Excess Capacity and Capital Malleability in a Fishery with Myopic Expectations

Steven Rust, Sarah Jennings, and Satoshi Yamazaki, *University of Tasmania*

ABSTRACT

Understanding the process whereby fishing capital accumulates and excess capacity emerges, particularly in fisheries where incentives for race to fish and race to invest are present, and where capital is not perfectly malleable, remains an important topic. We develop a dynamic model, incorporating quasi-malleable capital, race to fish and invest behaviors and myopic expectations, in which the level of excess capacity is endogenously determined. We show the importance of capital malleability, and of other biological and economic conditions, in determining the existence and strength of persistent equilibrium excess capacity in the fishery. We also highlight a link between the state of the fishery at the time race behavior emerges and the resultant level of excess capacity. Our results have implications for both the management of excess capacity and the use of empirical measures of excess capacity as performance indicators in fisheries where race behaviors are present.

Key words: Capital malleability, excess capacity, race to fish, race to invest, myopia.
JEL Codes: D24, Q22.

INTRODUCTION

Fishing capacity has long been recognized as a major obstacle to the conservation and long-term sustainable use of marine resources (Crutchfield 1956; Gulland and Robinson 1973; Clark 1977). In 1999, the Food and Agriculture Organization of the United Nations (FAO) committed to an International Plan of Action for the Management of Fisheries Capacity (FAO 1999). This plan called for FAO member nations to take immediate measures to monitor and address the level of capacity in their fisheries. Nevertheless, capacity remains a significant issue in world fisheries, and the goals of preventing the emergence of new, and managing existing, capacity remain high on the policy agendas of fishing nations worldwide (FAO 2008; OECD 2009; Pomeroy 2012; Salomon and Holm-Müller 2013).

The emergence of excessive fishing capacity is widely associated with situations where the ‘common-pool’ characteristics of a fishery result in a race to fish and invest (Clark and Munro 2002; Munro 2010). While such behavior can persist in regulated fisheries (Homans and Wilen 1997) and under a range of property institutions, including rights-based regimes (Costello and Deacon 2007; Asche et al. 2008; Emery et al. 2014), the twin problems of race

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Steven Rust is a PhD candidate, Tasmanian School of Business and Economics, University of Tasmania, Hobart, TAS 7001, Australia (email: steven.rust@utas.edu.au). **Sarah Jennings** is an adjunct senior researcher, Tasmanian School of Business and Economics, University of Tasmania, Hobart, TAS 7001, Australia (email: sarah.jennings@utas.edu.au). **Satoshi Yamazaki** is a lecturer, Tasmanian School of Business and Economics, University of Tasmania, Hobart, TAS 7001, Australia (email: satoshi.yamazaki@utas.edu.au).

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to fish and race to invest behavior are most pervasive in fisheries where access is unrestricted and fishing regulations are ineffective. In the fishery literature, overcapacity and excess capacity are defined as separate concepts and treated as different issues. Overcapacity is generally defined as the difference between the current and the target level of production in the fishery. The concept of overcapacity can thus be used as an indicator of long-term excessive fishing capacity and to indicate how much capacity needs to be adjusted in the fishery (Pascoe et al. 2003). Excess capacity, on the other hand, is defined as the difference between the current production level and the maximum potential production of the fishery for a given level of inputs under normal operating conditions.[1] Excess capacity is thus often portrayed as a temporary feature of the fishery, such as when fish stocks vary over time and the level of potential catch is different for different stock sizes (Pascoe et al. 2003).

Central to the problems of excess and overcapacity is the concept of malleable fleet capital (Gréboval and Munro 1999; Munro 2010), which describes the ease with which capital may be bought and sold. If capital is perfectly malleable, fishing capital can be bought and sold at no cost, so that there will be no excess and overcapacity in the fishery (Gréboval and Munro 1999). When this is not the case, the costliness of adjusting the capital stock means that fishing capital could be retained in the fishery that would otherwise have been disposed of in order to achieve the desired level of fishing effort. This additional capital, whether it continues to operate in the fishery or remains idle, contributes to excess and overcapacity. The resulting economic waste emerges because the existing level of fishing capacity, such as the number of vessels, exceeds its ‘optimal’ or ‘target’ level and from the existence of underutilized capacity, which is a product of the vessels that are not engaged or not ‘fully’ engaged in fishing (Gréboval and Munro 1999).

Our main aim is to develop a stylized model to explore the relationship between the malleability of capital and the emergent level of underutilized capacity, referred to here as excess capacity, in the case of a fishery where fishers engage in both a race to fish and invest. Although operating the fishery with some underutilized capacity may be desirable when the harvesting and investment behaviors are both optimally controlled (Poudel et al. 2013), the process whereby capital accumulates and excess capacity emerges in the presence of race to fish and invest behaviors is not well understood in the literature. In addition to the generation of pure economic waste in the form of underutilized fishing capacity, excess capacity results in reduced ability of fisheries managers to effectively regulate effort and catch. Furthermore, where the problem of excessive fishing pressure in one fishery is addressed by reallocating underutilized capacity to other fisheries, excess fishing pressure may spillover between fisheries (Bockstael and Opaluch 1983; Munro and Clark 2003). Understanding the drivers of excess capacity is therefore important for policy makers in developing measures that will result in improved management of marine resources by avoiding the problems of overharvesting and economic waste frequently associated with excessive fishing capacity (Munro and Clark 2003; Pascoe 2007).

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[1] It is important to note that various definitions of excess capacity and overcapacity have been proposed and discussed in the literature (Gréboval and Munro 1999; Clark and Munro 2002; Pascoe et al. 2003; Ward, Mace, and Thunberg 2004). In addition, the terms excess capacity, overcapacity, and overcapitalization are often used interchangeably.

There are a number of studies exploring issues of optimal fisheries management when capital adjustment is either not possible or costly (Clark, Clarke, and Munro 1979; Charles and Munro 1985; Boyce 1995; Singh, Weninger, and Doyle 2006; Poudel et al. 2013). To the best of our knowledge, there are only a small number of existing models of the fishery in which incentives to race to fish and invest are represented and capital adjustment is assumed to be costly (McKelvey 1985; Munro and Clark 2003; Eisenack, Welsch, and Kropp 2006). The previous studies, however, assume that the existing capacity is either fully utilized or not utilized at all by the fishers who exploit the fishery and are therefore unable to account for the extent of excess capacity. As far as we are aware, our model is the first to incorporate both purchase and resale prices for capital and specify an endogenous level of capacity utilization in a fishery where fishers engage in both a race to fish and race to invest.

We develop a dynamic model of a fishery with quasi-malleable capital, in which there is no constraint on investment, but such adjustment is costly because underutilized capacity can be sold only at a price lower than its purchase price (Clark, Clarke, and Munro 1979). The model incorporates race to fish behavior based on the assumptions of the conventional open-access fishery model (Smith 1969; Bjørndal and Conrad 1987). We adopt the investment rule described by McKelvey (1985), in which the capital stock is adjusted such that the average return to current capital is equalized to the average cost of investing, thereby representing the race to invest. Consistent with the traditional portrayal of fishers' behavior in the open-access fishery as a race to fish based on observed current profits (Berck and Perloff 1984) and with empirical evidence (Feeny, Hanna, and McEvoy 1996), our model assumes that fishers form expectations on the returns to capital with reference to current conditions in the fishery only. This form of myopic behavior is known as projection bias in the behavioral economics literature (Loewenstein 2000; Frederick, Loewenstein, and O'Donoghue 2002; Loewenstein, O'Donoghue, and Rabin 2003).

The contributions of this article are twofold. First, we analytically characterize the evolution of the capital stock and fish stock with quasi-malleable capital and show that multiple equilibria with varying levels of excess capacity exist due to the different purchase and resale prices of capital. Second, using a parameterized version of our model, we show how the initial conditions of the fishery, that is the initial levels of the biomass and capital stock, influence the steady-state level of excess capacity that will emerge in the fishery where a race to fish and invest is pervasive. We further explore the sensitivity of this relationship for various biological and economic parameters.

THE MODEL

FISHING EFFORT AND CAPITAL

In the conventional bioeconomic model of a fishery, fishing effort represents an aggregate measure of the levels of all inputs, such as time, capital, labor, and fishing gear. Following Clark, Clarke, and Munro (1979), however, we separate capital from other inputs involved in fishing and assume that the level of fishing effort, E, is constrained by the capital stock, K, measured in standardized vessel units, such that $0 \leq E \leq K$. We further assume that $E = \phi K$, such that $\phi \in [0,1]$ is the capacity utilization ratio that measures the proportion of the current capital stock effectively engaged in harvesting. Our specification of ϕ in this way is consistent with the technical definition of capacity (Kirkley and Squires 1999; Pascoe et al.

2003).[2] Using this definition, capacity utilization herein is measured as the ratio of fishery production to the maximum potential production for a given level of inputs, under normal operating conditions.

HARVEST FUNCTION AND BIOMASS DYNAMICS

For the harvest and effort relationship, we use the Schaefer production function (Schaefer 1957), given as:

$$h = qxE = qx\phi K, \tag{1}$$

where h is harvest, q is the catchability coefficient, and x is the total biomass of the fish stock. The biomass dynamics are:

$$\dot{x} = G(x) - qx\phi K, \tag{2}$$

where $G(x)$ is the natural growth of the population. We use the density-dependent logistic growth function $G(x) = rx(1 - x/\overline{x})$, where r is the intrinsic growth of the fish species and $\overline{x}$ is the environmental carrying capacity.

FISHERY PROFIT AND MALLEABILITY OF CAPITAL

The economic profit of the fishery accounts for the cost and benefit of investment in addition to the net revenue generated from fishing (Clark, Clarke, and Munro 1979), such that:

$$\pi = ph - cE - c_f(I), \tag{3}$$

where p is the unit price of landed fish, c is the cost per unit of fishing effort, and I is the level of investment. The cost of investment, $c_f(I)$, for the two cases of investment ($I > 0$) and disinvestment ($I < 0$) in the capital stock is given as:

$$c_f(I) = \begin{cases} c_I I & \text{if } I > 0 \\ c_S I & \text{if } I < 0 \end{cases}, \tag{4}$$

where c_I and c_S are the purchase and resale price of capital, such that $c_I > c_S > 0$.

Clark, Clarke, and Munro (1979) characterize the level of malleability of capital in terms of investment, I; the purchase and resale price of capital, c_I and c_S; and the rate of depreciation on capital, γ.[3] In the general case of quasi-malleable capital in which there is a second-hand market for capital ($c_s > 0$), there is no constraint on investment ($-\infty < I < \infty$), but such

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[2] An alternative definition of capacity is the "economic" definition, which attempts to account for an optimum level of output in terms of the economic parameters of the fishery. Klein (1960) and Berndt and Morrison (1981) develop such a concept based on short-run and long-run average cost curves. Fagnart, Licandro, and Portier (1999) and Coelli, Grifell-Tatje, and Perelman (2001) propose definitions centered on a profit-maximizing level of output, while others define capacity in terms of the firm's cost and revenue functions (Färe, Grosskopf, and Kirkley 2000). In most fisheries, however, the general lack of cost data often precludes the use of economic measures (Pascoe et al. 2003). A variant of this definition, known as technological-economic capacity, is commonly used in the empirical literature to measure capacity in fisheries (Dupont et al. 2002; Kirkley, Morrison-Paul, Squires 2002; Squires et al. 2010).

[3] When capital is perfectly non-malleable, investment is irreversible. Disinvestment or resale of capital is not possible ($I \geq 0$ and $c_S = 0$) and the depreciation on existing capital is zero ($\gamma = 0$). By contrast, when capital is perfectly malleable, investment is immediately reversible so that capital can be disinvested at its purchase price. There is no constraint on investment ($-\infty < I < \infty$) and the purchase and resale prices of capital are assumed equal ($c_I = c_S$).

adjustment is costly because the capital cannot be sold in the secondhand market at its purchase price ($c_I > c_S$). We represent the relationship between the purchase and resale prices of quasi-malleable capital in terms of two key parameters: the depreciation rate of the capital stock, γ, and the time discount rate, δ, as:[4]

$$c_s = \frac{\gamma c_I}{\gamma + \delta}. \tag{5}$$

The level of capital malleability, therefore, decreases as the time discount rate increases, reflecting the fact that the resale price of capital, c_S, in a competitive market will fall as the present value of the stream of services is expected to yield declines. Similarly, with equation (5), capital is assumed to be more malleable at higher rates of capital depreciation, which effectively results in a shorter period of time needed for a given capital stock to be reduced by the non-replacement of depreciated capital. We are interested in the case of quasi-malleable capital, where $c_I > c_S > 0$, and thus we assume that the discount rate, δ, and the depreciation rate, γ, are positive. Equation (5) can also be written as a ratio of the resale price of capital to the purchase price of capital, so that $c_S/c_I = \gamma/(\gamma + \delta) < 1$. We use this ratio as a measure of capital malleability, such that the closer the ratio is to one, the easier it is to adjust capital in the fishery and hence the greater the malleability of capital.

NET INVESTMENT

In a fishery involving a race to invest, positive economic profits attract new fishing operators that represent additional capital stock in the fishery. This continues until all economic returns from capital investment have been dissipated. We capture this capital accumulation process in our model by assuming the capital stock in the fishery continues to grow ($\dot{K} > 0$) as long as capital in the fishery earns a positive economic profit, or specifically as long as the average return to current capital ($\overline{\mu}$) is greater than the purchase price of capital ($\overline{\mu} > c_I$). Likewise, we assume that capital is removed from the fishery ($\dot{K} < 0$) when the average return to current capital is below the resale price ($\overline{\mu} < c_S$), since in this case fishers will profit from disinvesting the underutilized capital. Finally, we assume that fishers will have no incentive to adjust capital stock ($\dot{K} = 0$) when the average return to current capital is between the purchase and resale prices ($c_S < \overline{\mu} < c_I$). Given this investment behavior, the evolution of the capital stock can be written as:

$$\dot{K} = \left(\frac{\overline{\mu}}{c_f} - 1\right)K \text{ or } \dot{K} = \begin{cases} (\overline{\mu}/c_I - 1)K & \overline{\mu} > c_I \\ 0 & \text{if } \; c_I \geq \overline{\mu} \geq c_S \\ (\overline{\mu}/c_S - 1)K & \overline{\mu} < c_S \end{cases}, \tag{6}$$

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[4] From equation (4), replacing the depreciation on a single vessel; i.e., $I = \gamma.(1) = \gamma$, costs $c_I I = c_I\gamma$ at an instant of time. Using the standard cost of capital for the fishery, i.e. $\gamma + \delta$ (Clark, Clarke, and Munro 1979), the present value of this cost over the duration of a vessel's life can be given as: $c_s = \int_0^\infty \gamma c_I . e^{-(\gamma+\delta)\tau} d\tau$. Solving this equation gives $c_s = \gamma c_I/(\gamma + \delta)$, which is equation (5). This identity will hold in a competitive market because, if the scrap vessel is more expensive than c_s, the owner prefers to source replacement parts from a wholesaler or the vessel's manufacturer. Whereas if the scrap vessel is less expensive than c_s, the scrap capital will become the owner's preferred source of parts. In this case, the demand for scrap vessels will increase, which will push up their price, and this should continue until scrap vessels are no longer less expensive than the replacement parts from a wholesaler or the manufacturer. The value $c_s = \int_0^\infty \gamma c_I . e^{-(\gamma+\delta)\tau} d\tau$ therefore represents the price a vessel owner will ultimately be prepared to pay for a scrap fishing vessel.

where the term $(\bar{\mu}/c_f - 1)$ indexes the relative size of the average return on investment to its price in the fishery. Using equation (6) together with the capital dynamics equation, $\dot{K} = I - \gamma K$, we derive the investment rule as:

$$I = \left(\frac{\bar{\mu}}{c_f} - 1\right)K + \gamma K. \tag{7}$$

Following McKelvey (1985), we specify the expected current value of the average return on investment at time t as:

$$\bar{\mu}(t) = \int_t^\infty max[pqx^e(\tau) - c, 0]e^{-(\gamma+\delta)(\tau - t)}d\tau, \tag{8}$$

where max[.] is the max operator and $x^e(\tau)$ is the expected level of biomass for the future period $\tau > t$. Given that the values of $x^e(\tau)$ are not realized at time t for all $\tau > t$, the average return on investment at time t depends on the expectation of the future biomass level. In our model we adopt a form of myopic behavior known as projection bias, where individuals systematically interpret themselves in the future as being similar to how they are in the present, and therefore place an overemphasis on current conditions when making decisions (Loewenstein 2000; Loewenstein, O'Donoghue, and Rabin 2003). Examples of projection bias have been established in the behavioral economics literature (Frederick, Loewenstein, and O'Donoghue 2002; Mehra and Sah 2002; Loewenstein 2005; Busse et al. 2012). Berck and Perloff (1984) also use this form of myopic expectations in their model of an open-access fishery. Projection bias contrasts with the traditional model of myopia (Smith 1969; Bjørndal and Conrad 1987) in which fishers apply extremely high discount rates to future events (Johnson and Saunders 2014; Teh, Teh, and Sumaila 2014) so that only present conditions determine their behavior.

Assuming that in their race to invest, where fishers' expectations of future conditions are formed myopically, future biomass is expected to be the same as current biomass, (i.e., $x^e(\tau) = x(t)$ for all $\tau > t$), the average return to current capital given in equation (8) can be rewritten as:[5]

$$\bar{\mu}(t) = \int_t^\infty (pqx(t) - c)e^{-(\gamma+\delta)(\tau - t)}d\tau. \tag{9}$$

Integration of equation (9) yields:

$$\bar{\mu}(t) = [pqx(t) - c]/(\gamma + \delta). \tag{10}$$

Equation (10) represents the average return on investment at time t in the fishery with myopic expectations of future biomass.

CAPACITY UTILIZATION RATIO AND EXCESS CAPACITY

In the presence of race to fish behavior, fishing effort increases as long as the economic profit from the fishery is positive (Smith 1969; Bjørndal and Conrad 1987). We capture this process in our model through adjustment in the capacity utilization ratio, ϕ, which we assume occurs instantaneously and thus $\phi = c_f\ (I)/(pqxK - cK)$ from equations (1) and (3). Using this

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[5] The max[.] operator no longer appears in this expression since the fishery would not shut down in advance of the realization of negative net harvest revenue under the assumption of myopic expectations.

capacity utilization ratio and the investment rule in equation (7), the proportion of current capital engaged in fishing can be derived as:

$$\phi = \begin{cases} \dfrac{1}{\gamma+\delta} - \dfrac{(1-\gamma)c_I}{pqx-c} & \text{if } \ \bar{\mu} > c_I \\ \dfrac{\gamma c_I}{pqx-c} & \text{if } \ c_I \geq \bar{\mu} \geq c_S\,, \\ \dfrac{1}{\gamma+\delta} - \dfrac{(1-\gamma)c_S}{pqx-c} & \text{if } \ \bar{\mu} < c_S \end{cases} \tag{11}$$

where the capacity utilization ratio is bounded between zero and one.

The capacity utilization ratio in equation (11) represents the level of underutilized capacity in the fishery. In this article, we use ϕ to index the level of excess capacity as $\mathbf{\Phi} = 1 - \phi$, where $\mathbf{\Phi}$ takes a value between zero and one. For example, $\mathbf{\Phi} = 0$ implies that the fishery operates at full capacity, and hence $h/h_C = 1$, where h_C is the maximum harvest level attainable in the fishery for a given capital stock (i.e., capacity output). In contrast, when $0 < \mathbf{\Phi} \leq 1$, the actual level of harvest is less than full capacity output, such that $h/h_C < 1$; therefore, excess capacity exists in the fishery. Given equation (11), the level of capacity utilization, ϕ, and hence excess capacity, $\mathbf{\Phi} = 1 - \phi$, in the fishery is uniquely determined for a given level of the biomass, x, the catchability coefficient, q, and the economic parameter values of the fishery.

THE DYNAMICS OF A FISHERY WITH QUASI-MALLEABLE CAPITAL

Figure 1 presents a capital-biomass phase portrait showing the dynamics of the capital stock, K, and biomass, x, in a fishery with quasi-malleable capital. The evolution of the capital stock is defined by three regions, denoted as Region 1, Region 2 and Region 3. The boundaries between the regions are defined by the solid vertical lines at $x = \bar{x}^-$ and $x = \bar{x}^+$, where $\bar{x}^- = [(\gamma+\delta)c_S + c]/(pq)$ and $\bar{x}^+ = [(\gamma+\delta)c_I + c]/(pq)$. In Region 1, the capital stock in the fishery decreases because the average return to current capital is below the resale price of capital ($\bar{\mu} < c_S$), prompting disinvestment. By contrast, the capital stock increases in Region 3 because the average return on investment is greater than the purchase price ($\bar{\mu} > c_I$). In Region 2, the average return to current capital is between the purchase and resale prices ($c_S \leq \bar{\mu} \leq c_I$), and the capital stock is stable.

Using equation (11), we identify ranges of the biomass associated with corner solutions where the current capital stock is either fully utilized ($\phi = 1$) or not utilized at all ($\phi = 0$). In Region 1, when the biomass is between $x^a = c/(pq)$ and $x^b = [(1-\gamma)(\gamma+\delta)c_s + c]/(pq)$, no capital is utilized. In Region 3, the current capital is fully utilized when the biomass is greater than $x^c = [(1-\gamma)(\gamma+\delta)c_I + (1-\gamma-\delta)c]/[pq(1-\gamma-\delta)]$. For all other areas of the phase plane, the capacity utilization ratio is between zero and one ($0 < \phi < 1$). From an examination of x^a, x^b, x^c, $\bar{x}^-$, and $\bar{x}^+$ it can be shown that, for all parameterizations of the model, the following holds true:

$$0 \leq x^a < x^b < \bar{x}^- < \bar{x}^+ < x^c < \bar{x}. \tag{12}$$

The evolution of biomass is determined by the biomass nullcline, which is the set of curves marked as $\dot{x} = 0$ in figure 1. The biomass nullcline represents the combinations of capital and biomass for which the fish stock is constant over time, such that:

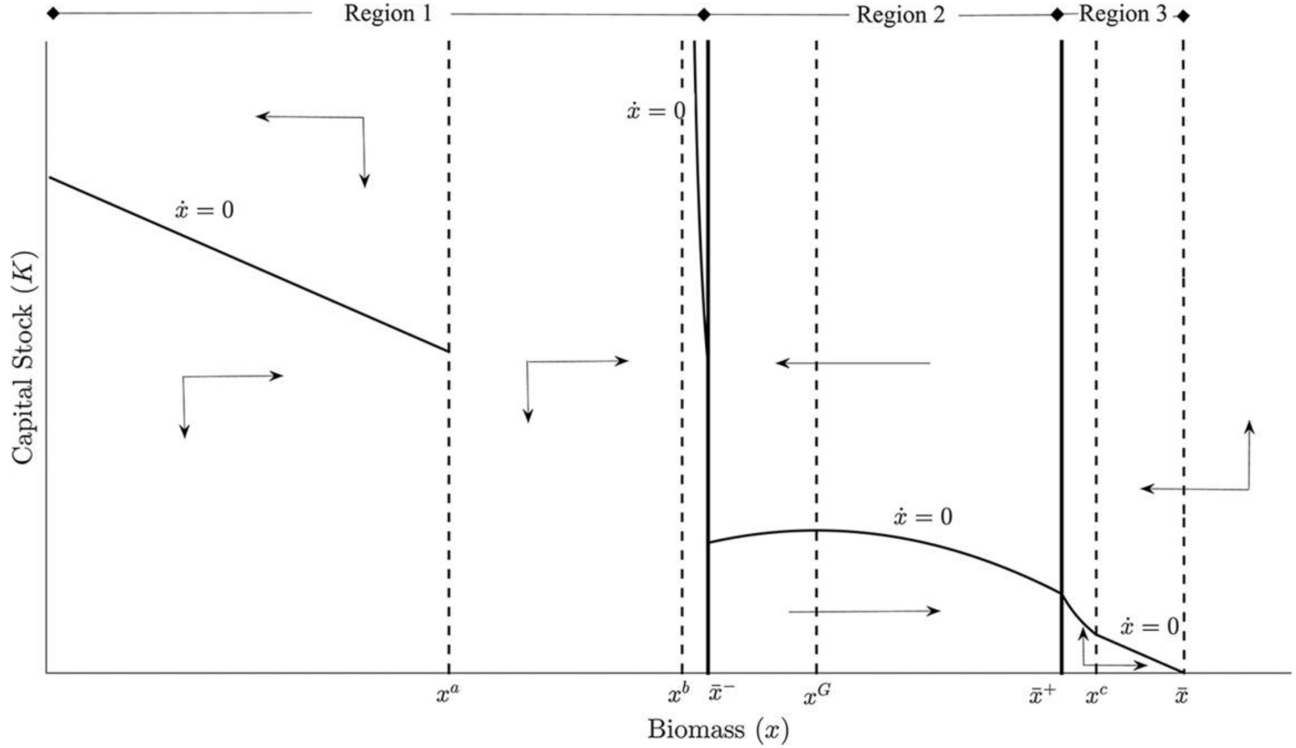

Figure 1. Phase Portrait: Capital and Biomass Dynamics with Quasi-malleable Capital

Note: Regions 1, 2, and 3 define the evolution of capital stock. The boundaries between each region are defined by the solid vertical lines at $\overline{x}^{-}$ and $\overline{x}^{+}$. The evolution of biomass is defined by the biomass nullcline denoted by $\dot{x} = 0$.

Table 1. The Biomass Nullcline

Biomass Level	Region	The Biomass Nullcline
$0 < x < x^a$	Region 1	$K = \frac{r}{q}\left(1 - \frac{x}{\overline{x}}\right)$
$x^a < x < x^b$	Region 1	$\lim_{\phi \to 0} K = \infty$
$x^b < x < \overline{x}^-$	Region 1	$K = \frac{r(1-x/\overline{x})(pqx-c)(\gamma+\delta)}{q[(pqx-c)-(1-\gamma)(\gamma+\delta)c_S]}$
$\overline{x}^- < x < \overline{x}^+$	Region 2	$K = \frac{r(1-x/\overline{x})(pqx-c)}{qc_I\gamma}$
$\overline{x}^+ < x < x^c$	Region3	$K = \frac{r(1-x/\overline{x})(pqx-c)(\gamma+\delta)}{q[(pqx-c)-(1-\gamma)(\gamma+\delta)c_I]}$
$x^c < x < \overline{x}$	Region3	$K = \frac{r}{q}\left(1 - \frac{x}{\overline{x}}\right)$

$$\dot{x} = 0 \Leftrightarrow K = \frac{rx(1-x/\overline{x})}{qx\phi}. \tag{13}$$

Using equations (11) and (13), we derive the full specifications of the biomass nullcline for all levels of biomass, as summarized in table 1. The dynamics of a fishery with quasi-malleable capital in our model are characterized by this biomass nullcline and the dynamics of the capital stock as discussed above. For instance, in Region 3 where the capital stock in the fishery increases over time, the biomass increases when the level of capital is below the biomass nullcline. This situation reflects a fishery in which the level of exploitable biomass is high, but the number of existing vessels exploiting the fish stocks is small and, in turn, the biomass increases. Conversely, the biomass decreases in the same region when the capital is above the nullcline because the number of vessels exploiting the fish stock is high and fishing pressure on the fish stocks is correspondingly relatively high. In Region 1, when the biomass is below the traditional bionomic equilibrium, x^a, the average return to current capital given in equation (10) is negative. This leads to an immediate disinvestment of existing capital to the level where there is no capital stock in the fishery and, therefore, the fishery is economically collapsed. By contrast, in the same region but when the biomass is above the traditional bionomic equilibrium, the average return to current capital is positive and an economic collapse of the fishery does not occur. This is a feature of the myopic characteristic of fishers' investment behavior.

RESULTS

The overarching aim of this article is to explore the link between the extent of capital malleability and excess capacity in the case of a fishery with quasi-malleable capital. We do this, in the first instance, analytically through an examination of model equilibria; that is, capital-biomass combinations for which there is simultaneous stability in the capital stock ($\dot{K} = 0$) and the biomass ($\dot{x} = 0$) of the fishery. Such equilibria are depicted in figure 1 as the set of points along the biomass nullcline in Region 2. By contrast, in Regions 1 and 3, such equilibria cannot be found given that capital is either increasing or decreasing for all biomass levels in these regions. Equilibria that lie on the positively sloped portion of the biomass nullcline in Region 2 are unstable in that minor perturbations in either the capital or biomass will result in further movements away from the equilibrium. We focus, therefore, on the set of stable equilibria that lie on the negatively sloped portion of the Region 2 biomass nullcline.

An examination of figure 1 indicates that the range of such biomass levels is determined by the relative positions of $\overline{x}^-$, $\overline{x}^+$, and x^G. For the case in which $x^G = 1/2[\overline{x} + c/(pq)]$ lies between $\overline{x}^-$ and $\overline{x}^+$, as in figure 1, the range of stable biomass is positively related to the cost of fishing effort, c. In contrast, the range of stable biomass is narrowed for higher population carrying capacity, $\overline{x}$; catchability coefficient, q; and fish price, p. The equilibrium level of biomass in our model is greater than the level at the traditional bionomic equilibrium, x^a, because investment decisions are assumed to be costly in our model. In other words, our model retains the traditional bionomic equilibrium at x^a when the cost of investment is zero; i.e., $c_I = c_S = 0$.

EXCESS CAPACITY AND QUASI-MALLEABLE CAPITAL

Stable equilibria that lie on the negatively sloped portion of the Region 2 biomass nullcline are associated with varying levels of excess capacity, $\mathbf{\Phi}$. More formally, for stable equilibria in the biomass range between x^G and $\overline{x}^+$, excess capacity ranges between a minimum of $\mathbf{\Phi}_{\min} = 1 - \phi^{\max}$ and a maximum of $\mathbf{\Phi}_{\max} = 1 - \phi^{\min}$, where $\phi^{\max}$ and $\phi^{\min}$ are the maximum and minimum steady-state capacity utilization ratios given as:

$$\phi^{max} = \phi(x^G) = min\left(\frac{2c_I\gamma}{pq\overline{x} - c}, 1\right) \tag{14}$$

$$\phi^{min} = \phi(\overline{x}^+) = \frac{\gamma}{\gamma + \delta}. \tag{15}$$

The maximum capacity utilization ratio, $\phi^{\max}$, and hence minimum excess capacity, $\mathbf{\Phi}_{\min}$, occurs at the biomass level x^G, which is the smallest biomass on the stable portion of the biomass nullcline. In contrast, the minimum capacity utilization ratio, $\phi^{\min}$, and hence maximum excess capacity, $\mathbf{\Phi}_{\max}$, occurs at the highest stable equilibrium biomass level $\overline{x}^+$. Our results, therefore, suggest that the level of underutilized capacity and the biomass at the equilibrium are positively related in a fishery with quasi-malleable capital. However, as is evident from figure 1, the equilibrium level of capital stock in the fishery increases with a decrease in the level of underutilized capacity. That is to say, total fishing effort, ϕK, increases as the equilibrium capacity utilization ratio increases, and the associated increased fishing effort results in a smaller level of biomass at the equilibrium (figure 1).

We also find from equation (14) that the minimum level of excess capacity, $\mathbf{\Phi}_{\min}$, will be higher, and the range of possible equilibrium excess capacity smaller, the lower the unit price of landed fish, p, or the higher the cost per-unit of fishing effort, c, for a fishery with a given carrying capacity and level of capital malleability. Furthermore, equations (5) and (15) together indicate that $\phi^{\min} = c_S/c_I$, where c_S/c_I indexes the malleability of capital as discussed in the section of fishery profit and malleability of capital. The greater the malleability of capital, the higher the minimum steady-state capacity utilization ratio, $\phi^{\min}$, will be. That is to say, when capital is easier to adjust, as indicated in our model by a smaller wedge between the purchase and resale prices of vessels, the smaller the maximum potential excess capacity,

$\mathbf{\Phi}_{\max}$, in the fishery. When capital is perfectly malleable or $c_S/c_I = 1$, for instance, the existing capital will be fully engaged in harvesting.

INITIAL CONDITIONS AND EQUILIBRIUM EXCESS CAPACITY

The dynamics of the capital stock, K, and biomass, x, in our model are shown in the phase portrait in figure 1 and discussed at the end of the model section. Casual observation of these dynamics suggest that the starting values of biomass, x_0, and capital, K_0, will determine both the trajectories and speed of adjustment of both variables and, therefore, uniquely identify the steady-state level of excess capacity arising in the fishery. That is, the condition of the fishery at the point at which a race to fish and invest begins determines the level of excess capacity in the steady-state.

We simulate a parameterized version of our model to investigate the nature of this relationship by calculating the equilibrium capacity utilization ratio, ϕ^*, for different combinations of the initial capital stock, K_0, expressed in terms of standardized vessel units ranging from 10 to 500 and the initial biomass, x_0, in terms of the proportion of the environmental carrying capacity. Each simulation is conducted for 1,000 periods to ensure that the fishery converges to the steady-state. Benchmark parameter values are reported in table 2. The parameter values for p, q, C, r and $\overline{x}$ are from Bjørndal and Conrad (1987), and the remaining parameters, c_I, c_S, γ, and δ, are from Singh, Weninger, and Doyle (2006).

Figure 2 presents the steady-state capacity utilization ratio for different combinations of the initial capital stock and biomass. The surface in figure 2 comprises four distinct Areas: I, II, III, and IV. In Area I where the initial biomass is below the traditional bionomic equilibrium $x_0 < x^a = 0.46\overline{x}$, regardless of the size of the initial capital stock, the fishery shuts down due to negative returns to current capital, resulting in no capital stock in the fishery and zero capacity utilization. The surface plot in figure 2 demonstrates an increasing relationship between both the initial biomass and capital stock of the fishery, and the steady-state capacity utilization ratio, ϕ^*. That is, the higher initial levels of biomass and capital stock correspond to greater levels of capacity utilization ratio and, therefore, less excess capacity in the fishery. For instance, Area IV represents combinations of initial capital stock and biomass that result in $\phi^* = 1$ and no excess capacity in the steady state. In Area IV, the high initial values of the biomass and capital stock mean higher levels of new investment and greater depletion of the biomass (Region 3 in figure 1). This eventually causes the average return to current capital, $\overline{\mu}$, to fall below the resale price of fishing vessels, c_S. The under-

Table 2. Model Parameterization

Parameter	Value	Description
p	36.68	Price per tonne ($)
q	6.77×10^{-4}	Catchability coefficient
c	38,895	Cost per unit of fishing effort ($)
γ	0.100	Depreciation rate of capital stock
δ	0.048	Time discount rate
r	0.800	Intrinsic growth rate
$\overline{x}$	3,200,000	Environmental carrying capacity (tonnes)
c_I	236,500	Purchase price of capital ($)
c_S	159,800	Resale price of capital ($)

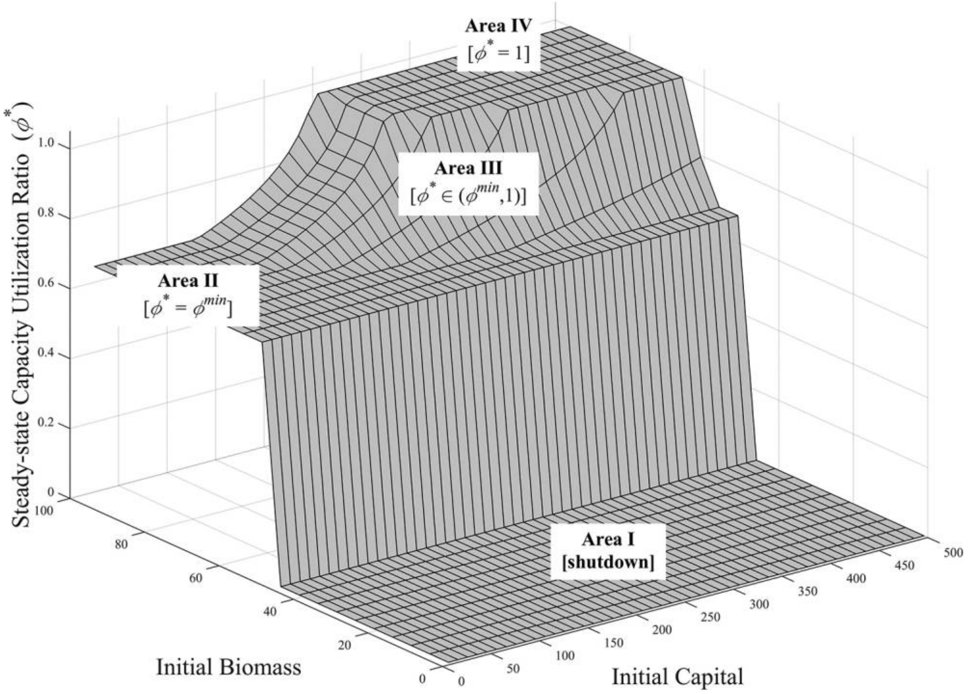

Figure 2. Steady-state Capacity Utilization Ratio for Different Initial Biomasses and Capital Stocks

Note: The steady-state capacity utilization ratio (ϕ^*) depends on the starting values of biomass and capital stock. Areas I, II, III, and IV represent combinations of initial biomass and capital stock that result in different values of ϕ^*.

utilized capital will then be sold off and the fishery will equilibrate with full capacity utilization at $\phi^* = 1$.

Figure 2 further shows that the maximum excess capacity at $\phi^* = \phi^{min} = 0.676$ occurs in the plateau of Area II, which represents about 23% of the set of initial values of the fishery examined in this article. Furthermore, when the initial biomass is above 51% of the environmental carrying capacity, $x_0 > 0.51\overline{x}$, increasing the initial capital increases the steady-state capacity utilization ratio up the ridgeline in Area III toward full capacity on the plateau in Area IV. For example, when the initial level of biomass is 76% of the carrying capacity, $x_0 = 0.76\overline{x}$, an initial capital of $K_0 < 130$ will result in $\phi^* = \phi^{min} = 0.676$ in Area II, whereas an initial capital of $K_0 = 230$ will lead to the higher capacity utilization ratio of $\phi^* = 0.811$ in Area III. If the initial capital stock further increases to $K_0 > 280$, an initial biomass of $x_0 = 0.76\overline{x}$ will give rise to an equilibrium with full capacity, $\phi^* = 1$, on the plateau of Area IV.

SENSITIVITY ANALYSIS

Equilibrium outcomes in a fishery for key fisheries variables such as biomass, effort, and harvest, have been shown to be sensitive to changes in biological and economic parameters in fisheries bioeconomic models (Gordon 1954; Smith 1969; Bjørndal and Conrad 1987). Thus, we analyze the sensitivity of the steady-state capacity utilization ratio, ϕ^*, to four key parameters, namely environmental carrying capacity, $\overline{x}$; the price of fish, p; the intrinsic growth rate, r; and the time discount rate, δ. Specifically, we calculate the proportion of the simulated trajectories corresponding to different initial conditions in the fishery that culminate in the maximum steady-state capacity utilization ratio, $\phi^* = \phi^{\max}$ (Area IV) and the minimum capacity utilization ratio, $\phi^* = \phi^{\min}$ (Area II) for a 10% increase and decrease in the base case value for each of the parameters, $\overline{x}$, p, r, and δ.

Panels (a) and (b) of figure 3 show that increasing the unit price of landed fish, p, or the environmental carrying capacity, $\overline{x}$, decreases the proportion of trajectories achieving the maximum steady-state capacity utilization ratio, $\phi^* = \phi^{\max}$, and increases the proportion of trajectories achieving the minimum capacity utilization ratio, $\phi^* = \phi^{\min}$. In other words, the higher the price of fish or the greater the maximum size of the population, the greater the likelihood of the steady-state capacity utilization ratio being either $\phi^{\min} < \phi^* < 1$ or $\phi^* = \phi^{\min}$ and, therefore, the higher the potential for excess capacity in the fishery. Panel (c) shows a similar case where increases in the intrinsic growth rate, r, decrease the likelihood of $\phi^* = \phi^{\max}$ but increases the likelihood of $\phi^* = \phi^{\min}$. For instance, when the intrinsic growth rate is $r = 0.72$, about 11.5 and 25.1% of the simulated trajectories achieve the maximum and minimum steady-state capacity utilization ratio, respectively. By contrast, when the intrinsic growth rate increases to $r = 0.88$, the proportion of the simulated trajectories achieving the maximum and minimum steady-state capacity utilization ratio becomes 7.24 and 28.3% respectively.

In the case of the time discount rate, δ, Panel (d) of figure 3 shows that lower values of the discount rate result in a greater proportion of the trajectories culminating in both the maximum and minimum capacity utilization ratio, $\phi^* = \phi^{\max}$ and $\phi^* = \phi^{\min}$. These changes reflect the two effects a change in the time discount rate has on the steady-state capacity utilization ratio. When the discount rate decreases, ceteris paribus, fishers put more weight on future returns, and the average return to capital increases as reflected in equation (10). At the same time, however, decreasing the discount rate also increases the resale price of capital relative to its purchase price, ceteris paribus, effectively making capital more malleable, as reflected in equation (5).

CONCLUSION

Managing fishing capacity remains one of the biggest issues facing fisheries managers worldwide (Lutchman and Hoggarth 1999; FAO 2008; OECD 2009). While much of the recent literature focuses on measures aimed at reducing capacity (Clark, Munro, and Sumaila 2005; Squires 2010; Pascoe et al. 2012), effective management also requires an emphasis on controlling the emergence of new capacity (FAO 2008; OECD 2009; Pomeroy 2012; Salomon and Holm-Müller 2013). Thus, understanding the process whereby capital accumulates and excess capacity emerges, particularly in fisheries where incentives to race to fish and invest are pervasive and where capital is quasi-malleable, remains an important and understudied issue.

We address the need to understand this process by proposing a model that allows us to describe the dynamic process whereby excess capacity, measured as the level of underutilized current fishing capacity, emerges in a fishery when there is a wedge between the purchase and resale prices of capital and where capital depreciates. For the case in which fishers form expectations of future biomass and harvest myopically and where the well-documented race behavior in common-pool resources exists in the fishery, we show that the fishery will have multiple stable equilibria of the capital stock and biomass that are distinguished by a varying

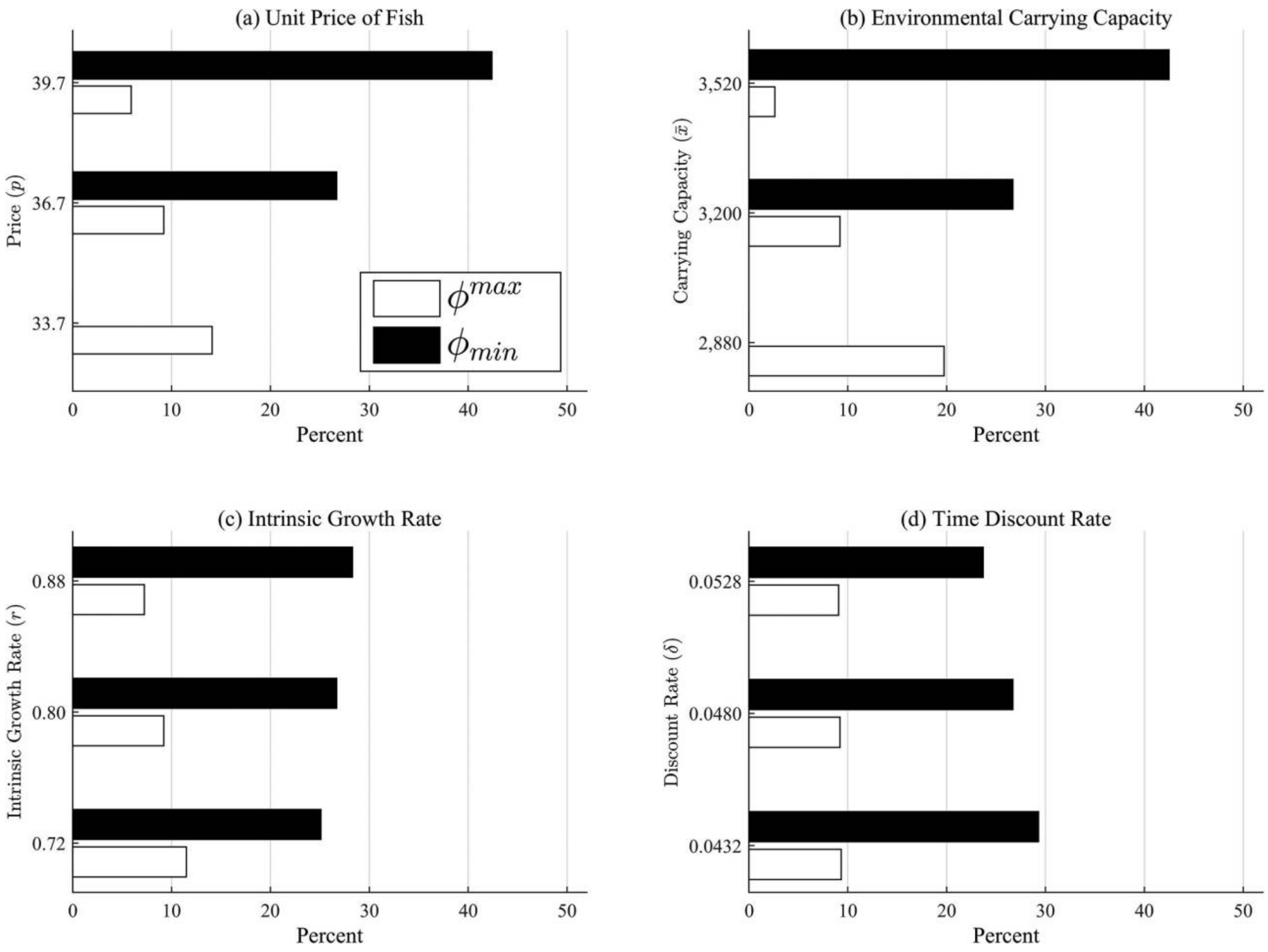

Figure 3. Sensitivity Analysis of Steady-state Capacity Utilization Ratio

Note: A likelihood of $\phi^* = \phi^{\min}$ and $\phi^* = \phi^{\max}$ for different values of the: (a) unit price of landed fish, (b) environmental carrying capacity, (c) intrinsic growth rate, and (d) time discount rate.

capacity utilization ratio. Our model results reinforce the importance of capital malleability in explaining the possible state of equilibrium excess capacity in such fisheries, identifying a positive relationship between the minimum steady-state capacity utilization ratio in the fishery and the ease with which downward adjustments in capital stock can be made. That is to say, the easier it is to dispose of underutilized capacity in a secondhand market, as indicated in our model by a smaller wedge between the purchase and resale prices of vessels, the smaller the maximum potential level of excess capacity in the fishery. The comparative statics of our analytical results indicate that when capital is non-malleable, fisheries based on higher-value species with higher intrinsic growth rates or greater carrying capacity will be more susceptible to persistent long-run underutilized capacity. These conditions, which have been shown to strengthen the race to fish and lead to greater overexploitation (Clark 2010), also fuel the race to invest and excess capacity.

Furthermore, the set of stable equilibria in our model reflects a range of possible outcomes in which high biomass and low capacity utilization go hand in hand in a fishery where fishers engage in a race to fish and invest, indicating a possible tradeoff between economic and conservation objectives. Our model shows that the problem of overexploitation in the fishery is underpinned by the large accumulated capital stock, but this does not correlate with the presence of high levels of excess capacity. This observation of a possible tradeoff between excess capacity and stock size highlights the importance of understanding the dynamic process of capital accumulation across a range of institutional contexts and under alternative assumptions about investment behavior. Overall our results suggest caution in using the extent of excess capacity, as defined in this article as the equilibrium level of underutilized capacity, as an indicator of the health or performance of the fishery (World Bank 2012). For example, different methodologies have been developed to estimate the capacity utilization of a fishery (Kirkley, Morrison-Paul, Squires 2002), and such methodologies have been used to evaluate fishery performance as well as to assess the effects of changes to management, such as from command-and-control managed to rights-based fisheries. However, our results suggest that such estimates alone should not be used to determine the state of a fishery in terms of the excess accumulation of capital stock.

Simulations of a parameterized version of our model further enabled us to explore the relationship between the level of equilibrium excess capacity in the fishery and the initial state of the fishery in terms of starting stocks of biomass and capital. Understanding this relationship is particularly pertinent in cases where capacity management programs in fisheries with high levels of underutilized capacity result in the redeployment of displaced fishing capacity to other stocks or fisheries (Gréboval and Munro 1999) or where climate change driven changes in the abundance and distribution of commercial fish stocks motivate the reallocation of fishing effort and capacity as fishers adapt (OECD 2010). Our results indicate that, while higher initial levels of capital result in more severe overexploitation and greater equilibrium capital stock, there is a negative relationship between the initial capital stock and the equilibrium level of excess capacity in the fishery. Applying a higher initial stock of capital to a biomass of given size will result in more overexploitation but less underutilized capacity in the fishery. Understanding this tradeoff will help managers charged with rebuilding fisheries and managing fishing capacity.

Conventional bioeconomic models of fisheries assume perfectly malleable capital and do not help us understand the process of capital investment and the development of excess capacity. While there are some studies dealing with fisheries with non-malleable capital (McKelvey 1985; Eisenack, Welsch, and Kropp 2006), they are unable to account for the extent of excess capacity, as their models assume that the existing capacity is either fully utilized or not utilized at all. We take a step toward developing this understanding by exploring the issue of excess capacity, or underutilized capacity, in a fishery with quasi-malleable capital. It is well known that the free-entry-and-exit nature of open-access fisheries leads to overinvestment in fishing capital, overexploitation of target and bycatch species, and the dissipation of economic rent. We show that where capital is quasi-malleable, the open-access nature of the fishery also results in excess capacity. That is, rather than being a purely short-run feature, even in equilibrium it is possible that fishing capacity remains underutilized.

While implementing policies that address the root causes of excess capacity in fisheries by removing incentives that drive race to fish and to invest behavior remains paramount, the question of how to manage existing excess capacity remains unclear. Our results suggest that increased utilization of current capacity without eliminating the race behavior would result in further overexploitation of already vulnerable stocks; yet efforts to remove and or redeploy excess capacity may be costly and have the potential to exacerbate excess capacity in other fisheries. This observation reinforces the need to approach the problem of fisheries capacity management as an issue at the sectorial or multi-fishery, rather than single fishery, level (Holland 1999) and makes the question of how best to manage existing capacity in such fisheries to meet economic, social, and environmental goals as they transition to regulated fisheries, of central importance. Furthermore, the importance of designing effective capacity management policies goes beyond the case of the fishery where fishing regulations are either absent or ineffective, as incentives to compete in harvesting and investment among fishers is evident in fisheries under a range of regulatory regimes, including individual transferable quotas (Costello and Deacon 2007; Emery et al. 2014).

A number of limitations to our analysis suggest useful directions for future research. A key feature of our model is the assumption that fishers are myopic and that they form expectations of the average return to current capital based only on the current level of the biomass in deciding the level of capital investment or disinvestment. While this assumption is consistent with the spirit of open-access resource use, incorporating alternative ways in which fishers form expectations (Holland 2008) into harvesting and investment behavior would be useful. In addition, and as called for by Nøstbakken, Thebaud, and Sørensen (2011), exploring the effect of alternative investment rules or heuristics on capacity development, reflecting alternative types of fishery business organizations, would be useful. Finally, our model of capital accumulation in the fishery is deterministic and, as such, does not account for the high levels of natural variability that are characteristic of many fish populations (Caddy and Gulland 1983; Hofmann and Powell 1998). For example, when the fish stock is subject to natural fluctuations, some level of excess capacity is acceptable or even desirable in a fishery where the fishing effort and investment rate are controlled optimally (Poudel et al. 2013). Yet, it is unclear whether excess capacity, which is ultimately developed through race to invest behavior, is similarly acceptable. If not, what are the economic costs or benefits with the development of such excess capacity? An extension of our work to incorporate the effects on the capital stock and excess capacity of uncertainty, in particular the stochastic specification of recruitment, is needed.

REFERENCES

Asche, F., H. Eggert, E. Gudmundsson, A. Hoff, and S. Pascoe, 2008. “Fisher’s Behaviour with Individual Vessel Quotas—Over-capacity and Potential Rent: Five Case Studies.” *Marine Policy* 32(6):920–27.

Berck, P., and J. Perloff. 1984. “An Open-access Fishery with Rational Expectations.” *Econometrica* 52 (2):489–506.

Berndt, E. R., and C. J. Morrison. 1981. “Capacity Utilization Measures: Underlying Economic Theory and an Alternative Approach.” *American Economic Review* 71(2):48–52.

Bjørndal, T., and J. M. Conrad. 1987. “The Dynamics of an Open Access Fishery.” *Canadian Journal of Economics* 20(1):74–85.

Bockstael, N., and J. Opaluch. 1983. “Discrete Modelling of Supply Response under Uncertainty: The Case of the Fishery.” *Journal of Environmental Economics and Management*: 10(2):125–37.

Boyce, J. 1995. “Optimal Capital Accumulation in a Fishery: A Nonlinear Irreversible Investment Model.” *Journal of Environmental Economics and Management* 28(3):324–39.

Busse, M. R., D. G. Pope, J. C. Pope, and J. Silva-Risson. 2012. “Projection Bias in the Housing and Car Markets.” NBER Working Paper 18212. National Bureau of Economic Research, Cambridge, MA.

Caddy, J., and J. Gulland. 1983. “Historical Patterns of Fish Stocks.” *Marine Policy* 7(4):267–78.

Charles, A., and G. Munro. 1985. “Irreversible Investment and Optimal Fisheries Management: A Stochastic Analysis.” *Marine Resource Economics* 1(3):247–64.

Clark, C. W. 1977. “Overcapitalization in Commercial Fisheries: Symptoms, Causes, and Cures.” *Environmental Biology of Fishes* 2(1):3–5.

———. 2010. *Mathematical Bioeconomics: The Mathematics of Conservation*. New Jersey: John Wiley & Sons.

Clark, C. W., F. Clarke, and G. Munro. 1979. “The Optimal Exploitation of Renewable Resource Stocks: Problems of Irreversible Investment.” *Econometrica* 47(1):25–48.

Clark, C. W., and G. Munro. 2002. “The Problem of Overcapacity.” *Bulletin of Marine Science* 70(2): 473–83.

Clark, C. W., G. Munro, U. R. Sumaila. 2005. “Subsidies, Buybacks, and Sustainable Fisheries.” *Journal of Environmental Economics and Management* 50(1):47–58.

Coelli, T., E. Grifell-Tatje, and S. Perelman. 2001. “Capacity Utilization and Short Run Profit Efficiency.” Working Paper, School of Economics, University of New England, Armidale, NSW.

Costello, C., and R. T. Deacon. 2007. “The Efficiency Gains from Fully Delineating Rights in an ITQ Fishery.” *Marine Resource Economics* 22(4):347–61.

Crutchfield, J. 1956. “Common Property Resources and Factor Allocation.” *Canadian Journal of Economics and Political Science* 22(3):292–300.

Dupont, D. P., R. Q. Grafton, J. E. Kirkley, and D. Squires. 2002. “Capacity Utilization Measures and Excess Capacity in Multi-product Privatized Fisheries.” *Resource and Energy Economics* 24(3):193–210.

Eisenack, K., H. Welsch, and J. P. Kropp. 2006. “A Qualitative Dynamical Modelling Approach to Capital Accumulation in Unregulated Fisheries.” *Journal of Economic Dynamics and Control* 30(12): 2613–36.

Emery, T. J., K. Hartmann, B. S. Green, C. Gardner, and J. Tisdell. 2014. “Does ‘Race to Fish’ Behaviour Emerge in an Individual Transferable Quota Fishery When the Total Allowable Catch Becomes Non-binding?” *Fish and Fisheries* 15(1):151–69.

Fagnart, J.-F., O. Licandro, and F. Portier. 1999. “Firm Heterogeneity, Capacity Utilization, and the Business Cycle.” *Review of Economic Dynamics* 2(2):433–55.

FAO (Food and Agricultural Organization of the United Nations). 1999. *The International Plan of Action for the Management of Fishing Capacity*. Rome: FAO.

———. 2008. *Fisheries Management: Managing Fishing Capacity*. Rome: FAO.

Färe, R., S. Grosskopf, and J. E. Kirkley. 2000. "Multi-output Capacity Measures and their Relevance for Productivity." *Bulletin of Economic Research* 52(2):101–12.

Feeny, D., S. Hanna, and A. McEvoy. 1996. "Questioning the Assumptions of the' Tragedy of the Commons' Model of Fisheries." *Land Economics* 72(2):187–205.

Frederick, S., G. Loewenstein, and T. O'Donoghue. 2002. "Time Discounting and Time Preference: A Critical Review." *Journal of Economic Literature* 40(2):351–401.

Gordon, H. 1954. "The Economic Theory of a Common-Property Resource: The Fishery." *Journal of Political Economy* 53(1):231–52.

Gréboval, D., and G. Munro. 1999. "Overcapitalization and Excess Capacity in World Fisheries: Underlying Economics and Methods of Control." In *Managing Fishing Capacity: Selected Papers on Underlying Concepts and Issues*, ed. D. Gréboval, 1–48. Rome: FAO.

Gulland, J., and M. Robinson. 1973. "Economics of Fishery Management." *Journal of the Fisheries Research Board of Canada* 30(12):2042–50.

Hofmann, E., and T. Powell. 1998. "Environmental Variability Effects on Marine Fisheries: Four Case Histories." *Ecological Applications* 8(sp1):23–32.

Holland, D. 1999. "On Direct and Indirect Management of Fishing Capacity." *Marine Resource Economics* 14(3):263–7.

———. 2008. "Are Fishermen Rational? A Fishing Expedition." *Marine Resource Economics* 23(3):325–44.

Homans, F., and J. Wilen. 1997. "A Model of Regulated Open Access Resource Use." *Journal of Environmental Economics and Management* 32(1):1–21.

Johnson, A. E., and D. K. Saunders. 2014. "Time Preferences and the Management of Coral Reef Fisheries." *Ecological Economics* 100:130–9.

Kirkley, J. E., C. J. Morrison-Paul, and D. Squires. 2002. "Capacity and Capacity Utilization in Common-pool Resource Industries." *Environmental and Resource Economics* 22(1-2):71–97.

Kirkley, J. E., and D. Squires. 1999. "Measuring Capacity and Capacity Utilization in Fisheries." In *Managing Fishing Capacity: Selected Papers on Underlying Concepts and Issues*, ed. D. Gréboval, 1–48. Rome: FAO.

Klein, L. R. 1960. "Some Theoretical Issues in the Measurement of Capacity." *Econometrica* 28(2):272–86.

Loewenstein, G. 2000. "Emotions in Economic Theory and Economic Behavior." *American Economic Review* 90(2):426–32.

———. 2005. "Projection Bias in Medical Decision Making." *Medical Decision Making* 25(1):96–105.

Loewenstein, G., T. O'Donoghue, and M. Rabin. 2003. "Projection Bias in Predicting Future Utility." *The Quarterly Journal of Economics* 118(4):1209–48.

Lutchman, I., and D. D. Hoggarth. 1999. *Net Losses: Untying the Gordian Knot of Fishing Overcapacity*. Gland, Switzerland and Cambridge, UK: International Union for Conservation on Nature and Natural Resources.

McKelvey, R. 1985. "Decentralized Regulation of a Common Property Renewable Resource Industry with Irreversible Investment." *Journal of Environmental Economics and Management* 12(4):287–307.

Mehra, R., and R. Sah. 2002. "Mood Fluctuations, Projection Bias, and Volatility of Equity Prices." *Journal of Economic Dynamics and Control* 26(5):869–87.

Munro, G. 2010. "The Economics of Overcapacity and the Management of Capture Fishery Resources: A Review." *International Review of Environmental and Resource Economics* 4(2):93–122.

Munro, G., and C. W. Clark. 2003. "Fishing Capacity amd Resource Management Objectives." In *Measuring Capacity in Fisheries*, ed. S. Pascoe, and D. Gréboval,13–34. Rome: FAO.

Nøstbakken, L., O. Thebaud, and L. Sørensen. 2011. "Investment Behaviour and Capacity Adjustment in Fisheries: A Survey of the Literature." *Marine Resource Economics* 26(2):95–117.

OECD (Organisation for Economic Co-operation and Development). 2009. *Reducing Fishing Capacity: Best Practices for Decommissioning Schemes*. Paris: OECD Publishing.

———. 2010. *The Economics of Adapting Fisheries to Climate Change*. Paris: OECD Publishing.

Pascoe, S. 2007. "Capacity Analysis and Fisheries Policy: Theory versus Practice." *Marine Resource Economics* 22(1):83–7.

Pascoe, S., L. Coglan, A. E. Punt, and C. M. Dichmont. 2012. "Impacts of Vessel Capacity Reduction Programmes on Efficiency in Fisheries: The Case of Australia's Multispecies Northern Prawn Fishery." *Journal of Agricultural Economics* 63(2):425–43.

Pascoe, S., J. E. Kirkley, D. Gréboval, and C. J. Morrison-Paul. 2003. *Measuring and Assessing Capacity in Fisheries*. Rome: FAO.

Pomeroy, R. S. 2012. "Managing Overcapacity in Small-scale Fisheries in Southeast Asia." *Marine Policy* 36(2):520–7.

Poudel, D., L. Sandal, S. F. Kvamsdal, and S. I. Steinshamn. 2013. "Fisheries Management under Irreversible Investment: Does Stochasticity Matter?" *Marine Resource Economics* 28(1):83–103.

Salomon, M., and K. Holm-Müller. 2013. "Towards a Sustainable Fisheries Policy in Europe." *Fish and Fisheries* 14(4):625–38.

Schaefer, M. B. 1957. "Some Considerations of Population Dynamics and Economics in Relation to the Management of the Commercial Marine Fisheries." *Journal of the Fisheries Research Board of Canada* 14(5):669–81.

Singh, R., Q. Weninger, and M. Doyle. 2006. "Fisheries Management with Stock Growth Uncertainty and Costly Capital Adjustment." *Journal of Environmental Economics and Management* 52(2):582–99.

Smith, V. 1969. "On Models of Commercial Fishing." *The Journal of Political Economy* 77(2):181–98.

Squires, D. 2010. "Fisheries Buybacks: A Review and Guidelines." *Fish and Fisheries* 11(4):366–87.

Squires, D., Y. Jeon, R. Q. Grafton, and J. E. Kirkley. 2010. "Controlling Excess Capacity in Common-pool Resource Industries: The Transition from Input to Output Controls." *Australian Journal of Agricultural and Resource Economics* 54(3):361–77.

Teh, L. S. L., L. C. L. Teh, and U. R. Sumaila. 2014. "Time Preference of Small-scale Fishers in Open Access and Traditionally Managed Reef Fisheries." *Marine Policy* 44:222–31.

Ward, J., P. Mace, and E. Thunberg. 2004. "The Relationship of Fish Harvesting Capacity to Excess Capacity and Overcapacity." *Marine Resource Economics* 19(4):525–9.

World Bank. 2012. *Evaluation of New Fishery Performance Indicators (FPIs): A Case Study of the Blue Swimming Crab Fisheries in Indonesia and Philippines*. Washington, DC: The World Bank.