in supply quantity and price makes some additional costs for agents in the value chain because they need to have some additional capacity. In order to mitigate this problem, understanding the cycle in the market is of importance.

In this article, I have exploited annual panel data set to estimate the cobweb model that explains Norwegian farmed Atlantic salmon supply and demand. I discovered that there is cobweb mechanism in this dataset. To estimate the cobweb mechanism I formed simple cobweb model and modified it by including some other control variable into the econometric model. The long-term supply decision model captures that the smolt input amount is determined by the price. The grow up model explains that smolt input amount is positively related to the amount of harvest weight. The demand model that is price determination model indicates that the supply amount has negative effect on the price as usual demand curve.

Based on these estimated models, I made several simulations to evaluate the model and observed how much does the cobweb mechanism can explain the cyclicality. The simulation of deterministic model indicated that some part of cyclicality in the market is explained by cobweb mechanism, although it could not explain the magnitude of the cycle. On the other hand, the simulation of stochastic model reproduced the cycle in price. However, this model produced too strong cycle in quantity, unless the stochastic term was excluded from long-term supply model and grow up model. In the simulation without the stochastic term in demand function, the magnitude of simulated price was smaller than the real data. This outcome indicates that the demand model can be improved by including other control variables.

When our understanding of this cyclicality in the market is improved, it is possible to suggest some policy for reducing this cycle to prevent the profitability loss. When farmer can hold large supply when other farmers try to reduce their production, the farmer is able to obtain higher profit, so that there is an incentive to be a free rider in here. This means that this cyclicality is not going to disappear without some effect from the outside. One of the possible solutions is optimal taxation on the biomass. Once the incentive for holding a large stock is taken away, suppliers will reduce the enlargement of their production response to the price cycle. As a result, we are able to expect the shrinkage of the cyclicality.

This research showed that the cobweb mechanism explains the cycle in some degree. However, the estimated model can be improve and reinforce the ability for explaining the cycle more by adding some control variable such as biological and geographical factor.

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Appendix: data detail

County: This annual panel data set is using Norwegian County as the individual dimension. The list of county is following.

Fylke, Finnmark, Troms, Nordland, Nord-Trøndelag, Sør-Trøndelag, Møre og Romsdal, Sogn og Fjordane, Hordaland, Rogaland og Agder.

$Supply_{it}$: Annual weight of sales of slaughtered fish at county i in year t. This value is gathered by FISKERIDIREKTORATET (Norwegian Directorate of Fisheries).[6]

$Price_{it}$: The local price of county i in year t. This is calculated by dividing the annual value of sold slaughtered fish by annual sales weight. The annual value of harvest is gathered by FISKERIDIREKTORATET.[7]

$Input_{it}$: The amount of smolt input at county i in year t. Number in 1,000 individuals. This data is gathered by FISKERIDIREKTORATET.[8]

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6 http://www.fiskeridir.no/english/content/download/11037/90357/version/18/file/sta-laks-mat-6-salg.xlsx

7 http://www.fiskeridir.no/english/content/download/11037/90357/version/18/file/sta-laks-mat-6-salg.xlsx

8 http://www.fiskeridir.no/english/content/download/11036/90354/version/19/file/sta-laks-mat-5-kjop.xlsx

$License_{it}$: The number of license at county i in year t. This data is gathered by FISKERIDIREKTORATET.[9]

$Currency_t$: The index of currency rate between Norway and France. France is the biggest importer of Norwegian salmon overtime. Therefore, French currency rate has the strongest effect on the price. Since France changed the currency from Fran to Euro in 2001, the currency rate has to be stylized in one measure in this duration. Firstly, I translated nominal value of currency rate into the real value by using CPI based on year 2001. Secondly, I transformed the real rate value between Fran and NOK by using the conversion rate from Fran to Euro in 2001. As a result, I obtained the real currency rate between EURO and NOK for this data set. This number means 1 EURO = x NOK. Thus, smaller number indicates stronger rate for Norway. Currency rate was gathered by NORGES BANK[10], and French CPI is corrected by French National Institute of Statistics and Economic Studies.[11]

$ExcessStock_{it}$: This is live stock in December 31 in year t-1 at county i. This data is

[9] http://www.fiskeridir.no/english/content/download/11032/90342/version/9/file/sta-laks-mat-1-tillatelser.xlsx

[10] http://www.norges-bank.no/en/price-stability/historical-monetary-statistics/historical-exchange-rates/

[11] http://www.insee.fr/en/bases-de-donnees/bsweb/serie.asp?idbank=000637909

gathered by FISKERIDIREKTORATET[12].

[12] http://www.fiskeridir.no/english/content/download/11038/90360/version/18/file/sta-laks-mat-7-utgbeh.xlsx