Post-season pricing as a mechanism for risk sharing: Evidences from controlled laboratory experiments on Bristol Bay sockeye salmon ex-vessel market

Abstract

Post-season pricing mechanism, where buyers determine prices paid to sellers after product delivery and realization of uncertainties, can be perceived as a mechanism which facilitates collusion. Post-season pricing essentially provides a channel for information sharing on price, which may incentivize buyers to maintain low price offers. However, we argue that post-season pricing allows processors to observe realized uncertainties prior to a price commitment. This allows buyers to transfer part of the risks to sellers and in return sellers obtain higher average prices. Price-at-landing, an alternative pricing mechanism, involves buyers and sellers determining prices prior to realization of uncertainties and product delivery. Treating price-at-landing mechanism as a benchmark, collusion would suggest that the order of the price levels between two pricing mechanisms remain the same regardless of whether there is a risk in the market. Risk-sharing would suggest a reverse in the order with an introduction of risk. We conduct controlled laboratory experiment using Bristol Bay sockeye salmon fishery as a case study. We find that prices offered by buyers are lower (higher) under post-season pricing relative to price-at-landing under certainty (uncertainty) condition. We also demonstrate the need for buyers to be competitive under post-season pricing to maintain future market product shares by comparing repeated interaction with one-shot post-season pricing.

Key words: Post-season pricing mechanism, price-at-landing mechanism, risk sharing, laboratory experiment, Bristol Bay

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I. Introduction

There exist many mechanisms in which ex-vessel price is determined in fisheries. Auctions (for example, auctions of scallops and variety of fish in New England), price-arbitration system (adopted by the Bering Sea and Aleutian Island crab fishery) where the ex-vessel price of crab is determined after some realization of the wholesale market prices through a price-arbitration system (NPFMC and NMFS 2004)[1], and bilateral price negotiation are some examples of pricing mechanisms. Depending on *when* the ex-vessel price is determined, we can categorize different pricing mechanisms into two groups: determination of price at landing and determination of price post-harvest season.

[1] Bering Sea and Aleutian Island (BSAI)'s pricing mechanism is induced by regulations as a result of 2005 crab rationalization program (CRP). A unique feature of the CRP is the 90-10 split of individual processor quota (IPQ) where participating vessels have to deliver 90 percent of their catch within a particular region. Since each processor has a cap, most harvesters end up forming a fixed long-term contractual relationship with the same processor and it is costly for a harvester to switch processors between fishing seasons. A fixed long-term contractual relationship tends to increase processors' market power, which in term gives processors the ability to decrease the equilibrium price below the competitive level (Davis and Williams, 1991). In this fishery, the ex-vessel price of crab is determined after some realization of the wholesale market prices through a price-arbitration system, which is designed to achieve one of the CRP policy objectives: preserving historical distribution of rents (NPFMC and NMFS 2004).

The Bristol Bay sockeye salmon fishery and the Australia Western rock lobster fishery have adopted post-season pricing mechanism.[2] In Bristol Bay, a harvester signs a contract with a processor guaranteeing the delivery of all his catch prior to the beginning of a fishing season. In return, processors will provide their harvesters with non-cash benefits such as boat storage, bunk, and prompt off-loading of catch. After end of a fishing season, processors start making price offers to their harvesters. The final ex-vessel price is usually determined months after the initial offered price and the differences between the final ex-vessel price and initial offered price is paid by processors sending checks to harvesters later. Processors typically offer harvesters similar prices.

There are two potential arguments to account for the pricing mechanism observed in Bristol Bay. On one hand, some argue that the pricing environment promotes implicit colluding. Post-season pricing adjustment allows processors to know what each other offer and thus the ability to maintain low prices. Similar ex-vessel prices offered by processors further substantiate such claim.[3] Collusion would suggest post-season pricing facilitates processors to lower the ex-vessel price of fish and decreases competitiveness of fishery.

On the other hand, we argue that since Bristol Bay processors face stock and wholesale market demand uncertainties, allowing the ex-vessel price to be determined after delivery helps processors to minimize risks.[4] By negotiating prices after the end of the season, processors can reflect part of the risks through continuation of updating its ex-vessel prices. In exchange, harvesters obtain higher average ex-vessel prices. In addition, processors, who wish to continue operating in the subsequent year, must keep price competitive relative to other processors to attract harvesters for subsequent seasons. Both factors would contribute to higher ex-vessel prices.

In order to test for the post-season pricing induced risk-sharing mechanism, we use price-at-landing mechanism as a benchmark. Price-at-landing mechanism involves processors and harvesters determining ex-vessel prices prior to realization of uncertainties and product delivery. Processors, knowing that harvesters can negotiate with other processors, will provide the best ex-vessel price possible to harvesters under bilateral bargaining ex ante.[5] However, since processors endure risks, ex ante best ex-vessel prices may be lower than ex post best ex-vessel prices. Facing uncertainties, risk averse processors may prefer a pricing mechanism which allows them to share risks with harvesters (Savage 1954, von Neumann and Morgenstern 1944). Alternatively, ex-vessel prices can be the best price offered in the absence of risks.

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[2] Australian Western rock lobster fishery is another fishery which adopts similar pricing system as Bristol Bay. The final payment received by harvesters is a combination of beach price (price paid at landing) and the loyalty bonus at the end of the season (Brolos News 2013 and personal communications with George Kailis).

[3] A major anti-trust lawsuit, "Alakayak et al, vs. All Alaska Seafoods", was filed in 1995. The lawsuit was originated in 1991 Bristol Bay salmon fishery where harvesters had alleged processors of price-fixing. The processors were found not guilty in a conspiracy of price fixing between 1991 to 1995 in 2003. Plaintiffs' arguments during the price fixing lawsuits included a significant drop in harvesters' share of processor margins during the alleged time of price fixing, similar ex-vessel prices offered across major processors, and the easy-to-collude pricing environment in Bristol Bay. Refer to Knapp (2006) for more details.

[4] The stock uncertainty risk arises from high variability of catch. Most product forms produced in Bristol Bay, canned and headed and gutted, are usually sold months after production. This is where the wholesale market demand uncertainty originates from.

[5] The best price here does not necessarily refer to Walrasian competitive price. Many fisheries' ex-vessel markets are often oligopolistic markets in which there are few processors and many harvesters. The best price offer refers to the most competitive outcome given the market structure of a fishery.

Bertrand oligopoly price competition offers possible predictions on the outcome of price-at-landing mechanism depending on the model assumptions. In the original Bertrand model (1883), firms with constant marginal and unlimited capacity constraint assumptions lead to the competitive outcomes with more than one firm in a market. With the introduction of capacity constraint or increasing marginal cost modification, Edgeworth (1925) concludes that pure strategy Nash equilibrium (NE) does not generally exist. Edgeworth's conclusion is later modified by Dastidar (1995), where he proves the existence of Bertrand pure strategy NE in a homogenous product with strictly convex cost. He demonstrates that positive profit pure strategy NE is feasible if firms are identical and equilibria are necessarily non-unique. With the introduction of two stage game in which firm sets capacity first before price competition, Kreps and Scheinkman (1983) show that this game yields a unique Cournot outcome.

Reinhorn and Weinger [RW] (1999) and Weinger (1999) approach the problem by fixing the supply rather than the capacity constraint under a oligopsony market structure. Under highest offer first (HOF) allocation rule, where highest offer prices get purchased at its desired quantity first by the firm, RW shows the existence of pure NE solution when number of competing firms is sufficiently large and the equilibrium prices are near the firm's marginal valuation of input. Even though both papers use Bristol Bay as the basis for the theoretical model, neither papers discuss the dynamic of post-season pricing discussed in this paper. Their theoretical set up is same as the price-at-landing mechanism described in this paper.

Reinhorn and Weinger (1999) and Dastidar (1995) both suggest that positive profits are feasible under one-shot game price-at-landing mechanism. This implies that an implicit collusion may still be feasible under infinitely repeated interactions. Therefore, a comparison between post-season and price-at-landing do not directly eliminate the collusion argument under post-season. However, if implicit collusion is the only explanation to post-season pricing mechanism, whether risks are presented would not affect the order of ex-vessel price levels between two pricing mechanisms. Alternatively, an introduction of risk would reverse the pricing order between two pricing mechanisms under risk-sharing.

Literature offers limited predictions on the outcome of post-season pricing described in this paper. Mestelman and Welland (1988) demonstrate that with both advance production and perishable goods, the seller has relatively more bargaining power, which results in a price significantly lower than the competitive price. Nevertheless, their model differs from post-season pricing mechanism in two ways. First, they assume that sellers can control how much they produce, but how much a harvester can catch in Bristol Bay is constrained by nature. Also, processors are responsible for determining ex-vessel prices rather than harvesters. Another important difference lies on the fact that Mestelman and Welland focus their comparison between advance production and a competitive market solution. Since there is no clear evidence in which whether price-at-landing mechanism would yield a competitive outcome, their results do not necessarily provide a comparison for this paper.

The uniform price competitive seal-bid auction (UPA) is another literature that resembles post-season pricing. Supply is fixed during the price negotiation process and by UPA rules, buyers end up paying the same price to the seller. This fits the stylized fact of the ex-vessel price of fish observed in Bristol Bay. Theoretically, UPA provides bidders an incentive to reduce demand on some of their units since they gain some monopsony power by demanding multiple units. As a result of demand reduction, it reduces rents received by the seller relative to full demand revelation (Engelbrecht-Wiggans and Kahn 1998). The theoretical result on a shift of rents from buyers to sellers has also been confirmed with controlled laboratory and field experiments as well (Smith et al 1982, List and Lucking-Reiley 2000). However, there are several reasons why we cannot apply UPA results directly to the post-season pricing mechanism. First, processors in post-season pricing cannot reduce how much they are willing to purchase because the fish have already been delivered prior to discussion of ex-vessel price. Also, there is more than one seller under post-season pricing. Thus, it is not reasonable to assume that post-season pricing would result in a rent transfer from buyers to seller based on UPA. In addition, the pricing mechanism is fundamentally different between post-season pricing and UPA. Therefore, there is a need to develop a model to examine post-season pricing more closely.

In order to test post-season pricing induced risk-sharing mechanism, we conduct controlled laboratory experiments, where University of Washington undergraduate student participants play the role of harvesters and processors. The experiment is a 3 by 2 design, with three pricing mechanism, post-season, price-at-landing, and one-shot game post-season, and two conditions, wholesale market certainty and uncertainty.[6] The one-shot game post-season pricing is same as (repeated) post-season pricing with one exception – harvesters cannot distinguish the identify of processors from one season to another.

The design of one-shot game post-season pricing allows us to understand whether buyers have incentive to be competitive under repeated post-season pricing in order to maintain future market shares of fish. Under one-shot post-season pricing mechanism, processors have no incentive to offer higher ex-vessel prices since harvesters cannot tell who is being competitive from one season to another. Harvesters knowing that processors have no incentive to be competitive, they may choose to opt out the market (by not signing the contract in the first place). The one-shot game post-season market pricing may result in a collapsed market in which little to no trades occur between processors and harvesters. This is regardless of whether there is risks.

There are three main hypotheses we are testing to support the post-season pricing induced risk-sharing mechanism:

H1: Facing no uncertainty in the wholesale market, (repeated game) post-season yields lower ex-vessel prices than price-at-landing mechanism.
H2: Facing uncertainties in the wholesale market, (repeated game) post-season yields higher ex-vessel prices than price at landing mechanism.
H3: One-shot game post-season pricing yields lowest ex-vessel prices regardless of risk conditions.

There are many obstacles in testing these hypotheses empirically. First, results from analyzing changes in the rents distribution for the Bristol Bay using real world data are biased due to endogeneity. Since the ex-vessel price of fish is influenced by demand from the wholesale market and supply from both within fishery and rest of the world, it is extremely difficult to identify any changes in ex-vessel prices of fish due to changes in market structure. Even if endogeneity is resolved with econometric techniques, data required to conduct empirical analysis may not exist because it would require private

[6] To simplify the complexity of the experiments, we design the experiments to reflect only the wholesale market uncertainty, which allows us to isolate the effect of uncertainty across mechanisms more easily. If risk-sharing is the key to explain post-season pricing in Bristol Bay, more uncertainties would yield better results than our experiment design here.

information from processors and harvesters. Through conducting controlled laboratory experiments, it allows us to create and analyze the model under a manageable condition without loss of generality.

The technique of using controlled laboratory experiment to conduct fishery policy analysis has been utilized previously. For instance, Charles Plott (Caltech) has been commissioned by the North Pacific Fishery Management Council to experimentally compare price arbitration rules for the CRP (NPFMC 2004). Also, Anderson and Holland (2006) were contracted by the New Zealand Ministry of Fisheries and Seafood Industry Council to evaluate performance of several auction mechanisms for allocating quota for species being introduced into the Quota Management System. Anderson has also published several papers tradable lobster trap tags (Anderson 2004, Anderson and Sutinen 2005, and Anderson and Sutinen 2006).

Our initial step in examining the risk-sharing mechanism is to compare ex ante efficiency across pricing mechanisms. One critics of collusion is that it often results in lower prices, which discourages sellers from producing, thereby lower the efficiency and decrease competitiveness of a market. This is regardless of whether risk is a factor. Efficiency is defined as the ratio of total actual and possible aggregate ex ante profits of processors and harvesters in a period. We find that the ex ante efficiency is lower (higher) across all forecast levels when we compare price-at-landing against repeated post-season pricing mechanism under uncertainty (certainty) condition. One-shot game post-season pricing yields the lowest ex ante efficiency across all forecast levels. Ex ante efficiency calculations provide evidences on that collusion does not explain post-season pricing completely.

Using random effects model with session fixed effects and controlling for quantity supplied, we find that processors pay 0.56 dollars more under price-at-landing than repeated post-season pricing in the absence of risks. Under uncertainty condition, processors pay 1.35 dollars less under price-at-landing than post-season pricing. When the pricing mechanism switches from repeated to one-shot game post-season pricing, processors pay 1.57 and 2.7 dollars less under certainty and uncertainty condition. The empirical results support our hypotheses that processors do pay harvesters higher (lower) average ex-vessel prices under repeated post-season relative to price-at-landing mechanism when uncertainty (certainty) condition is presented. One-shot game post-season pricing yields the lowest ex-vessel prices regardless of whether the risk is presented.

To evaluate whether repeated game post-season processors pay more or less depending upon realized wholesale prices in comparison to the forecast, we interact realized wholesale prices with post-season pricing to look at changes in the processor margin (defined as the difference between realized wholesale price and ex-vessel price). We find that processors margins interacting with repeated post-season pricing are lower (higher) when the realized wholesale prices are above (below) the forecast. This is consistent with the risk-sharing mechanism in which processors share higher (lower) proportion of their profits with harvesters when the market condition is well (bad).

The rest of the paper is organized as the following: the design of the experiment is first outlined with the results reported in section 2 and 3. Discussion of the experimental results in the last section concludes the paper.

II. Experiment Design

We design our experiments to compare price levels under repeated post-season pricing and price-at-landing mechanism with particular attention to the uncertainty in the demand of wholesale market. We also design a one-shot game post-season pricing mechanism to study whether processors try to maintain competitive prices in order to maintain future market shares of fish under repeated post-season pricing. The experiments were conducted in a computer laboratory via a computer program called z-Tree (Fischbacher 2012). During each session, 13 participants were recruited from University of Washington undergraduate students. Each participant receives 7 dollars if they show up for the session. Exactly how much they earn depends on their performance during the session. A total of 10 sessions were conducted, with average payout of 27 dollars per student.

Under each session, participants are first randomly assigned a role, either as a buyer or a seller in a market. There are three buyers (processors/firms) and ten sellers (harvesters/producers/fishermen) each period.[7] Each seller produces 1 indivisible unit of good to sell to the buyer or sign a contract with at most one buyer if they decide to produce. If sellers decide to not produce, they receive their reservation wage according to a random initial assignment. Reservation wage schedule is in table 1 with each possible reservation wage value assigned to two sellers. Buyers purchase good(s) from sellers and incur processing costs depending on how many units of good they purchase. Each buyer can purchase up to 5 goods or sign up with at most 5 sellers each period. We want to model the processing capacity Bristol Bay processors face.

Each good a buyer purchased from a seller requires a processing fee. Each additional unit purchased requires a higher processing fee than the previous unit except for the first one. Quasi-fixed cost with increasing marginal cost schedule is designed to reflect the nature of production in Bristol Bay. Remote location of Bristol Bay requires processors to ship all its packing and processing materials from Seattle few months before the season starts. It also requires processors to hire workers and fly them over to Bristol Bay.[8] Hence, the first unit of processing cost is very expensive to mimic the initial startup cost for the season. The second unit of processing fee is significantly lower than the first one because once the system is set up and ready to process, processing an additional fish is going to be cheap. Since the processing plant is fixed in size, costs increase as number of fish processed increased. When the number of fish exceeds the processing capacity in Bristol Bay, processors typically calls in long haul-out to process fish into lower values (which translates into extra costs to the processors) or ship extra fish to processing plants a day or two away from Bristol Bay. Table 2 describes the complete cost processing schedule.

A forecast wholesale price is shown to all players at the beginning of each period. Under the certainty condition, the forecast value is identical to the realized value. Only processors observed realized wholesale price under the uncertainty condition. Differences in forecast and realize wholesale price is applied to mirror the wholesale market demand uncertainty risk. The wholesale price

[7] We select 3 to be number of buyers. In particular, we want to reduce collusive behaviors between firms that may be an artifact of what we are trying to test here. Huck, Norman, and Oeschssler (2004) have shown that three firm oligopolies tend to produce output at the Nash level. On the other hand, Fouraker and Siegal (1963) demonstrate that Cournot triopoly exhibits rivalistic rather than tacit collusive behaviors. Under constant marginal cost Bertrand competition, Dufwenberg and Gneezy (2001) have shown that three competitors predict the Bertrand solution well. Though due to our increasing marginal cost structure, it is not clear whether any collusive behaviors may occur with 3 buyers.

[8] According to 2010 US population census, the population of Bristol Bay Borough and Dillingham (two main cities in Bristol Bay) are 997 and 4847. Local employment ranges from 1.7% - 3.5%. Most of processing plants workers have to flown over to Bristol Bay. These facts suggest an quasi fixed cost schedule.

distribution is symmetric with the mean of the distribution equal to the forecast wholesale price. At the end of a period, roles that each participant plays get reshuffled with 15% probability. In order to deal with end game problems that may occur under one-shot and repeated game post-season pricing (where buyers may decide to not pay anything to their sellers), the game ends with 15% probability and 0% probability of role reshuffling starting from period 19. If the session does not end before period 25, the game will terminate at period 25.[9] We always run the same pricing mechanism with two different conditions in each experiment session.[10] To avoid any learning behavior from one condition to another, we use different sets of wage and forecast values. We use value set 1 (2) for certainty (uncertainty) condition. The difference between value set 1 and 2 is that both wages and the forecast values are 2.4 higher in value set 2 (see table 1).

Table 1: Wage schedule based on conditions, forecast/realized wholesale prices under each condition

Reservation wage	
Uncertainty Condition	Certainty Condition
5.7	3.3
6.2	3.8
6.7	4.3
7.2	4.8
7.7	5.3

		Forecast Wholesale Price		
	Probability	10.6	12.5	14.4
Realized Wholesale Price	5%	5.8	7.7	9.6
	10%	6.9	8.8	10.7
	20%	8.5	10.4	12.3
	30%	**<u>10.6</u>**	**<u>12.5</u>**	**<u>14.4</u>**
	20%	12.7	14.6	16.5
	10%	14.3	16.2	18.1
	5%	15.4	17.3	19.2

Forecast Wholesale Price Under Certainty
8.2
10.1
12

Table 2: Processing cost schedule

Processing cost		
Unit	Marginal Cost	Total Cost
0	0	0
1	3.6	3.6
2	0.2	3.8
3	0.9	4.7
4	1.7	6.4
5	3.4	9.8

Under price-at-landing mechanism, sellers decide whether they want to produce for the period before entering selling stage. Next, buyers and sellers buy and sell goods via double-auction mechanism in which participants can offer and bid prices simultaneously. Lastly, profits are revealed to each participant for the period and buyers now observe the realized wholesale price. Under post-season pricing, buyers first offer contracts to sellers in which sellers have to decide whether they want to accept

[9] Experimental economists have different views on how the termination rule affect infinitely repeated game results. Normann and Wallace (2012) summarize different points of views and conduct experiments to show that there are not really significant differences across views. However, our trial experiments do suggest a strong endgame effect. Hence, we have chosen the current experiment design.

[10] Previous test pilot sessions have shown that switching pricing mechanism within a session may introduce confusions to the participants.

the contract offer or not. After the contracting stage, buyers first observe the realized wholesale price then decide how much they want to pay their contracted sellers. All participants know how much each buyer pays his or her sellers. Lastly, the profits are revealed to each player. Under one-shot game post-season pricing, the timing of the game is identical to repeated post-season pricing. The only difference is at the end of each period, the ID number of a buyer gets randomly reassigned so that sellers cannot distinguish which buyer they sign a contract with last period. Profit per period per seller is equal to the price seller obtains from selling their good or their wage value if they decide not to produce. Profit per period per buyer is equal to realized wholesale prices multiply by number of goods purchased minus total payments paid to sellers minus processing cost, which depends on number of good bought. Timeline of each market structure is shown in figure 1 – 3.

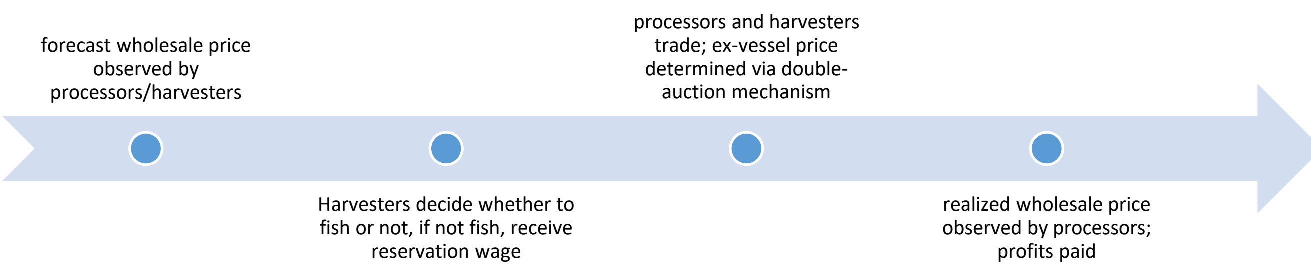

Figure 1: Price-at-landing pricing mechanism time line each period

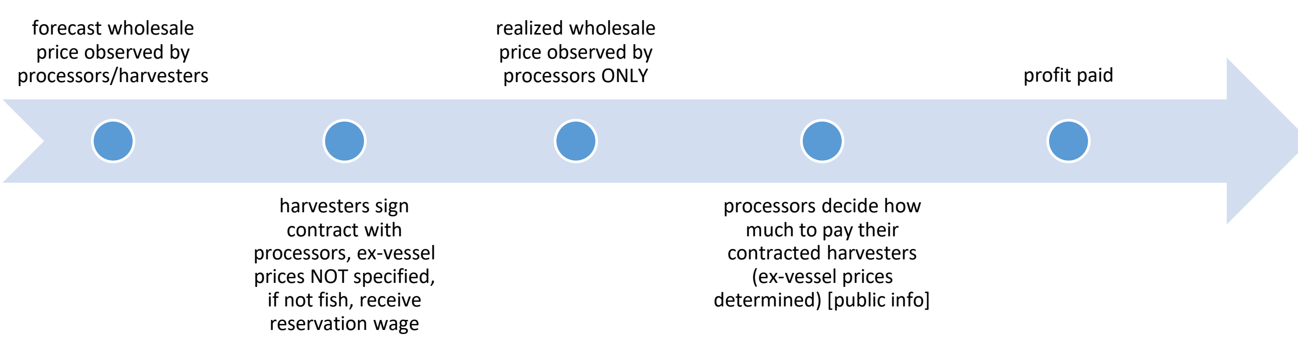

Figure 2: Post-season pricing mechanism time line each period

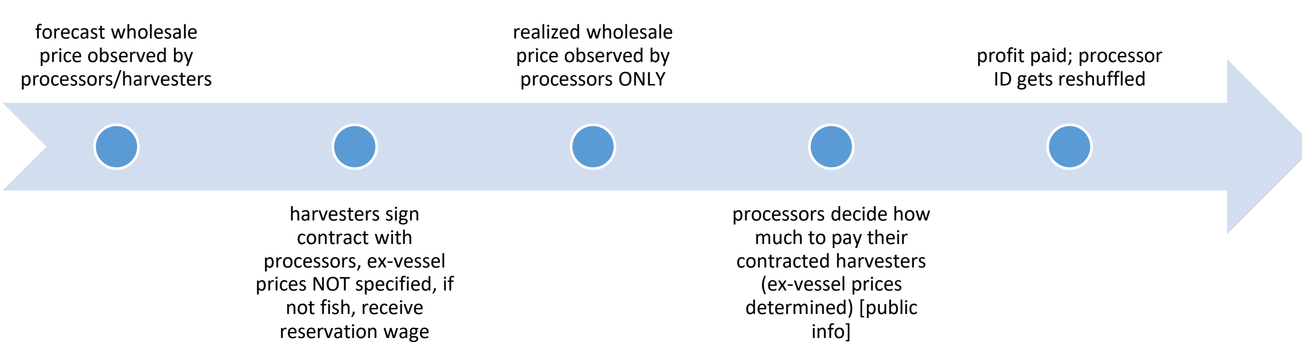

Figure 3: one-shot game post-season pricing mechanism time line each period

III. Experiment Results

We have run a total of 10 sessions, four of each for post-season and price-at-landing mechanism for each condition, and two sessions for one-shot game post-season pricing certainty and uncertainty condition.[11] For price-at-landing and post-season pricing mechanism, we ran three sessions with certainty condition first, then uncertainty condition. For one-shot game post-season pricing, there was one session with certainty condition first and another with uncertainty condition first. Table 4 shows summary statistics by forecast levels, conditions, and pricing mechanism for all periods and all sessions.

Summary statistics from table 4 seems to support H1 and H3 but not H2. Under certainty, price-at-landing yields ex-vessel price of 6.2, 7.2, 8.5, with post-season pricing yielding ex-vessel price of 4.2, 5, and 6, and one-shot post-season pricing yielding ex-vessel price of 3, 4.3, 3.8 across three forecast level. Under uncertainty, price at landing yields ex-vessel price of 7, 8.1, 8.3, with post-season pricing yielding ex-vessel price of 6.8, 7.7, 9.4, and one-shot game post-season pricing yielding ex-vessel price of 4.7, 5.7, 5 across three forecast level. With exception of high forecast level, price at landing uncertainty yields higher prices than post-season which contradicts our second hypothesis. However, the differences between ex-vessel prices are insignificant between post-season and price-at-landing uncertainty condition. This suggests a need for further analysis.

Table 4: Summary statistics of ex-vessel price and number of producers by forecast levels, conditions, and pricing mechanisms for all periods

Forecast level	Pricing Mechanism	Price-at-landing		(repeated) Post-season pricing		One-shot post-season pricing	
Condition		Uncertainty	Certainty	Uncertainty	Certainty	Uncertainty	Certainty
Low	ex-vessel P	7.021	6.199	6.834	4.196	4.700	2.963
	std. dev.	(1.316)	(0.922)	(2.124)	(2.138)	(4.334)	(2.106)
	number of producers	6.125	8.870	7.083	6.806	4.583	3.313
	std. dev.	(2.669)	(0.856)	(2.710)	(2.559)	(2.882)	(1.626)
Mid	ex-vessel P	8.111	7.160	7.653	4.977	5.694	4.259
	std. dev.	(1.346)	(0.983)	(3.455)	1.840	3.616	3.294
	number of producers	8.517	9.846	8.886	8.000	4.333	5.875
	std. dev.	(1.934)	(0.363)	(1.571)	(1.852)	2.923	1.650
High	ex-vessel P	8.277	8.540	9.406	6.053	5.061	3.828
	std. dev.	(1.671)	(1.210)	(3.120)	(2.185)	4.100	3.103
	number of producers	9.235	9.552	9.308	8.931	5.308	7.176
	std. dev.	(1.036)	(0.818)	(1.302)	(1.237)	2.364	1.438

[11] Since processing costs are the same under two values sets, simply adding 2.4 dollars to uncertainty condition to compare prices with certainty condition may result in a biased evaluation.

Next, we calculate ex ante and ex post efficiency across pricing mechanisms. The ex ante (ex post) efficiency is defined as the ratio of total actual and possible aggregate ex ante (ex post) profits of sellers and buyers in a period. Possible aggregate ex ante (ex post) profits of sellers and buyers are calculated as forecast (realized) wholesale price multiplied by 10 units minus total processing costs of 15.8 minus aggregate reservation wage.[12] Actual aggregate ex ante (ex post) profits of sellers and buyers are calculated as forecast (realized) wholesale price multiplied by actual number of units processed minus total processing costs minus aggregate reservation wage of sellers who participated.

Table 5-1: Ex ante and ex post efficiency calculations by forecast levels, conditions, and pricing mechanisms

Forecast	Efficiency	Price-at-landing		Repeated post-season pricing		One-shot post-season pricing	
Condition		Uncertainty	Certainty	Uncertainty	Certainty	Uncertainty	Certainty
Low	Ex ante	51.25%	82.03%	63.78%	61.51%	40.62%	27.88%
	Ex post	20.12%	82.03%	56.20%	61.51%	36.40%	27.88%
Mid	Ex ante	79.83%	93.94%	83.73%	74.89%	40.63%	57.38%
	Ex post	77.15%	93.94%	86.05%	74.89%	39.46%	57.38%
High	Ex ante	89.27%	91.59%	89.77%	84.93%	50.90%	69.19%
	Ex post	87.59%	91.59%	89.13%	84.93%	48.56%	69.19%

Table 5-2: One-sided t-test mean comparisons between two pricing mechanisms' ex ante efficiencies.

Forecast	Repeated post-season pricing to price-at-landing	One-shot to repeated post-season pricing	Repeated post-season pricing to price-at-landing	One-shot to repeated post-season pricing
Condition	Uncertainty		Certainty	
Low	-12.5%***	23.2%***	20.5%***	33.6%***
	(0.0413)	(0.0521)	(0.0349)	(0.0423)
Mid	-3.9%*	43.1%***	19.0%***	17.5%***
	(0.0255)	(0.0363)	(0.0229)	(0.0423)
High	-0.5%	38.9%***	6.7%***	15.7%***
	(0.0177)	(0.0324)	(0.0173)	(0.0227)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Comparing ex ante efficiencies allow us to tackle whether post-season pricing induces lower ex-vessel prices and result in lower ex ante efficiency regardless of risk conditions. What we find is that ex

[12] We are treating each seller's reservation wage as a production cost. The aggregate ex ante profit of this market in a period is calculated from a social planner's perspective. Given that social planner wants to maximize the usage of resources given production and processing costs, she would minimize processing cost and given the expected marginal revenue to decide whether it is worth it to have all sellers produced in the first. Minimum total processing cost is defined as two buyers purchasing 3 units and one buyer purchasing 4 units. Since the 4th unit (3rd unit) processing cost is 1.7 (0.9) and the highest reservation wage is 7.7, 9.4 (8.6) is still lower than the expected marginal revenue when the forecast level is low (10.4) under value set 2. With value set 1, the highest reservation wage, 5.3, with the 4th (3rd) unit of processing cost implies a marginal production cost of 7 (6.2). This is still lower than the marginal revenue of 8.2 when the forecast is low. Hence, it makes sense for the social planner to have all sellers produced across the forecast levels and utilize 3 firms to process the goods.

ante efficiency is 20.5%, 19%, and 6.7% (low, mid, and high forecast levels) higher under price-at-landing relative to repeated post-season pricing when risk is absent. With introduction of uncertainty, ex ante efficiency is 12.5%, 3.9%, and 0.2% (low, mid, and high forecast levels) lower under price-at-landing relative to repeated post-season pricing. Out of the three pricing mechanisms, one-shot game post-season produces the lowest ex ante and ex post efficiencies under both uncertainty and certainty. Refer to table 5-1 and 5-2 for a complete list calculation of ex ante and ex post efficiencies and one-sided t-test ex ante efficiency mean comparisons between two pricing mechanism given condition.

Table 6: Regression analysis using ex-vessel price as dependent variable

	(1)	(2)	(3)	(4)
VARIABLES	Ex-vessel Price: OLS	Ex-vessel Price: REM	Ex-vessel Price: REM	Ex-vessel Price: REM
Mid Forecast	0.912***	0.884***	0.874***	0.566***
	(0.177)	(0.163)	(0.146)	(0.159)
High Forecast	1.712***	1.747***	1.750***	1.279***
	(0.173)	(0.158)	(0.173)	(0.228)
Price-at-landing = 1	2.250***	2.313***	0.566	0.564
	(0.223)	(0.363)	(0.471)	(0.442)
uncertainty	2.859***	2.747***	2.788***	2.677***
	(0.223)	(0.270)	(0.434)	(0.353)
(Price-at-landing)* uncertainty	-2.406***	-2.322***	-2.374***	-1.910***
	(0.308)	(0.361)	(0.501)	(0.433)
One-shot post season =1	-1.567***	-1.060**	-2.162***	-1.569**
	(0.281)	(0.446)	(0.770)	(0.696)
(one-shot post-season)* uncertainty	-1.243***	-1.419***	-1.428	-1.132
	(0.407)	(0.466)	(1.063)	(0.963)
total_producers				0.265***
				(0.0669)
Constant	4.203***	4.100***	5.349***	3.193***
	(0.191)	(0.277)	(0.449)	(0.686)
Session Fixed Effect	No	No	Yes	Yes
Observations	1,125	1,125	1,125	1,125
R-squared	0.334	0.332	0.397	0.426
Number of id		104	104	104

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Using ex-vessel price as dependent variable, we try to understand how much buyers are willing to pay to sellers across different pricing mechanism under each condition. We start with ordinary least square (OLS) including forecast level dummies, pricing mechanism dummies interacting with uncertainty condition dummy as independent variables (regression #1). Under uncertainty, buyers are willing to pay 0.16 dollars *less* under price-at-landing than repeated post-season even though the coefficient is not significant. Under certainty, processors are willing to pay 2.25 dollars more under price-at-landing than repeated post-season pricing. When the pricing mechanism switches from repeated to one-shot game post-season pricing, buyers are willing to pay 1.57 and 2.81 dollars less under certainty and uncertainty conditions. The OLS regression result supports H1 and H3 and but again rejects H2.

To isolate individual pricing pattern, we run a random-effect model (REM) (regression #2). A unique person is defined as a person who has participated as buyer within the same session. Even though coefficients we obtain under REM is similar to OLS, rejecting the null hypothesis for Breusch and Pagan Lagrangian multiplier test for random effects (LM test) does suggest that REM is a better model. Based on the summary statistics, we know that each sessions' average ex-vessel prices do vary. To control for cross session variation, we run a REM including session fixed effect (regression #3). The buyer's willingness to pay under each pricing mechanism changes dramatically. Under uncertainty, buyers are willing to pay 1.81 dollars *less* under price-at-landing than repeated post-season pricing. Under certainty, processors are willing to pay 0.57 dollars more under price-at-landing than repeated post-season even though the coefficient is not significant. Repeated post-season buyers are paying on average 2.16 and 3.59 dollars more under certainty and uncertainty conditions in comparison to one-shot post-season buyers. The LM test still supports approaching REM with session fixed effect a better model than OLS.

Table 7: Average ex-vessel prices under repeated post-season pricing relative to price-at-landing and one-shot post-season pricing

Average ex-vessel prices paid under repeated post-season pricing relative to price-at-landing				
Conditions\Models	(1) OLS	(2) REM	(3) REM with session dummies	(4) REM with session dummies
Certainty	2.250***	2.313***	0.566	0.564
(Std. Dev.)	(0.223)	(0.363)	(0.471)	(0.442)
Uncertainty	-0.156	-0.009	-1.808***	-1.346***
(Std. Dev.)	(0.213)	(0.362)	(0.434)	(0.416)

Average ex-vessel prices paid under repeated post-season pricing relative to one-shot post-season				
Conditions\Models	(1) OLS	(2) REM	(3) REM with session dummies	(4) REM with session dummies
Certainty	-1.567***	-1.060**	-2.162***	-1.569**
(Std. Dev.)	(0.281)	(0.446)	(0.770)	(0.696)
Uncertainty	-2.810***	-2.478***	-3.589***	-2.701***
(Std. Dev.)	(0.295)	(0.453)	(0.788)	(0.696)

To control for quantity supplied on the ex-vessel price, we include total number of producers in the market each period to proxy for the effect (regression #4). Including total number of producers in the market yields similar results as regression #3 with better R-squared (from 0.397 to 0.426). Key results remain unchanged under regression #4. Table 6 displays the regression results #1 - #4. Table 7 calculates the differences in average prices paid by processors between repeated post-season and price-at-landing and repeated to one-shot post-season.

Part of the post-season pricing induced risk sharing mechanism is that processors pay different prices depending on realization of wholesale prices. We first focus on the comparison between repeated post-season and price-at-landing mechanism. To detect for ex-vessel price variations conditional on realized wholesale prices under post-season, we include dummies for all possible realization of wholesale prices except and interact these dummies with post-season pricing mechanism dummy. Two dependent variables are used: processor margin (which is equal to realized wholesale price – ex-vessel price) and harvesters' share of processor revenue (which is equal to ex-vessel price divided by realized wholesale price) (Regression #5 and #6). Regression results are recorded in table 8.

What we are most interested from regression 5 and 6 is the coefficient from the interaction terms between realized wholesale prices and post-season dummy variables. These interactions terms inform us whether processors pay more (less) or whether harvesters receive more (less) when realized wholesale prices are above or below the forecast wholesale prices under repeated post-season. The interaction terms are -0.623, -0.958, and -0.5 for regression 5 and 0.04, 0.075, and 0.008 for regression 6 when realized wholesale prices are 2.1, 3.7, and 4.8 dollars above the forecast. None of the coefficients are significant even though the signs are what we would have expected. When realized wholesale prices are 2.1, 3.7, and 4.8 dollars below the forecast, the interaction terms are -1.078, -1.041, and -0.87 for regression 5 and -0.118, -0.133, and -0.142 for regression 6. Only when the realized wholesale prices are 2.1 dollars below the forecast the interaction terms are significant at 5% level. Signs are also what we expect. We do need to keep in mind that processors are already paying higher ex-vessel prices under post-season relative to price at landing. Hence, this may explain why these interaction terms are not significantly different than zero. Another possibility could be small sample issue.

To accurately evaluate whether post-season processors pay more (less) depending upon whether realized wholesale prices are higher (lower) than the forecast, we need to calculate the dollar amount (share amount) in conjunction with the higher average prices paid under post-season uncertainty condition coefficients. The calculation is recorded in table 9. Processor margins are -2.16, -2.50, and -2 dollars lower when realized wholesale prices are 2.1, 3.7, and 4.8 dollars above forecast prices at 5 % significance level. On the other hand, processor margins are positive although not significant when forecast prices are above realized retail prices. Similar story can be told with harvester share.

To study whether repeated interactions under post-season is one of the key drivers for competitive pricing, we compare the results from one-shot and repeated post-season pricing. Regression 7 and 8 record the regression results using processor margin and harvester share as dependent variable. The signs of interaction terms are all over the place for these two regressions. A possible explanation to what we observe here could be free-rider problem in the initial stage of the game. Some processors in the game under one-shot post-season pricing may try to encourage harvesters to sign up by offering some ex-vessel prices even though harvesters would not be able to distinguish one processor from another in the next period. Other processors, knowing that harvesters cannot distinguish one processor from another in the next period, may take advantage of the processor who offers some positive ex-vessel price to get some harvesters to sign the contract and pays nothing. Harvesters, who learns throughout participating in the game, may refuse to sign up contracts at all or decide to gamble depending on the risk preferences. We also do not have a lot of data to explain one-shot post-season pricing since we only conducted two sessions for this pricing mechanism. Higher averages prices paid under repeated relative to one-shot post-season informs us that processors do try to be maintain competitive under repeated post-season pricing. Harvester share is positive and significant with the exception when realized wholesale price is 4.8 dollars above forecast.

Table 8: Examine how processor margin or harvester share changes from price-at-landing to repeated post-season pricing or one-shot to repeated post-season pricing including realized wholesale price with pricing mechanism interactions

	(5)	(6)	(7)	(8)
	Price-at-landing and repeated post-season pricing		**One-shot and repeated post-season pricing**	
VARIABLES	Processor Margin	Harvester Share	Processor Margin	Harvester Share
Mid Forecast	1.289***	-0.0698***	1.540***	-0.0561**
	(0.160)	(0.0159)	(0.251)	(0.0229)
High Forecast	2.088***	-0.0793***	2.706***	-0.0724***
	(0.173)	(0.0174)	(0.344)	(0.0252)
RWP 2.1 dollars above forecast	2.437***	-0.113***	-0.491	0.143**
	(0.203)	(0.0130)	(0.737)	(0.0559)
RWP 3.7 dollars above forecast	3.497***	-0.160***	3.895***	-0.0983
	(0.244)	(0.0238)	(1.093)	(0.0806)
RWP 4.8 dollars above forecast	4.923***	-0.179***	4.021	-0.0414
	(0.205)	(0.0134)	(3.674)	(0.166)
Repeated post-season = 1	0.551	-0.0844*	-1.417**	0.327***
	(0.456)	(0.0456)	(0.676)	(0.0706)
RWP 2.1 dollars above forecast*PS	-0.623	0.0397	2.255**	-0.220***
	(0.455)	(0.0299)	(0.882)	(0.0639)
RWP 3.7 dollars above forecast*PS	-0.958	0.0745	-1.412	0.00606
	(0.768)	(0.0501)	(1.357)	(0.0942)
RWP 4.8 dollars above forecast*PS	-0.500	0.00837	0.388	-0.123
	(0.763)	(0.0482)	(3.766)	(0.173)
RWP 2.1 dollars below forecast	-1.942***	0.127***	-3.771***	0.217**
	(0.151)	(0.0158)	(1.087)	(0.0915)
RWP 3.7 dollars below forecast	-3.745***	0.271***	-2.046*	-0.000324
	(0.196)	(0.0266)	(1.167)	(0.108)
RWP 4.8 dollars below forecast	-4.234***	0.384***	-2.746***	-0.0719
	(0.315)	(0.0881)	(1.052)	(0.127)
RWP 2.1 dollars below forecast*PS	1.077**	-0.118***	2.808**	-0.213**
	(0.445)	(0.0412)	(1.145)	(0.0981)
RWP 3.7 dollars below forecast*PS	1.041	-0.133	-0.492	0.127
	(0.995)	(0.118)	(1.465)	(0.151)
RWP 4.8 dollars below forecast*PS	0.387	-0.142	-1.023	0.295*
	(0.971)	(0.123)	(1.425)	(0.155)
uncertainty	1.646***	-0.0721***	0.919	0.0457
	(0.278)	(0.0224)	(0.979)	(0.0863)
PS*uncertainty	-2.088***	0.205***	-1.242	0.0818
	(0.433)	(0.0377)	(1.012)	(0.0896)
total_producers	-0.169***	0.0180***	-0.380***	0.0341***
	(0.0462)	(0.00444)	(0.0800)	(0.00678)
Constant	3.757***	0.562***	7.369***	0
	(0.483)	(0.0446)	(0.737)	(0)
Session FE	Yes	Yes	Yes	Yes
Observations	933	933	635	635
R-squared	0.610	0.458	0388	0.283
Number of id	81	81	63	63

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; RWP stands for realized wholesale prices

Table 9: Average processor margin or harvester share under price-at-landing or one-shot post-season relative to repeated post-season pricing under uncertainty condition

Pricing mechanism	Price-at-landing relative to ***repeated*** post-season		One-shot relative to ***repeated*** post-season pricing	
Models	(5) REM with processor margin as DV	(6) REM with harvester share as DV	(7) REM with processor margin as DV	(8) REM with harvester share as DV
Regardless of realized wholesale prices	-1.537***	0.120***	-2.66***	0.409***
(Std. Dev.)	(0.362)	(0.031)	(0.761)	(0.102)
Realized price 2.1 dollars above forecast	-2.160***	0.160***	-0.404	0.189*
(Std. Dev.)	(0.607)	(0.046)	(1.15)	(0.101)
Realized price 3.7 dollars above forecast	-2.494***	0.195***	-4.07***	0.415***
(Std. Dev.)	(0.851)	(0.061)	(1.26)	(0107)
Realized price 4.8 dollars above forecast	-2.037**	0.129**	-2.27	0.286
(Std. Dev.)	(0.824)	(0.058)	(4.08)	(0.223)
Realized price 2.1 dollars below forecast	0.459	0.002	0.150	0.196*
(Std. Dev.)	(0.577)	(0.054)	(0.922)	(0.116)
Realized price 3.7 dollars below forecast	0.496	-0.012	-3.15**	0.537***
(Std. Dev.)	(1.066)	(0.121)	(1.47)	(0.167)
Realized price 4.8 dollars below forecast	1.150	-0.021	-3.682***	0.705***
(Std. Dev.)	(0.996)	(0.126)	(1.304)	(0.145)

IV. Discussion

Repeated post-season pricing mechanism, in the case of Bristol Bay sockeye salmon fishery, has been thought as a mechanism which aids implicit collusion. However, we argue that repeated post-season pricing creates a channel for risk-sharing between processors and harvesters when there are uncertainties in the market. We conduct controlled laboratory experiments treating price-at-landing mechanism as a benchmark. We find that without risks, processors are willing to pay 0.56 dollars extra under the price-at-landing than repeated post-season pricing. Price-at-landing also yields higher efficiencies than repeated post-season pricing across all forecast levels. Processors under repeated post-season pricing certainty know how much their competitors are paying their harvesters at the pricing stage, which allows processors to maintain low price offers. On the other hand, harvesters under the price-at-landing certainty condition are free to name their price and sell their unit to the highest possible offer. Processors, knowing harvesters are free to choose who they sell their products to, must keep their prices competitive to obtain any fish.

With introduction of uncertainty in the wholesale market, processors are willing to pay 1.346 dollars extra under repeated post-season pricing relative to price-at-landing. Repeated post-season pricing also yields higher efficiencies than price-at-landing across all forecast levels. Risk averse processors under price-at-landing uncertainty condition knowing that they need to endure the risks (for better or worse outcome) would not be willing to pay as much to harvesters up front. On the other hand, processors under repeated post-season pricing uncertainty already know how much they are getting at the pricing stage. They can pay harvesters according to the realized wholesale prices and harvesters receive higher average ex-vessel prices in return.

Part of the post-season pricing induced risk sharing mechanism is that processors pay different prices depending on realization of wholesale prices. We find that processor margins are 2.1, 2.5, and 2 dollars lower when the realized wholesale prices are 2.1, 3.7, and 4.8 dollars above the forecast price under repeated post-season pricing in comparison to price-at-landing. The coefficients are all significant at 5% level. Processor margins are lower when the realized wholesale prices are below the forecast price. However, none of the coefficients are significant. This indicates that processors do pay harvesters greater share of their processing margin when realized outcomes are good while maintaining competitive pricing when realized outcomes are inferior.

To understand whether post-season pricing processors try to keep prices competitive relative to other processors in order to secure future share of fish, we compare ex-vessel prices under repeated and one-shot post-season pricing. We find that repeated post-season processors are willing to pay 1.57 and 2.7 dollars more under certainty and uncertainty condition relative to one-shot post-season processors. Processors, knowing that harvesters can still switch to other processors next season under repeated post-season pricing, may be willing to offer slightly higher ex-vessel prices hoping that more harvesters would sign up with him in subsequent seasons. On the other hand, harvesters cannot distinguish processors from one season to another under one-shot post-season. This results in lower ex-vessel prices.

The experimental data has provided evidences that risk-sharing explains the post-season pricing mechanism observed in Bristol Bay. Since we have selected parameter value choices and cost structures based on Bristol Bay, it is unclear whether risk-sharing explains post-season pricing mechanism in general. It would be interesting to test for factors which sustains a post-season pricing induced risk-sharing mechanism. The theoretical models on price-at-landing suggest that oligopoly or oligopsony pricing are sensitivity to capacity constraints and cost structures. Finding out critical values for post-season pricing will rely a rigorous theoretical model or more experimental data in the future.

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