Implications of Dual Permit Regulation on the Market Values of Limited Entry Permits in the Bristol Bay Salmon Drift Gillnet Fishery

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Abstract

Implications of dual permit regulation on the market values of limited entry permits in the Bristol Bay salmon drift gillnet fishery

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In 2003, a regulation allowing two drift salmon permits to actively fish on one fishing vessel was adopted by the Alaska Board of Fisheries. This thesis aims to determine whether the new dual permit regulation impacted the market values for buyers and sellers of limited entry salmon permits beyond inherent noise in the permit price data by estimating a difference-in-differences (DiD) model. I compare monthly average permit prices between the treatment fishery, Bristol Bay, and two control fisheries, Prince William Sound and Area M. I also account for exogenous drivers of fishermen's perceptions of discounted future profits by controlling for exvessel prices, sockeye salmon run forecasts, and harvests in the DiD regression. Initial results indicate a 51.3% decrease in Bristol Bay permit prices occurred after the regulation was enacted. This result is statistically significant. The model proved to be extremely sensitive to sockeye

salmon run forecasts in particular, however; and running the regression without this variable and others create drastically different outcomes that are not statistically significant. The analysis can be improved by future work refining control variables to more accurately reflect the information fishermen have about future profitability in the fishery.

Introduction

Fisheries entry and management is a hot topic for academics, politicians, and stakeholders interested in the welfare of marine resources and coastal communities. Global fisheries and the human interactions therewith are changing rapidly, and maintaining a sharp eye toward how to effectively manage fisheries for biological and economic success will be increasingly critical in a world of growing populations and hungry, interconnected marketplaces. Limited entry in Alaska salmon fisheries presents a unique case study along these lines. I attempt to shed light on a specific rule change in 2003—the adoption of dual permit regulation—which tweaked the inherent structure of limited entry in Bristol Bay's sockeye salmon drift net fishery. Immediate changes occurred in the ways that some fishermen exercised their right to fish. However, discord and misinformation about the issue persist over a decade later in political and social forums as stakeholders wrestle with continued questions surrounding access and efficiency. It is therefore critical to analyze whether this rule change impacted the market values for limited entry permits in a significant way. This is a question that remains unanswered in academic literature. Any additional clarity afforded to the topic could contribute to the fisheries governance process in Bristol Bay and other limited entry frameworks in the future.

To investigate whether the dual permit regulation impacted limited-entry permit prices in Bristol Bay, I estimate a difference-in-difference (DiD) model, comparing monthly average permit prices between the treatment fishery, Bristol Bay, and two control fisheries, Prince William Sound and Area M. The model controls for other variables in the seafood industry which can impact market values of fishing permits. Bristol Bay was "treated" in December 2003 with the enactment of the dual permit regulation, which affords one vessel to fish two permits and an extra complement of gear. Prince William Sound and Area M, neighboring fisheries utilizing the same gear type, serve as control groups in the model. They have not been subject to this rule change and are therefore not impacted by the regulation. However, both treatment and control fisheries harvest the same species of salmon and export similar product forms to market. Exogenous market trends consequently are assumed to impact these fisheries similarly.

Regression results, after controlling for all explanatory variables, show that permit prices in the treatment fishery were negatively impacted by 51.3% in the after period, relative to the control groups, as a result of dual permit regulation adoption in 2003. While the result is statistically significant, the findings are questionable when considering economic theory and other qualitative assumptions about the nature of the fishery, stakeholder behavior, and other dynamics. It is clear that future work is needed to explore the robustness of this result after taking into account other variables capturing omitted theoretical drivers of permit prices and other industry dynamics.

I begin with a historical overview of the fishery's history and its evolution since the early days of commercial sockeye salmon harvests, followed by background on the limited entry framework. This includes discussion of underlying theories which address how permits are valued, based on other academic literature. The paper then describes dual permit regulation and rationale for its implementation. I continue with an overview of the methods used for quantifying impacts on permit prices, followed by results from applying the DiD model. While the results do not define an entirely clear outcome, the discussion section of the paper addresses some of the limitations of the current model and considerations for future work.

History

Bristol Bay, Alaska is home to the world's most prolific commercial sockeye salmon fishery. Since California fishing fleets and processors began to industrialize the resource beginning in the late 19th century (Hilborn, 2006), Bristol Bay has seen well over one hundred years of economic output fueled by sockeye salmon. Today, the towns of Naknek, Dillingham, and many outlying villages swell in population every June and July to accommodate thousands of captains, crew, processors, and industry support services for what is a month-long race to catch and deliver as much sockeye as possible. Because of the extremely short period of time in which fishermen are able to harvest fish, successful performance by all involved in the fishery is a combination of operational proficiency and luck (Link et al., 2003).

Harvest of the Bristol Bay resource for subsistence goes back thousands of years, but commercialization of the fishery began earnestly in the late-19th century (Link et al., 2003). By the year 1912, 19 canneries were in operation, utilizing 1,083 sailing vessels and fish traps, shipping product to market in mostly canned form (Hilborn, 2006; Link et al., 2003). By the 1950s, Bristol Bay's fish production showed evidence of serious decline due to a threatening combination of disorganized federal fishery management and highly-efficient fish traps used for harvesting sockeye. The trap was "like a giant octopus that grasps everything in its tentacles," and its days of unchecked harvests and lucrative profits became numbered after decades of political opposition in the then-Territory of Alaska (King, 2009a). Bristol Bay, as it turned out, was destined for a small-boat, high-employment, rights-based fishery management system.

After Alaska transitioned to statehood in 1959 and saw the subsequent migration of fisheries management from federal to state control during the 1960s, the Alaska legislature signed the Limited Entry Act into law in 1973 (King, 2009a, 2009b). A significant response was needed to address several years of extremely poor salmon harvests in Bristol Bay. The historical practice of restricting vessel lengths and gear complements were proving insufficient for curbing harvest efficiency (Koslow, 1982). Other factors outside of the control of fishery managers were also impacting salmon returns, such as high seas driftnet interception by Japanese fishing vessels and extremely harsh winters during the early 70s, leading to poor spawning recruitment. Koslow (1982), in his paper entitled, *Limited Entry Policy and the Bristol Bay, Alaska Salmon Fishermen,* explains that because salmon runs in previous years had been poor and a response was so desperately needed to curtail fleet efficiency, limited entry was adopted in response to crisis and not necessarily methodical planning based on sound economic theory. However, for better or worse, Alaska now had a new regime through which access to state managed fisheries was capped at a fixed number of participants.

Concerted effort was made to issue permits by qualifying recipients based on economic and social circumstances, such as residency, experience in the fishery, and the extent to which one's income depended on fishing (Koslow, 1982). Striking a balance was difficult, and it remains so to this day. People living year-round in rural western Alaska villages, many in poverty by federal standards, were issued permits alongside those from urban Alaska and out-of-state areas who enjoyed lower costs of living and other jobs to supplement their fishing income. Questions about equity and the elimination of open access abounded, especially as it pertained to local residents. Several hundred lawsuits were filed and even a state referendum was held to challenge limited entry. In all cases, however, courts found and Alaskans voted to uphold the act, viewing it as a suitable framework under which to manage finite salmon resources throughout the state without violating federal or state constitutionality (Koslow, 1982).

Background

There are currently 1,863 active permits in the Bristol Bay salmon drift fishery (CFEC, 2018). A permit holder may own up to two permits but may actively fish only one. A fisherman often will transfer his or her second permit into another's name, such as a family or friend, and "lease" it. It is technically against Alaska law to lease limited entry permits, however, so most lease agreements are made off-the-record and are administratively permanent transfers. One permit affords a fisherman an opportunity to fish on a vessel restricted to no more than 32 feet in length with an allowable gillnet complement of 150-fathoms long by 29 meshes deep. Permit and equipment constraints force the limited number of allowed participants in the fishery to "race" for a share of the sockeye resource as it quickly migrates from its life in the ocean to its native estuarine spawning grounds during the months of June and July. Fishing is open and closed on short notice each day by area management biologists who are monitoring the escapement of fish up several key rivers.

In this constrained system, capital and operating costs are increasingly expended by individuals for the sake of increasing capacity, as much as is possible, within the sideboards of the imposed entry and equipment limitations (Huppert, Ellis, & Noble, 1996). This phenomenon is otherwise known as capital stuffing. In the late 1970s, an aluminum, diesel-powered, 32-foot fishing vessel could be built and shipped to Bristol Bay for around $30,000. Today, in 2018, a used vessel in good shape sells for $200,000 to $300,000, while new construction costs easily $500,000 to $600,000. Commodities such as aluminum and copper, as well as construction services, have become more expensive. However, vessels have also become faster, wider (given the length constraint), and more technologically-advanced. Fishermen must try to keep pace with demands from fish processors who are hungry for deliveries of high-quality catch while staying ahead of fierce competition on the fishing grounds. A "capital gulf" among permit holders continues to widen between those who are able or willing to reinvest in more capable fishing platforms and those who are neither willing nor able reinvest for financial or other reasons. The latter group increasingly finds itself left behind in the ability to compete and seize available opportunities for adding value to the catch.

An example of reinvesting to add value to one's catch is the purchase of a refrigerated seawater (RSW) unit. This enables a vessel to circulate cold seawater through its holds, thereby holding caught salmon nearly at freezing during the transit from fishing grounds to the point of delivery. This practice fetches a premium exvessel price, as it significantly improves salmon flesh quality and adds value to the product throughout the supply chain. Installing a RSW unit in a boat can cost anywhere from $20,000 to $50,000.

Developing context around how permits are valued is imperative for the purposes of this paper. There is a good amount of literature linking fishing permit market values to several key drivers.

Asset pricing theory and total earnings, respectively, are key drivers of permit valuation (Huppert et al., 1996; Karpoff, 1984a; Knapp, 2011). The risk-neutral fisherman, viewing a permit as a capital investment, will pay up to the present value of expected future profits so long as the fishermen exercises his or her right to fish with that permit. Knapp adds that, in addition to discounted future profits, economic theory supports valuation based on one's own intangible ideals about participation in the fishery (Knapp, 2011). Opportunity costs of other relinquished employment opportunities, non-pecuniary benefits, individuals' particular fishing proficiencies (or lack thereof), and fishing styles are all non-monetary factors to consider when assessing permit values (Knapp, 2011).

Jonathan Karpoff (1984a; 1984b) published several papers on limited entry and its associated theoretical valuation models. In one paper, he assigns quantitative relationships between permit prices and their drivers such as a fisherman's recent memory, profitability, biological run forecasts, available low-interest capital, and risk premiums (Karpoff, 1984a). He quantifies nearly all of these concepts in the paper. For example, he notes that, "…11% of the *change* in a measure of the expected value of the fish run is reflected in permit price changes. A second test estimates that a one percentage point deviation in the fish run forecast from a long-term average correlates with a $60.50 increase (for positive deviations) or decrease (for negative deviations) in permit price levels" (Karpoff, 1984a). He further points to low-interest capital (e.g., subsidized loan programs for Alaska residents) contributing to a 23% or $8,242 increase over baseline expectations of permit prices (Karpoff, 1984a). While much has changed in salmon fisheries since the 1984 Karpoff publication, salmon run forecasts and subsidized loans remain just as relevant to this day and their impacts should not be disregarded.

Karpoff (1984b) inquires further into the topic of low-interest, state-funded loans and how they impact permit values. He points to microeconomic theory which predicts increases in demand-prices of permits "by the value of the effective subsidy" (Karpoff, 1984b). Indeed, empirical tests concluded that permit prices and transfer volume increased as a result of 7% state loan money by 23% and 21.9%, respectively (Karpoff, 1984b).

I have briefly described some exogenous drivers of limited entry permit valuation because the consideration of such drivers is critical for understanding how policies, regulations, market conditions, and other changes to industry can act as significant independent influencers on prices.

Dual permit regulation

While limited entry itself seems to effectively control access and contribute to, along with sound biological management, the successful long-term sustainable yield of the resource, it was not (and still is not) commonly accepted among stakeholders as a mechanism which necessarily guarantees the equal right among all citizens to participate in a fishery (Hébert, 2014). Historically, concern has been expressed about inequity among individuals who desire to buy in to the Bristol Bay fishery, or who simply wish to remain solvent within it but may not be able to do so because of economic circumstances.

Bristol Bay is unique because of the sheer volume of sockeye that return to the watershed each year in such a compressed time frame. Affording all in the fleet the opportunity to capture this quickly-migrating resource inside of four weeks while controlling for optimum biological yield *and* allowing for equal economic opportunity across a diverse array of participants is a dizzying and complex challenge.

In 2003, a citizen-generated proposal addressing the idea of allowing "dual permits" in Bristol Bay was heard at the Alaska State Board of Fisheries meeting. The Board of Fisheries is the governor-appointed body that meets every three years to hear, analyze, recommend, and enact policies and laws for state-managed fisheries. While one permit in the Bristol Bay fishery affords a permit holder one 150-fathom complement of gillnet on a 32-foot vessel as previously described, a dual permit regulation would allow two permits, owned by two separate individuals, to "team up" on one vessel. This would allow an extra 50-fathom complement of gear to be fished, for a total of 200 fathoms per vessel. The rationale behind the policy was primarily to lower barriers to entry and allow an individual to be able to fish his or her permit on another's vessel, eliminating for the second permit holder the capital outlay required for a separate vessel, gear, maintenance, crew, fuel, and other costs associated with fishing. Low economic returns during seasons of depressed prices or decreased salmon landings (Hilborn, 2006) could be alleviated, and profits would therefore be expected to climb over the aggregate number of active permits fished (Hébert, 2014). Some permits would surely be brought out of latency, as not all active permits actually fish year-to-year. Furthermore, the amount of "gear in the water" would diminish, as the net effect of each dual permit vessel results in 100 fewer fathoms of gear in the water as compared to the 300 fathoms of gear fished between the same two permits fished on separate vessels (Hébert, 2014). The dual permit proposal was passed by the Board of Fisheries in December of 2003, made effective the following April, and remains codified today under Alaska Administrative Code, 5 AAC 06.333 (Requirements and specifications for use of 200 fathoms of drift gillnet in Bristol Bay, 2004).

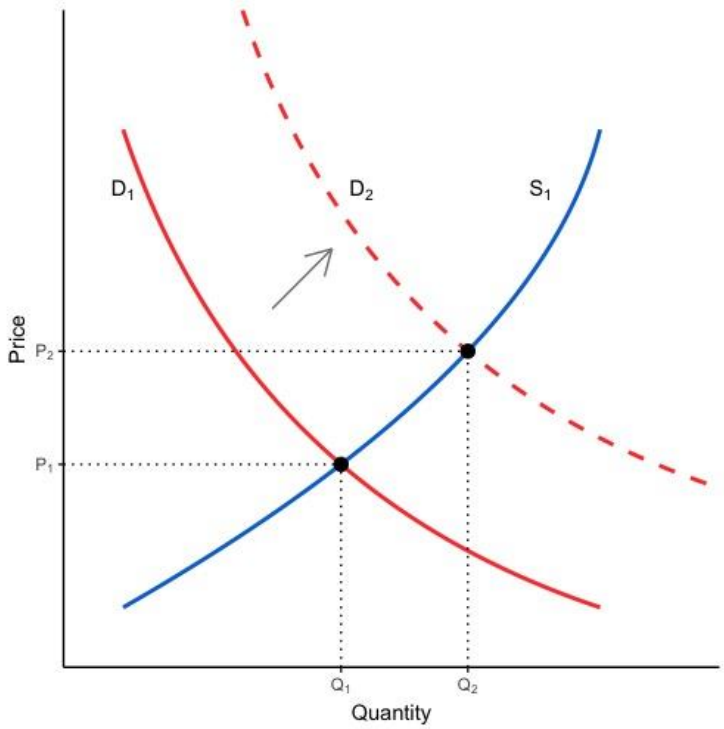

Figure 1. Theoretical Permit Regulation Supply/Demand Shift.

Figure 1 shows a basic supply and demand model and the associated theoretical shift in the demand curve, occurring after dual permit regulation is newly codified. An outward shift in the demand curve (D_1 to D_2) could result from a perceived increase in future profits, should a fisherman elect to take advantage of the newfound option to fish two permits. Equilibrium price for a permit, P_1, would increase to P_2 as a result of the outward shift in demand. The equilibrium quantity of permits traded, Q_1, both active and latent, would likely increase to Q_2 as more fishermen become interested in transitioning into dual permit operations and subsequently increasing their earnings.

It is important to remember that Figure 1 only represents a theoretical demand shift. Overcapacity and rent dissipation in Alaska's salmon fisheries, in particular Bristol Bay, likely challenge this theory, however. It could be that there is no increase in future expected profits by fishermen and therefore little to no shift in the demand curve (C. Anderson, personal communication, May 22, 2018; Hébert, 2014; Link et al., 2003). Furthermore, potential supply curve implications are not represented in the figure because questions pertaining to whether or not the supply curve shifted are unclear. It is possible that permit holders would be less willing to sell their permits after the regulation was implemented, shifting the supply curve in and exacerbating the theoretical upward pressure on price. Regardless, theory predicts the policy should increase permit prices in Bristol Bay. An analysis like the difference-in-differences model employed in this paper can help bridge the distance between this type of theory and the actual impacts of the dual permit policy.

Changes to a regulation such as this can drastically change the playing field for participants, sometimes overnight. I investigate how the dual permit regulation impacted limited entry permit market values for the drift gillnet fishery in Bristol Bay. I hypothesize that dual permit regulation, codified in early 2004, did not impact permit values in a quantifiable way above and beyond other noise inherent in the data.

The rule allows for the "teaming up" of two fishing permits, owned (and fished) by two separate individuals, on one vessel. Teaming up in this way is based solely on a fisherman's discretion. The regulation does not change the number of permits issued to the fishery under the Limited Entry Act. Rather, it affords fishermen an opportunity to team up, collectively fish extra gear, and hopefully become more profitable.

If a fisherman's willingness to buy or sell is driven, among other things, by the perception of future discounted profits, that perception is, in turn, driven by exogenous variables influencing the health of the fishing industry. These include, but are not limited to, exvessel prices, biological predictions of sockeye salmon runs, habitat conditions, wholesale and consumer market demand for salmon, the strength of the US dollar, global farmed salmon output, and processor or distributor inventories. While theory suggests that permit prices are dependent on changes occurring both within and outside the fishing industry, the magnitude with which these shifts impact limited entry salmon permits is highly variable; and it interfaces, complicatedly, with fishermen's reactions to these shifts in the form of willingness to trade. The difference-in-differences approach to teasing out the implications of the dual permit regulation change controls for several, but not all, of these permit price influences. Specifically, in this thesis, I control for forecast, harvest, and exvessel price.

Furthermore, it is important to qualify the reason for why testing a hypothesis which predicts, to a large degree, either a null or barely-quantifiable result, is necessary. Because laws and regulations governing the Bristol Bay salmon fishery are subject to review, deliberation, and changes every three years through the Alaska Board of Fisheries process, many, if not all of these meetings over the years have included stakeholder proposals asking the board to adopt measures to consolidate participation or harvest in the fishery through permit or gear modifications. Unfortunately, there is a deficiency in clear answers regarding implications of these types of regulations. This thesis attempts to contribute to that discussion by using real observations (average monthly permit prices) to help quantify the impacts by a regulation which effectively leads to a “voluntary” type of permit consolidation. A null result should contribute to policy outcomes in the same way as significantly negative or positive results. If answers to these questions cannot be achieved or at least attempted in good faith, healthy deliberation preceding potentially consequential public policy decisions is compromised.

Methods

The difference-in-differences approach is used commonly among economists and statisticians to analyze the implications of policy outcomes. The method became renowned after a paper addressing changes in employment as a result of minimum wage policy in the fast food industry was published in 1994 (Card & Krueger, 1994). I estimate the extent to which dual permit regulation has influenced Bristol Bay permit prices over time by establishing a counterfactual and using the empirical approach of comparing treatment and control fisheries through a DiD estimation. A statistical link is therefore established between the adoption of dual permit regulation and permit prices. Bristol Bay monthly average permit prices is the treatment group and monthly average permit prices for the Prince William Sound and Area M (Alaska Peninsula) sockeye gillnet fisheries are two control groups. These, along with additional data on historical annual biological forecasts, harvests, and exvessel prices are included in a regression model as I attempt to control for other events and changes in the seafood industry which may also impact permit prices over time. Commercial Fisheries Entry Commission (CFEC) data sets containing monthly average permit prices for all three fisheries between 1991 and 2016 are employed, with some missing values during early years for Area M. The Alaska Department of Fish and Game (ADF&G) provided data on historical exvessel prices and forecasts for all fisheries, and CFEC held data on harvests.

Given that the fleet would have been immediately aware of dual permit proposal adoption in December of 2003 (the treatment event), the empirical model attempts to identify how the treatment and control permit prices compare to one another pre-treatment and post-treatment. A DiD estimator with a positive value would indicate that permit prices increased as a result of the regulation change. The model is as follows:

$$\log(y) = \beta_0 + \beta_1 t + \beta_2 p + \beta_3 tp + \alpha_1 fcst + \alpha_2 avgex + \alpha_3 hvst + \boldsymbol{mn} + \boldsymbol{yr} + \epsilon$$

where y represents the dependent variable in dollars adjusted for inflation with 2016 as the base year, t identifies the treatment group when equal to 1, p is a dummy variable that equals 0 during years prior to 2004 and 1 for years greater than or equal to 2004; tp is the policy interaction (producing the DiD estimator) between t and p; $fcst$ indexes all of the pre-season biological salmon forecasts; $avgex$ indexes monthly average exvessel prices; and $hvst$ indexes harvests of sockeye. The terms $\boldsymbol{mn}$ and $\boldsymbol{yr}$ are vectors for month and year fixed effects. It is important to note that $avgex$ and $fcst$ are constructed in a manner that accounts for timing issues with the receipt and interpretation of information by fishermen. For example, the forecast for the 2015 Bristol Bay salmon season (occurring in June and July) is released to the public in November of 2014. Therefore, the forecast "year" should run December 1 through November 30 of the following year. Additionally, I estimated the exvessel price "year" to run approximately August 1 through July 31; as by midsummer (around August 1), prices have stabilized, and fishermen have a good idea of how they are being compensated for their catch.

Run forecasts are an important driver of permit values because they impact a fisherman's perception of discounted future profits (Karpoff, 1984a). Forecasts are typically released in the late fall and early winter for the coming spring and summer harvests. If a forecast specifies a poor return of salmon this summer, expectations of revenues may change in a permit holder's mind; and, if he or she decides to sell after a poor forecast is released but before fishing begins, the price may indeed be lower than if the permit were made available for sale prior to the dissemination of bad news. The same may be true for the opposite scenario.

Exvessel prices are critical to consider because they are perceived as the most significant factor in determining whether or not a fisherman will be profitable in a given season. Figure 2 includes average exvessel prices for both treatment and control fisheries across the full study period.

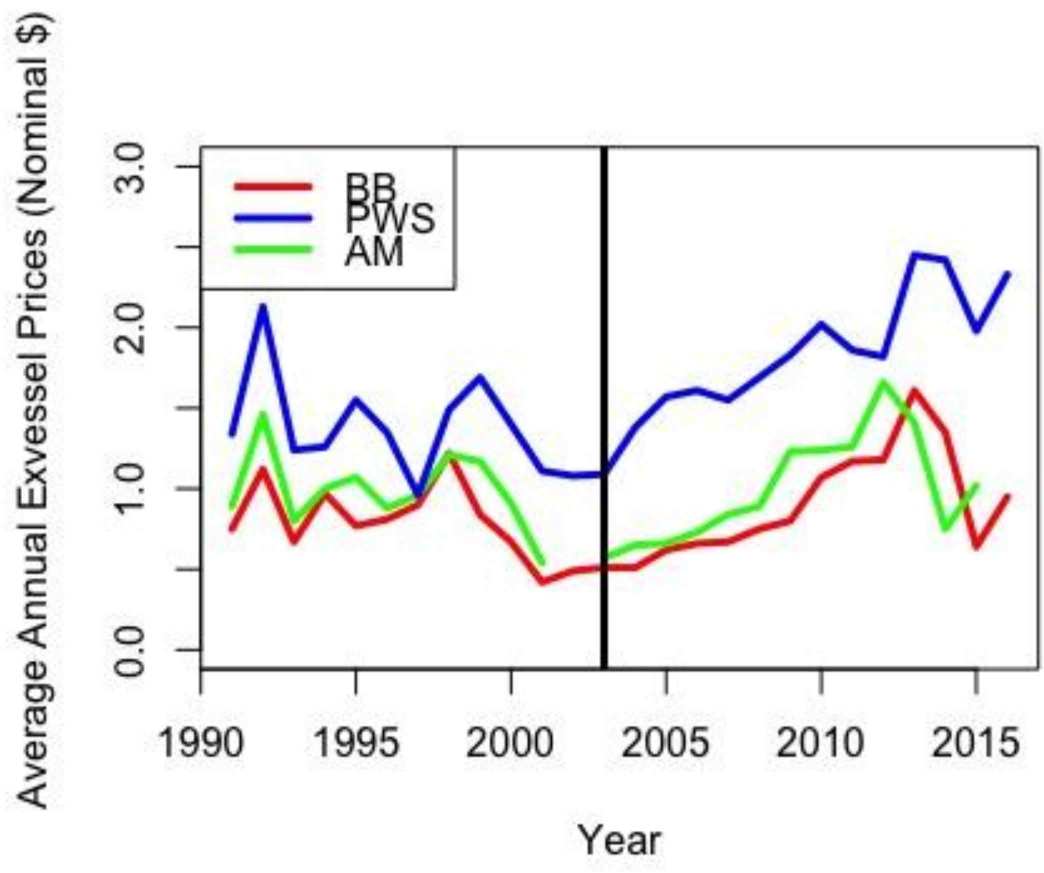

Figure 2. Average Annual Exvessel Prices, 1991-2016 (in nominal $, not adjusted for inflation).

If a fisherman gets paid a poor exvessel price for his or her catch, permit prices and other values for real property can decline based on reduced cash flow and lowered expectation of future profits.

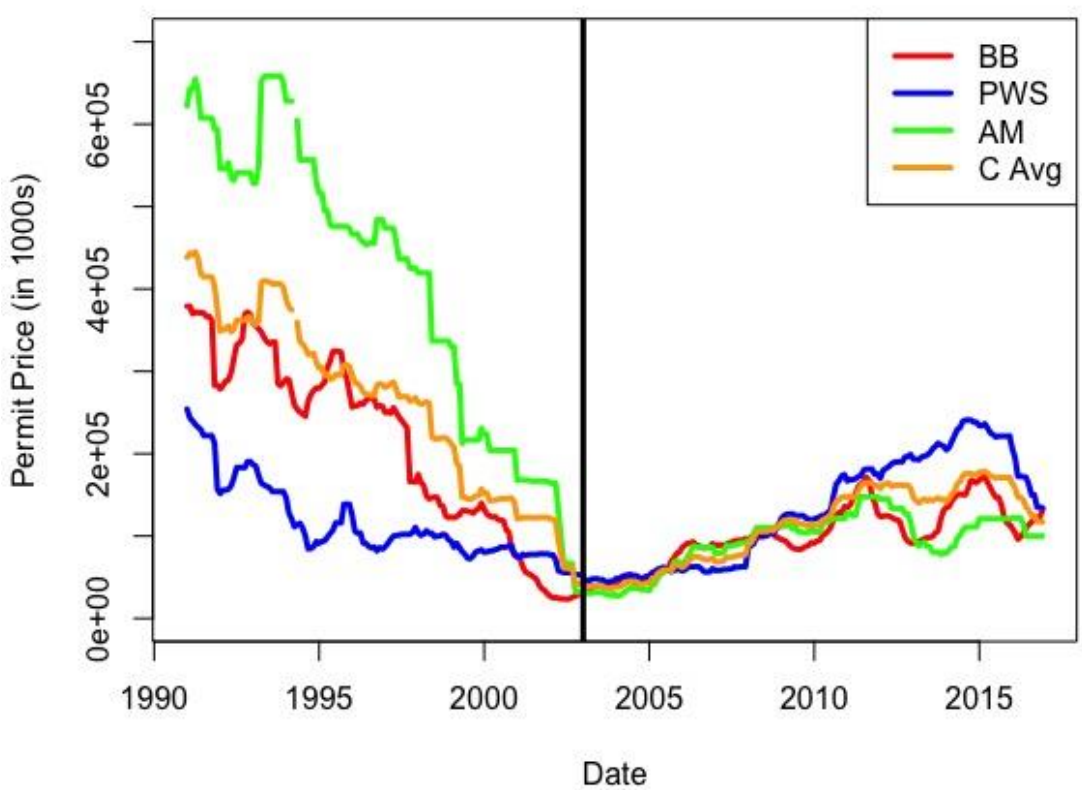

Figure 3. Monthly Average Permit Prices for Bristol Bay (BB), Area M (AM), and Prince William Sound (PWS) 1991-2016 in Real 2016 USD. C Avg denotes average of PWS and AM.

Results

Figure 3 helps visualize the interaction of permit prices for the three fisheries included in the model over the timeframe tested. It also shows a good fit between the combined average prices in the two control fisheries (C Avg) and Bristol Bay. A plot unequivocally supporting my hypothesis would show a constant price differential between the treatment and control fisheries prior to treatment in 2003, with a slight increase in the differential after treatment, though that is clearly not the case here. Also noteworthy is the back-and-forth in value that occurs between the two control groups between roughly 2003 and 2007, with the definitive switching of value occurring in the 2008-2009 period whereby Price William Sound salmon permits are worth more than those in Area M. The two appear to meet again by 2016. Moreover, it is useful to contextualize industry-wide downtrends in permit prices through the turn of the century: this is widely reported to be due to simultaneous crashes in biological run strength and exvessel price combined with an oversupplied farmed salmon marketplace, which undercut demand for wild salmon products originating in Alaska (Link et al., 2003). The model accounts for biological run strength and ex-vessel prices by including *fcst* and *avgex* respectively as control variables. To the extent that the remaining drivers (e.g. farmed salmon supply) of permit prices equally impacted the treatment and control fisheries, the difference-in-difference model controls for these factors by essentially "differencing them away".

Table 1 shows a summary of regression coefficients across three variations of model runs, as shown by the indication of whether or not forecast, harvest, and exvessel price explanatory variables are included. Month and year fixed effects were employed for all model runs. The coefficient for the difference-in-differences estimator *PostxTreat* shows a 7.8% and 7.2% post-treatment increase in mean permit prices for the treatment fishery in regressions 1 and 2, respectively; however, these results are not statistically different than zero. Regression 3 shows a 51.3% drop in permit prices as a result of the dual permit regulation in the post-treatment period, controlling for all explanatory variables. This result is statistically significant. Full regression results, including all month and year fixed effect coefficients, can be found in Appendix A.

Table 1.
Summary Regression Results

	Dependent variable:		
	Average Permit Price (Real 2016 USD)		
	(1)	(2)	(3)
treat	-0.129***	-0.212***	-0.334***
	(0.041)	(0.045)	(0.056)
Post	-1.099***	-1.013***	-0.637***
	(0.100)	(0.123)	(0.068)
PostxTreat	0.078	0.072	-0.513***
	(0.058)	(0.059)	(0.030)
FORECAST	NO	NO	YES
HARVEST	NO	NO	YES
EXVESSEL PRICE	NO	YES	YES
MONTH FE	YES	YES	YES
YEAR FE	YES	YES	YES

Note. ***p<0.01

Discussion

The negative DiD estimator in the third model, while significant, does not necessarily lead to a reasonable conclusion that dual permit regulation had a negative effect on permit prices, especially to the degree indicated. The model is extremely sensitive to forecast and harvest explanatory variables. This makes sense from a realistic standpoint. Considerable changes in both these categories have always led to considerable changes in valuation of limited entry permits in Bristol Bay. If the forecast or harvest is poor, boats and permits are usually worth less. Interestingly, the exvessel price variable by itself does not have a significant impact on the DiD estimator. Additional analysis is needed to further determine relationships between these variables.

Continuing work is needed to determine the right mix of explanatory variables, fixed effect parameters, and models to best fit the data. An enhanced understanding of what drives fishermen's behavior in exercising the right to fish within the constraints of the current limited entry regime and amendments thereto would strengthen qualitative assumptions about key drivers of model outputs. It very well could be that there *was* significant downward pressure on permit prices after dual permit regulation was codified. However, given all of the other randomness in behavior and in the industry, which have proven for decades to be major influences on capital valuation in Alaska salmon fisheries, more background information would be needed to better explain the result.

Furthermore, economic theory reasonably assumes that demand will increase as a result of the policy, because fishermen expect increased future profits with the added opportunity of the second permit. The only statistically significant result counters this assumption to a large degree, and this is a compelling reason to attempt a better understanding of the interface between theory, behavior, and how the model fits.

Additional research into latent permits and their impact on the supply curve (potentially offsetting demand shifts), fishermen's perceptions of transaction costs associated with teaming up in a dual permit operation, and a better understanding of willingness to trade considering all of these circumstances within the limited entry regime would add substance and clarity to this topic.

Conclusion

This work attempts to define how observed permit prices in the Bristol Bay sockeye salmon fishery were impacted by a regulation change adopted by the Alaska Board of Fisheries in 2003. This change to allow dual permits on a single vessel inherently altered the way fishermen exercise their right to fish. Instead of one permit holder operating on one vessel with the required maximum complement of fishing gear afforded to a single permit, fishermen, as of the 2004 season, could now join with another fisherman on a single vessel and fish an additional 50 fathoms of gear.

Considering that a major barrier to entering the Bristol Bay fishery is purchasing the permit itself, how did the new regulation impact their market values? Regression results show that a 51.3% decrease in market value for limited entry permits occurred as a result of the dual permit regulation while controlling for several key explanatory variables. However, based on randomness in the model and other drivers of permit price potentially unaccounted for, more work is needed to effectively produce results that can better explain behavior in Bristol Bay salmon permit prices, post-treatment.

Perhaps the greatest takeaway from the results generated in this paper is that the interface between human behavior (vis-à-vis buying and selling the right to fish) and the bioeconomic model in limited entry salmon fisheries is complex. Evaluating regulatory decisions and quantifying their implications on stakeholders using econometric tools is imperative for quantifying progress in fisheries policy.

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Appendix A

Table 2.
Complete regression results

	Dependent variable:		
	Average Permit Price (Real 2016 USD)		
	(1)	(2)	(3)
treat	-0.129***	-0.212***	-0.334***
	(0.041)	(0.045)	(0.056)
Post	-1.099***	-1.013***	-0.637***
	(0.100)	(0.123)	(0.068)
PostxTreat	0.078	0.072	-0.513***
	(0.058)	(0.059)	(0.030)
fcst (millions of fish)			0.000***
			(0.000)
avgex		-0.157***	0.228***
		(0.043)	(0.022)
hvst (millions of lbs)			0.000***
			(0.000)
mn2	0.001	0.001	0.001
	(0.067)	(0.069)	(0.035)
mn3	0.002	0.002	0.006
	(0.067)	(0.069)	(0.035)
mn4	-0.003	-0.004	0.014
	(0.067)	(0.069)	(0.035)
mn5	0.005	0.004	0.021
	(0.067)	(0.069)	(0.035)
mn6	-0.002	-0.004	0.023
	(0.067)	(0.069)	(0.035)
mn7	-0.003	-0.003	0.025
	(0.067)	(0.068)	(0.035)
mn8	-0.003	-0.007	0.013
	(0.067)	(0.068)	(0.035)
mn9	-0.006	-0.010	0.010
	(0.067)	(0.068)	(0.035)

mn10	-0.021	-0.016	0.002
	(0.067)	(0.068)	(0.035)
mn11	-0.027	-0.021	-0.003
	(0.067)	(0.068)	(0.035)
mn12	-0.029	-0.024	-0.006
	(0.067)	(0.068)	(0.035)
yr1992	-0.165*	-0.084	-0.249***
	(0.098)	(0.121)	(0.070)
yr1993	-0.128	-0.038	-0.394***
	(0.098)	(0.121)	(0.071)
yr1994	-0.387***	-0.345***	-0.733***
	(0.099)	(0.121)	(0.072)
yr1995	-0.366***	-0.306**	-0.677***
	(0.098)	(0.121)	(0.072)
yr1996	-0.485***	-0.429***	-0.767***
	(0.098)	(0.121)	(0.071)
yr1997	-0.531***	-0.490***	-0.585***
	(0.098)	(0.121)	(0.070)
yr1998	-0.731***	-0.672***	-0.636***
	(0.098)	(0.121)	(0.071)
yr1999	-0.981***	-0.894***	-0.847***
	(0.098)	(0.121)	(0.071)
yr2000	-1.075***	-1.010***	-1.003***
	(0.098)	(0.121)	(0.070)
yr2001	-1.448***	-1.425***	-1.305***
	(0.098)	(0.121)	(0.070)
yr2002	-2.016***	-1.987***	-1.642***
	(0.098)	(0.125)	(0.071)
yr2003	-2.275***	-2.123***	-1.620***
	(0.098)	(0.130)	(0.071)
yr2004	-1.077***	-1.062***	-0.802***
	(0.098)	(0.105)	(0.052)
yr2005	-0.769***	-0.829***	-0.572***
	(0.098)	(0.099)	(0.049)
yr2006	-0.502***	-0.548***	-0.340***

	(0.098)	(0.099)	(0.048)
yr2007	-0.468***	-0.511***	-0.339***
	(0.098)	(0.099)	(0.048)
yr2008	-0.202**	-0.238**	-0.108**
	(0.098)	(0.098)	(0.048)
yr2009	-0.164*	-0.184*	-0.066
	(0.098)	(0.098)	(0.048)
yr2010	-0.028	-0.023	-0.006
	(0.098)	(0.098)	(0.048)
yr2011	0.209**	0.237**	0.230***
	(0.098)	(0.098)	(0.048)
yr2012	0.128	0.154	0.219***
	(0.098)	(0.098)	(0.048)
yr2013	-0.035	0.024	0.044
	(0.098)	(0.099)	(0.049)
yr2014	0.186*	0.278***	0.196***
	(0.098)	(0.101)	(0.050)
yr2015	0.238**	0.273***	0.175***
	(0.098)	(0.098)	(0.048)
yr2016			
Constant	12.860***	13.001***	11.698***
	(0.084)	(0.121)	(0.072)
FORECAST	NO	NO	YES
HARVEST	NO	NO	YES
EXVESSEL PRICE	NO	YES	YES
MONTH FE	YES	YES	YES
YEAR FE	YES	YES	YES
Observations	935	893	758
R^2	0.689	0.657	0.881
Adjusted R^2	0.676	0.641	0.874
Residual Std. Error	0.416 (df = 896)	0.415 (df = 853)	0.197 (df = 716)
F Statistic	52.175*** (df = 38; 896)	41.919*** (df = 39; 853)	129.456*** (df = 41; 716)
Note:			*p<0.1; **p<0.05; ***p<0.01