APPENDIX A: DERIVATION OF THE OPTIMAL FOOTROPE EQUATION

A daily profit equation of vessels at *t* time, π_{it}^{d}, which is a function of footrope size (F_{it}) given the vessel length (L_{it}), is defined as exponential revenue equation minus a linear cost equation:

(A.1) $$\begin{aligned}\pi_{it}^{d}(F_{it} \mid L_{it}) = \exp(a_0 + a_1 \ln(L_{it}) + a_2 \ln(F_{it}) + \tilde{\varepsilon}_{Rit}) \\ -(b_0 + b_1 L_{it} + b_2 F_{it} + \tilde{\varepsilon}_{Cit})\end{aligned}.$$

If gear units are permanent and we assume the fishery is in a steady state, a vessel would maximize the net rents over time as follows:

(A.2) $$\underset{F_i}{Max} \sum_{t=0}^{\infty} \frac{1}{(1+r)^t} \pi_i(F_i \mid L_i) - P_{FG}(F_i - F_i^0) = \frac{\pi_i(F_i \mid L_i)}{r} - P_{FG}(F_i - F_i^0).$$

The initial gear unit under a FG is represented by F_i^0. The first order condition of equation (A.6) in terms of gear units, F_i, is

(A.3) $$\frac{a_2 \exp(a_0 + a_1 \ln(L_i) + a_2 \ln(F_i) + \tilde{\varepsilon}_{Ri})}{F_i} = b_2 + P_{FG} r,$$

which can be simplified to yield F_i^* as a function of P_{FG}, r and random variable $\tilde{\varepsilon}_{Ri}$:

(A.4) $$F_i^* = \exp\left\{\frac{-\ln\left(\frac{b_2 + P_{FG} r}{a_2}\right) + a_1 \ln\left(L_i\right) + a_0 + \tilde{\varepsilon}_{Ri}}{1 - a_2}\right\}.$$

Finally, to solve for P_{FG} in a FG market, we impose that aggregate FG restriction hold, i.e.,

(A.5) $$\sum_i F_i^* = (1-\alpha) F^0,$$

where α represents the ratio of the FG restriction, and F^0 represents the aggregate gear prior to the FG program. Substituting equation (A.8) into equation (A.9) and summing over F_i^*, we can obtain an expression that can be segregated into two terms: a constant term and a sum of vessel-specific terms:

(A.6) $$\exp\left\{\frac{-\ln\left(\frac{b_2+P_{FG}r}{a_2}\right)+a_0}{1-a_2}\right\}\left[\sum_i \exp\left\{\frac{a_1\ln\left(L_i\right)+\tilde{\varepsilon}_{Ri}}{1-a_2}\right\}\right]=(1-\alpha)F^0 .$$

Letting $C=\sum_i \exp\left\{\frac{a_1\ln\left(L_i\right)+\tilde{\varepsilon}_{Ri}}{1-a_2}\right\}$, the market price of FG, P_{FG}, can be written as follows,

(A.7) $$P_{FG}=\frac{a_2\exp\left\{a_2\ln\left(\frac{F^0(1-a)}{C}\right)+a_0\right\}C-b_2\left[F^0(1-a)\right]}{r\left[F^0(1-a)\right]}=$$

$$\frac{a_2\exp\left(a_0\right)\left\{\frac{C}{F^0(1-a)}\right\}^{1-a_2}-b_2}{r}$$

In order to decide to exit or stay in the fishery, each vessel will compare the profits under each situation according to equation (3.12). If average net present value per footrope size of each vessel is greater than the market price of FG, $\frac{\pi_i^*(F_i^{1*})}{rF_i^{1*}}\geq P_{FG}$, then the vessel will stay in the fishery. Otherwise, it will exit the fishery. The market equilibrium is found numerically using equation (11) and the entry-exit decision of equation (3.12). First, equation (11) is solved assuming all vessels continue to fish. Using this price, equation (3.12) is evaluated for each vessel and a subset of remaining vessels is retained. Using this subset, a new price is found by equation (11). This process continues until an equilibrium is reached where all participating vessels are following equation (A.8) and all vessels remain or exit following equation (3.12), i.e.,

(A.1) $$\begin{cases} F_i^*=\exp\left\{\frac{-\ln\left(\frac{b_2+P_{FG}r}{a_2}\right)+a_1\ln\left(L_i\right)+a_0+\tilde{\varepsilon}_{Ri}}{1-a_2}\right\}, & if\ \frac{\pi_i^*(F_i^*)}{r}\geq P_{FG}F_i^* , \\ F_i^*=0 & ,otherwise \end{cases}$$

where, F_i^* represents the optimal footrope size in the i^{th} vessel.

APPENDIX B: ECONOMETRIC MODEL FOR THE REVENUE, COST, AND FOOTROPE EQUATIONS

For the coefficient estimation, the functions for the revenue, cost, and footrope in Appendix A are estimated using non-linear simultaneous equations[1]. Specifically, we seek to estimate the following equations including year and market dummy variables:

$$\text{(B.1)} \quad \ln\left(F_{ijk}\right) = \frac{a_0 + \sum c_i YD_i + \sum d_j MD_j + a_1 \ln\left(L_{ijk}\right) + \ln a_2 - \ln b_2 + \varepsilon_{Rijk}}{1 - a_2} + \varepsilon_{Fijk}$$

$$\text{(B.2)} \quad C_{ijk} = b_0 + \sum e_i YD_i + \sum f_j MD_j + b_1 L_{ijk} + b_2 F_{ijk} + \varepsilon_{Cijk}$$

$$\text{(B.3)} \quad \ln\left(R_{ijk}\right) = a_0 + \sum c_i YD_i + \sum d_j MD_j + a_1 \ln\left(L_{ijk}\right) + a_2 \ln\left(F_{ijk}\right) + \varepsilon_{Rijk},$$

where F_{ijk} represents footrope size of i^{th} year, j^{th} market , k^{th} vessel. YD_i and MD_j represent i^{th} year dummy variable and j^{th} market dummy variable, respectively. The error term of footrope size, ε_{Fijk} , is included in the footrope equation.

The reduced forms of the three equations are derived as in the following equations. Here the vessel length, year, and market dummy variables are considered as independent variables, and revenue, cost, and footrope size are considered as dependent variables.

$$\text{(B.1')} \quad \ln\left(F_{ijk}\right) = \gamma_1 + \sum \alpha_i YD_i + \sum \theta_j MD_j + \gamma_2 \ln\left(L_{ijk}\right) + \varepsilon_{Fijk}$$

$$\text{(B.2')} \quad \begin{aligned} C_{ijk} &= b_0 + \sum e_i YD_i + \sum f_j MD_j + b_1 L_{ijk} \\ &\quad + \gamma_3 L_{ijk}^{\gamma_2} \exp\left(\varepsilon_{Fijk}\right) \prod \exp(\alpha_i YD_i) \prod \exp(\theta_j MD_j) + \varepsilon_{Cijk} \end{aligned}$$

$$\text{(B.3')} \quad \ln\left(R_{ijk}\right) = \gamma_4 + \sum \alpha_i YD_i + \sum \theta_j MD_j + \gamma_2 \ln\left(L_{ijk}\right) + a_2 \varepsilon_{Fijk} + \varepsilon_{Rijk}$$

where,

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[1] Since the footrope equation (A.8) was derived from a profit equation (A.5), the simultaneous equation would increase efficiency to the coefficient estimation.

$$\gamma_1 = \left[\frac{a_0}{1-a_2} + \frac{\ln a_2}{1-a_2} - \frac{\ln b_2}{1-a_2} \right], \gamma_2 = \frac{a_1}{1-a_2}$$

$$\gamma_3 = b_2 \exp\left(\frac{a_0}{1-a_2} + \frac{\ln a_2}{1-a_2} - \frac{\ln b_2}{1-a_2} \right) = b_2 \exp(\gamma_1)$$

$$\gamma_4 = a_0 + a_2\gamma_1$$

$$\alpha_i = \frac{c_i}{1-a_2}, \theta_i = \frac{d_i}{1-a_2}.$$

The non-linear simultaneous estimation was estimated without all the error terms. Hence the estimated equations are:

(B.1") $\ln(F_{ijk}) = \gamma_1 + \sum \alpha_i YD_i + \sum \theta_j MD_j + \gamma_2 \ln(L_{ijk})$

(B.2") $C_{ijk} = b_0 + \sum e_i YD_i + \sum f_j MD_j + b_1 L_{ijk} + \gamma_3 L_{ijk}{}^{\gamma_2} \prod \exp(\alpha_i YD_i) \prod \exp(\theta_j MD_j)$

(B.3") $\ln(R_{ijk}) = \gamma_4 + \sum \alpha_i YD_i + \sum \theta_j MD_j + \gamma_2 \ln(L_{ijk})$

The estimated coefficients were then transformed into the coefficients presented in Table 1.2 and Table 1.7