to LE_{78} (treatment E). Thus, the two sets of treatments differ only by whether ITQs are introduced before or after consolidation. The effects of treatments B (ITQ_{232} - LE_{232}) and E (ITQ_{78} - LE_{78}) capture the incentive effect by holding consolidation constant, while the effects of treatments C (ITQ_{78} - ITQ_{232}) and D (LE_{78} - LE_{232}) capture the consolidation effect by holding the regulatory institution constant. Note that even though the total effects B + C and D + E are both equal to the effects of treatment A, the treatment effects are not additively separable, so that sequencing of the treatments matters for their effects. That is, the effects of treatments B and E are not necessarily equivalent so that incentive effects depend on the number of vessels in the fishery before ITQs are introduced. Similarly, the effects of consolidation treatments C and D are conditional on the regulatory institution of the fishery.

5.3 Results

The results from each of the model simulations used in our hypothetical experiment in Figure 7 are presented in Table 2, where the use of production inputs have been grouped according to their use of time or space. To frame the following discussion, we consider increases in both velocity and pot lifts per day as indicators of *temporal* input intensification, while an increase in the number of pots used and a reduction in the spacing between pots are considered indicators of *spatial* input intensification. Note that spatial and temporal intensity are intricately connected in that temporal intensity depends on input use over space. For example, decreasing the distance between pots d increases both spatial and temporal intensity by increasing the number of pot lifts per day.[20]

The total effects of ITQ introduction (Figure 8) support the traditional hypothesis that fisheries operations will be less "intensive" relative to race to fish conditions, across both time and space. This is reflected through decreases in both velocity and pot lifts per day, indicating an overall decrease in temporal intensity, along with an increase in spacing between fewer pots, indicating an overall decrease in spatial intensity. Furthermore, substantial rents are generated due to increases in daily productivity and reductions

[20]To see this, note that pot lifts per day is the inverse of handling time τ^h and that handling time decreases with a reduction in distance d between pots (equation 6).

	Use of Time				
Institution	Velocity (knots)	Pot Lifts per Fishing Day	Soak Time (days)	Fishing Days	Trips
(a) LE_{232}	12.5	143.6	1.24	3.71	1
(b) LE_{78}	12.5	160.1	1.74	6.45	1
(c) ITQ_{232}	5.94	61.4	1.05	5.43	1
(d) ITQ_{78}	6.55	85.2	1.49	10.29	2
	Use of Space				
Institution	Pots	Distance (nm)	Inverse Cong. Index	Own Inverse Cong. Index	
(a) LE_{232}	178.61	1.10	0.716	0.974	
(b) LE_{78}	278.88	0.89	0.961	0.977	
(c) ITQ_{232}	64.67	1.85	0.975	0.981	
(d) ITQ_{78}	126.65	1.33	0.979	0.982	
	Production/Rents				
Institution	Catch per Day (crabs)	Ave. Variable Cost ($/crab)	Rents per Vessel ($)[a]	Total Rents ($)[a]	
(a) LE_{232}	2581	2.24	234,370	54,373,840	
(b) LE_{78}	4412	1.18	795,850	62,076,300	
(c) ITQ_{232}	1762	1.10	244,590	56,744,880	
(d) ITQ_{78}	2765	0.81	810,220	63,197,160	

[a]The rents reported in this table are measured before payments to labor, reflecting the nature of the share system in the RKC fishery.

Table 2: **Simulation results** - Results for different institution types and number of vessels. The total effect of ITQ introduction is row (a) vs. row (d) (movement A). The incentive effect is row (a) vs. row (c) (movement B) or row (b) vs. row (d) (movement C). The consolidation effect is row (a) vs. row (b) (movement D) or row (c) vs. row (d) (movement E).

in average variable costs from increases in the scale of operation of remaining vessels as excessive capital is eliminated and as new incentives are introduced with secure harvesting rights.[21]

Figure 8 also depicts the separation of the total effects of ITQ introduction into incentive and consolidation effects, where column (a) presents the effects from introducing ITQs before consolidation (treatments B and C) while column (b) presents the effects from effecting consolidation before introducing ITQs (treatments D and E). While the magnitudes of the consolidation and incentive effects differ between the two sets of treatments, their qualitative directions are consistent. Consolidation alone appears to have

[21]We define average variable costs as the seasonal cost of production (15) minus the seasonal rental cost of a vessel r, divided by the number of harvested crab within a season.

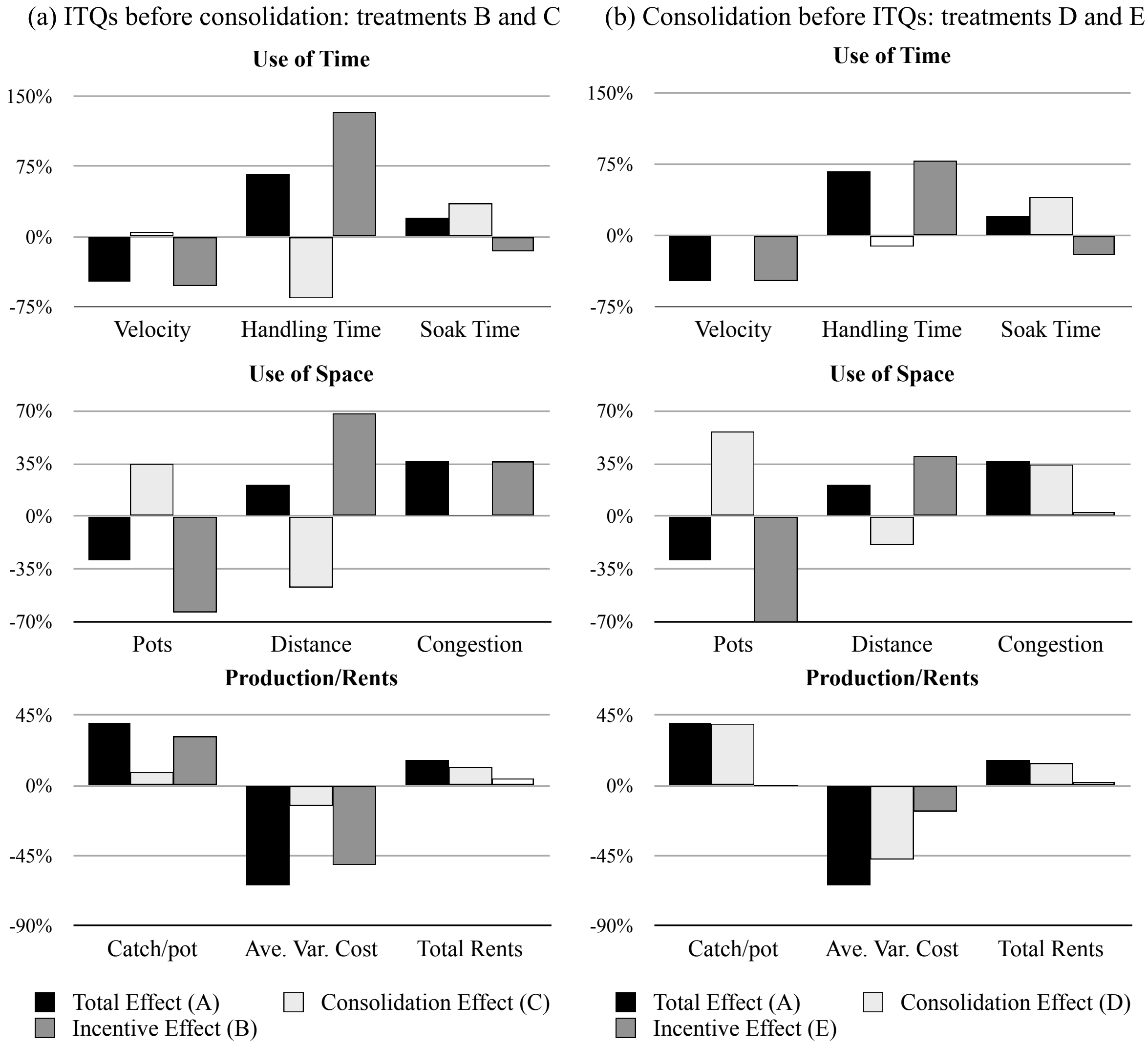

Figure 8: The effects of introducing ITQs - Decomposing the total percentage effects from introducing ITQs. The total effect of ITQs (treatment A) is the percentage difference between ITQ_{78} and LE_{232}. Figure (a) depicts the composition of the total effects that arises from introducing ITQs before consolidation while Figure (b) depicts the composition of the total effects by allowing consolidation before introducing ITQs. Note that for both Figure (a) and (b), the sum of the incentive effects and the composition effects are equal to the total effects.

the effect of intensifying harvester behavior in both the temporal and spatial dimensions as vessels increase scale of operations. In contrast, incentive effects in isolation seem to diminish the intensity of input use over time and space respectively. Thus, isolating the incentive and consolidation effects from ITQ introduction reveals that the total effects from ITQ introduction are the sum of two competing effects.

Perhaps counter intuitively, soak time per pot actually tends to decrease from incentive effects (and vice versa for consolidation effects). The reason for this is that soak time is jointly determined by spatial and temporal input use so that the increase in soak time that occurs from slower velocity and increased distance between pots is overwhelmed by the substantial reduction in the use of pots with incentives alone. However, this incentive is buffered somewhat by the effects of consolidation under the ITQ to employ more pots, due to scale economies. This result provides an example for which the consolidation effect dominates the incentive effect and suggests that the longer soak times witnessed with ITQ introduction in the RKC fishery may actually be due to consolidation rather than from ITQ-specific incentives.

A glance at Table 2 reveals that both LE fisheries generate a considerable amount of rents, despite the lack of secure harvesting rights. In particular, Figure 8 indicates that consolidation in an LE fishery, perhaps by relaxing trade restrictions or through a vessel buyback program, is capable of generating large increases in rents. The reduction in average variable costs with consolidation in the LE (and ITQ) fishery indicates that vessels are able to exploit scale economies, contributing to overall rent generation.

The ability to generate substantial rents in an LE fishery is perhaps surprising, since lack of secure harvesting rights is typically associated with the dissipation of fishery rents (Homans and Wilen, 1997). As has been demonstrated by Campbell and Lindner (1990) and Deacon et al. (2011), however, the extent of rent dissipation can be mitigated if the use of some inputs to the production process is restricted and the ability to substitute between restricted and unrestricted inputs is imperfect. In this case, the key restrictions are the limit on the number of vessels in the fishery and the technological constraint on velocity. In particular, for both the LE_{232} and LE_{78} fisheries, maximum velocity ($\bar{v} = 12.5$ knots) is binding and prevents rent dissipation in the limited entry fishery. To illustrate this phenomenon, Figure 9 presents the SNE outcomes for the LE_{78} fishery for different levels of $\bar{v}$, relative to the LE_{78} fishery with $\bar{v} = 12.5$ knots. As the maximum velocity increases, the true "race for fish" intensifies in the LE fishery; harvesters are induced to travel faster ($\bar{v}$ is always binding), lift more pots per day, drive up their average variable costs, and dissipate fishery rents. In the RKC case, it is thus a technological constraint—i.e. an upper bound on velocity and imperfect substitutability between velocity, distance, and number of pots—rather than the regulatory institution itself that allows the LE fishery to generate substantial rents in this fishery.[22]

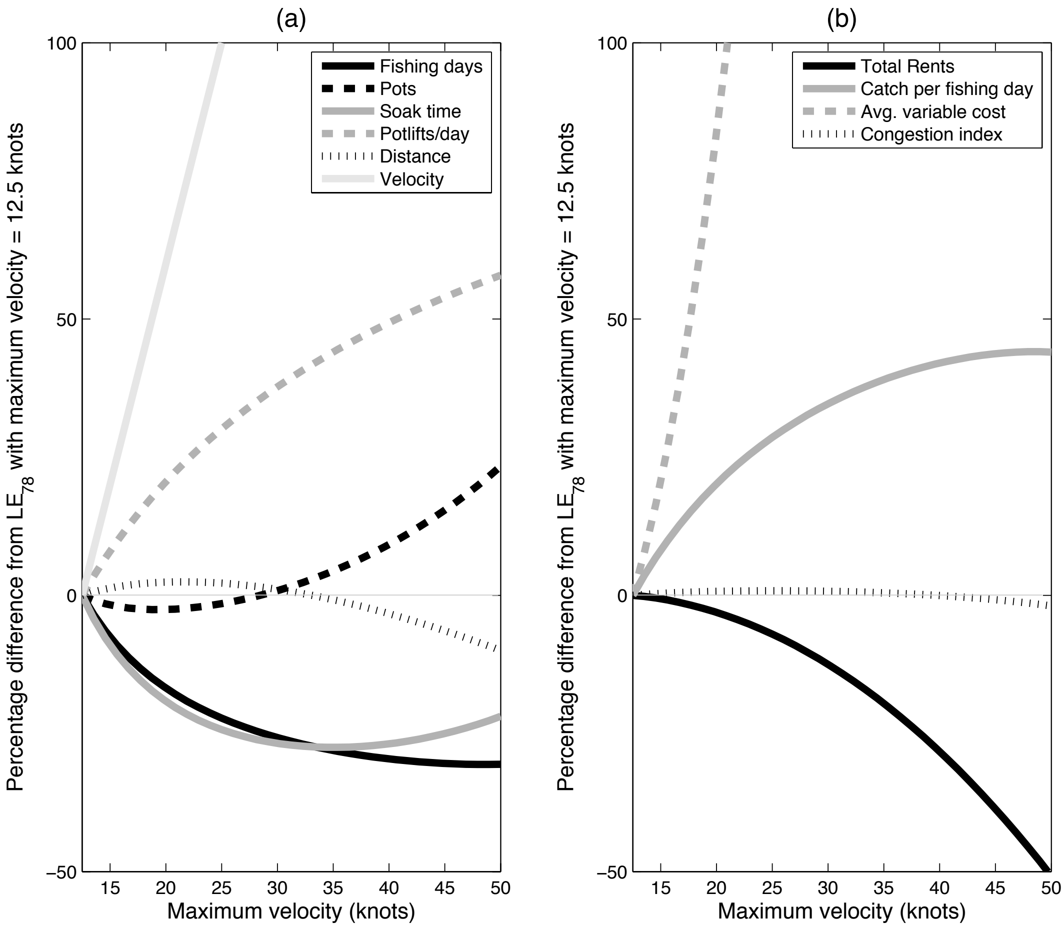

Figure 9: Increasing maximum velocity and rent dissipation - Outcomes from the LE_{78} fishery for different levels of maximum velocity ($\bar{v}$). The percentage difference in (a) model predictions and (b) performance measures, relative to the LE_{78} fishery with $\bar{v}$=12.5 knots.

[22] This result was highlighted in interviews with skippers as I began to conduct this analysis. When queried about the most dramatic changes in fishing practices, skippers often cited the leisurely pace in pot handling behavior after ITQs (described as "idling" the vessel from pot to pot) compared with the derby fishery (described as "pedal to the metal" from pot to pot).

The analysis above provides some general insights into the behavioral changes and sources of rent generation that occur from the consolidation and incentive effects from ITQ introduction. At the same time, considering only LE and ITQ fisheries with 232 and 78 vessels limits our ability to fully explain why harvesters intensify their fishing practices with the elimination of vessels from the fishery. It is also clear from Figure 8 that incentive effects depend on the number of vessels in the fishery; thus, it is worth investigating whether our tentative conclusion that ITQ incentives have the effect of reducing the intensity of input usage over time and space is robust to different fleet sizes.

To further examine the behavioral effects from consolidation, we consider treatments C and D from our hypothetical experiment to be continuous along the interval between 78 and 232 vessels (Figure 10). Many interesting changes in harvesting behavior occur as vessels are successively eliminated from either fishery. First, a discrete shift in fishing practices, average variable costs, and daily productivity in the ITQ fishery marks the number of vessels at which the fleet can make the transition to two trips. This transition is not witnessed in the LE fishery since, for the number of vessels considered here, intensive derby behavior closes the season before the binding hold capacity constraint is reached. LE harvesters thus fail to collectively make the transition to two trips at a larger number of vessels—like the ITQ harvesters do—even though they would be better off from reducing the amount of crab deterioration that occurs from longer trips. In addition, the trend in behavioral changes by LE harvesters is not affected when the transition to a second trip is made (not pictured), whereas ITQ harvesters display a large reduction in the intensity of their fishing practices after making the transition to two trips. This is due to the fact that harvesters from each respective fishery are racing against two different things: harvesters from the LE fishery are racing against each other so that transitioning to a second trip means nothing more than an additional lump sum cost, whereas harvesters from the ITQ fishery are racing against deteriorating crab so that once a harvester's quota is divided between two trips, the fishing pace can slow down again.

Second, the elimination of vessels from the fishery does not necessarily have a monotonic effect on the incentives to intensify input use with consolidation. This is seen by

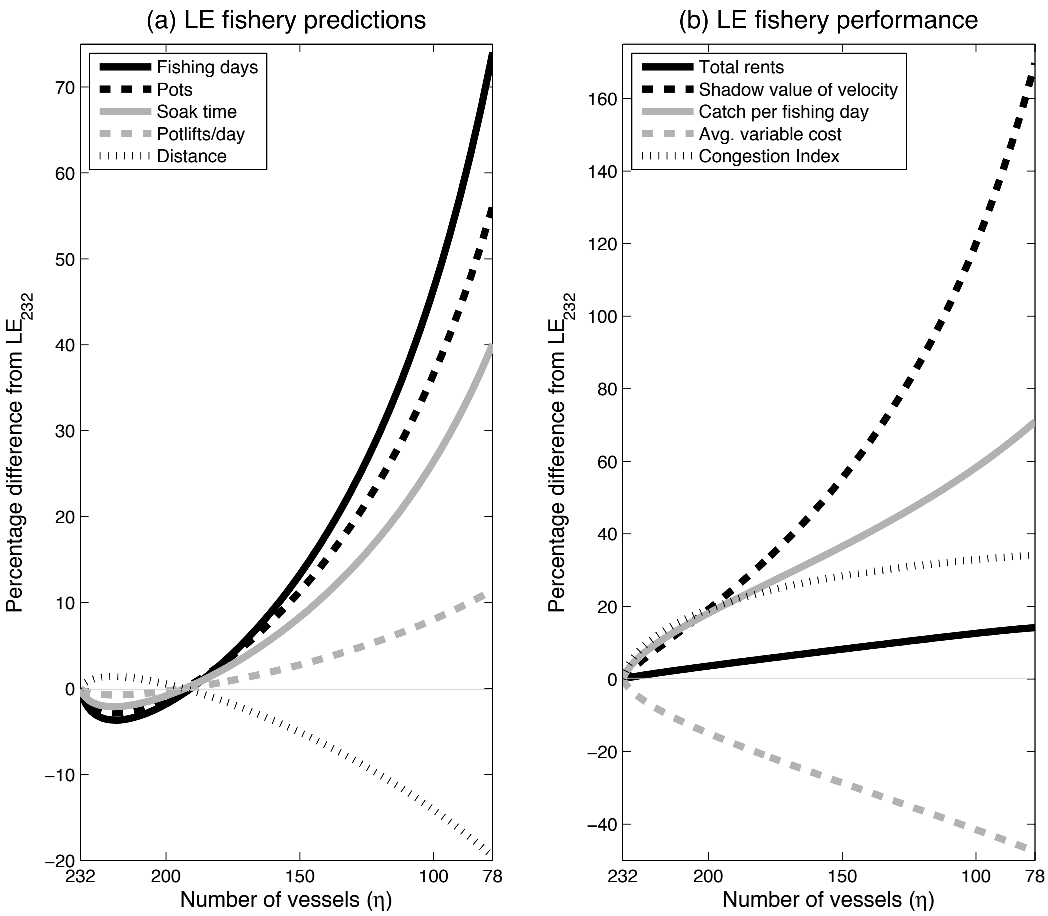

Figure 10: Consolidation in the limited entry fishery - Reducing the number of vessels in the limited entry (LE) fishery. Changes in (a) LE model predictions and (b) LE performance measures, relative to LE_{232}.

a *reduction* in spatial and temporal intensity as vessels are initially eliminated from the LE fishery (Figure 10a), indicating that there is a competing mechanism—which I call a congestion effect—that operates alongside the consolidation effect as fleet size becomes smaller. As vessels exit the fishery, the number of pots in the fishery decreases, reducing cross-pot congestion and improving catch per unit effort for the remaining vessels. Improved catch per unit effort, ceteris paribus, allows fishermen to pursue a more relaxed pace of fishing since crab deterioration is no longer as much of a threat as before, resulting in reduced temporal and spatial fishing intensity.[23] The initial domination of the congestion effect indicates initial overcapacity in the LE fishery, placing fishermen on a relatively steep portion of the cross-pot inverse congestion curve. Productivity improvements from reduced congestion are initially so large in the LE fishery that the season length declines even as fleet size shrinks and the number of pot lifts per day decreases. As downsizing continues, however, the marginal effect on cross-pot congestion shrinks in importance as the inverse congestion index approaches one. Consolidation of the TAC on fewer vessels now becomes the dominant driver of behavior. With an increased threat of product deterioration and substantial costs from dividing a single trip into two, consolidation pressures fishermen to increase their catch rate per day of fishing, as indicated by the increasing shadow value of velocity in Figure 10b.[24]

The ITQ fishery reveals a subtly different picture in that the initial non-monotonic effects of consolidation of TAC on fishing intensity witnessed in the LE simulations fail to materialize (Figure 11). Instead, the consolidation scale effect dominates throughout the entire range of the experiment. Congestion improves minimally in the ITQ fishery with smaller η because the index is already near one in the ITQ_{232} fishery due to much lower numbers of pots per vessel than under limited entry (Table 2). This demonstrates that it is the combination of both a large number of vessels and lack of property rights

[23]Simulations in which vessels are successively eliminated from the fishery while the TAC is adjusted so that seasonal catch per vessel remains constant confirm the role of the congestion effect. These simulations mimic the qualitative reduction in intensity Ive noted. However, once the fleet reaches a size in which cross-pot congestion is no longer elastic to further downsizing, eliminating vessels while keeping seasonal catch constant no longer affects harvester behavior.

[24]The shadow value of velocity is defined here as an individual harvesters maximum willingness to pay for an"infinitesimally" small increase in their own maximum velocity, holding the actions of all other players at their SNE values.

the fishing process as static. We would expect, however, that over the course of the season, harvesters obtain information in regards to the spatial whereabouts of the fish stock and change their input usage accordingly (Marcoul and Weninger, 2008). Thus, further research is needed to isolate harvesting behavior that may be better described as searching for crab than as fishing.

Our results provide a detailed and nuanced accounting of the many margins of fishing behavior influenced by ITQs, and the consequent sources of rent generation from the implementation of secure rights. Importantly, we show that the total effect of ITQ introduction is the sum of two competing effects. In particular, ITQ incentives tend to slow down the intensity of harvesting over time and space as harvesters slow down their speed of travel, lift less pots per day, employ fewer pots, and increase the distance between pots. Consolidation, in contrast, tends to act in the opposite direction, intensifying harvesting behavior over time and space, as fewer boats increase input use to harvest their increased allocations. Reducing fleet size may not always intensify harvesting behavior, however, as reducing fleet size also reduces congestion in the fishery, inducing harvesters to respond as they would to ITQ incentives. In this particular application, the incentive effects dominate over most behavioral margins so that overall intensity in the fishery is reduced. However, this may not always be the case with all decisions, as illustrated by the domination of consolidation effects for soak time. Therefore, in contrast to the received wisdom, it is not necessarily the case that ITQ introduction results in less "intensive" behavior. "Details" such as the initial magnitude of excess capital (and congestion) in the fishery and the extent to which a fishery consolidates matter.

Rent generation and reductions in average variable cost occur from both the incentives reflected in the security of harvesting rights and reducing the size of the fleet. Our results suggest that, for the RKC fishery, the majority of rent generation from ITQ introduction stems from the elimination of excess capital and its associated seasonal opportunity cost, in addition to increases in the average scale of operation. This is despite the fact that ITQ incentives generate a substantial reduction in average variable costs. The relative role played by consolidation reflects the fact that the RKC fishery is capital intensive;

large multi-million dollar investments and associated high fixed costs are necessary to successfully access crab in the harsh environment of the Bering Sea. Different findings on the relative contributions of consolidation versus incentives may emerge from fisheries that are less capital intensive—including nearshore fisheries such as sea urchin, salmon, or sablefish. Incentive effects may also dominate in settings in which a fairly stringent limited entry program exists before the introduction of ITQs—limiting post-ITQ consolidation.

It is also important to point out that management programs that promote consolidation without harnessing the incentives reflected in secure harvesting rights may not be able to sustain the increased economic rents in the long run. In this particular case, a binding maximum velocity limits the extent to which harvesters can compete away fishery rents. The positive shadow value of velocity in Figure 10b indicates that incentives exist for limited entry harvesters to invest in faster boats in the longer run, and these incentives motivate boat builders to design boats that relax the technological constraint. While the velocity constraint is real in this fishery, it may be viewed more generally as a metaphor for any temporarily binding technological or regulatory constraint in very flexible fishing processes under limited entry. Without secure harvesting rights, incentives always exist to intensify input use to compensate for any binding constraint, and to adopt new technology and practices that relax the constraint. In an LE fishery without secure rights, we would thus expect dissipation of the consolidation gains from intensifying the race to fish, as indicated in Figure 9, in addition to dissipation from misdirected rent seeking investments in technology and methods to gain an ultimately ephemeral advantage over ones competitors. This general lesson has been well known since the early literature on capital stuffing and from the considerable practical experience with limited entry fisheries.

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