The Senegalese artisanal fleet under seasonality & irreversible investment

Structure

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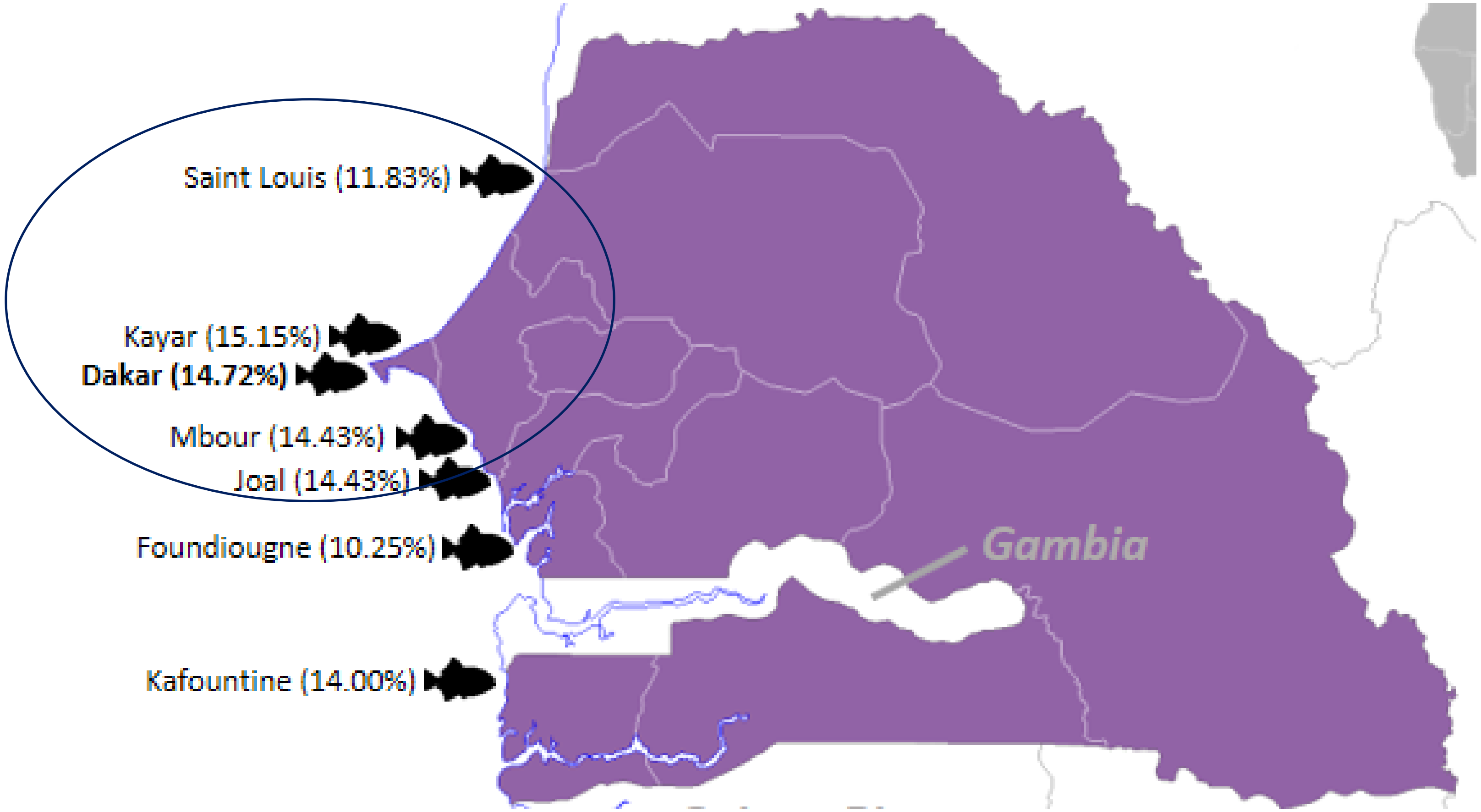
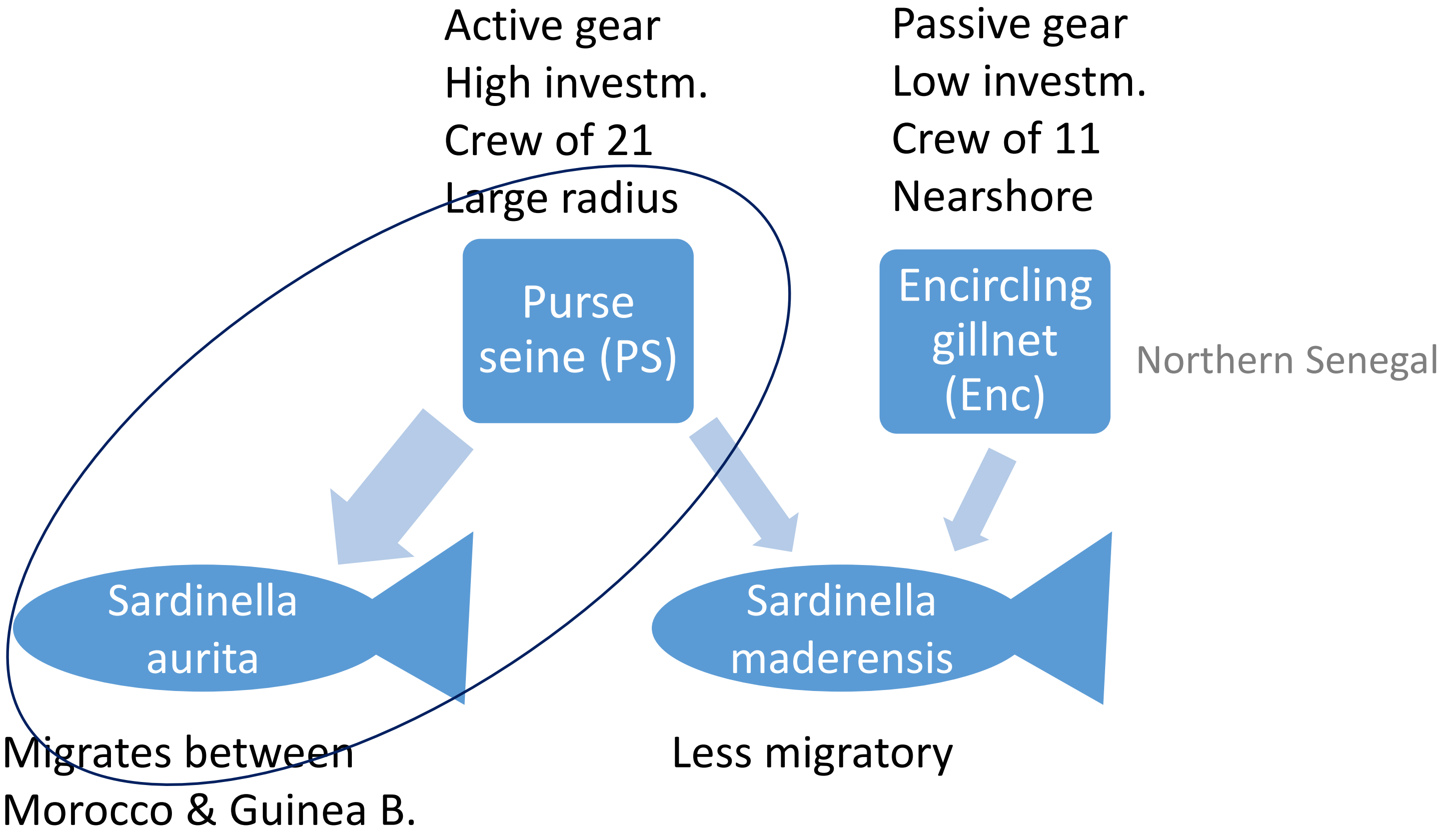
3. Model
4. Data & Estimation
5. Conclusion

Motivation: The research area



% of observations on artisanal fishing vessels in Senegal in the PREFACE survey

Motivation: Species and sectors



Corten et al (2012): *The Sardinella of Northwest Africa*, Commission Sous-Régionale de la Pêche, Dakar.

Motivation: Species and sectors

Active gear
High investm.
Crew of 21
Large radius

Passive gear
Low investm.
Crew of 11
Nearshore

Purse seine (PS)

Encircling gillnet (Enc)

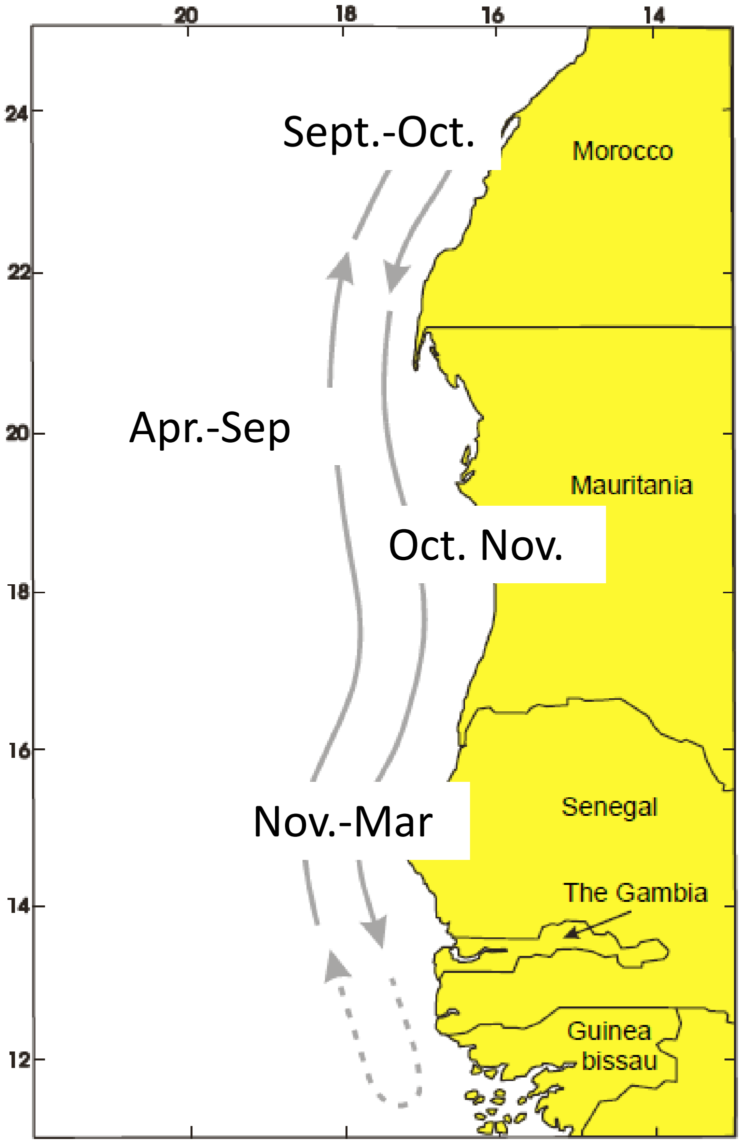
Northern Senegal

Sardinella aurita

Sardinella maderensis

Migrates between
Morocco & Guinea B.

Less migratory



+: Cultural sharing system: Fixed shares to labor and capital
→ Labor has a share in seasonality

Corten et al (2012): *The Sardinella of Northwest Africa*, Commission Sous-Régionale de la Pêche, Dakar.

Motivation

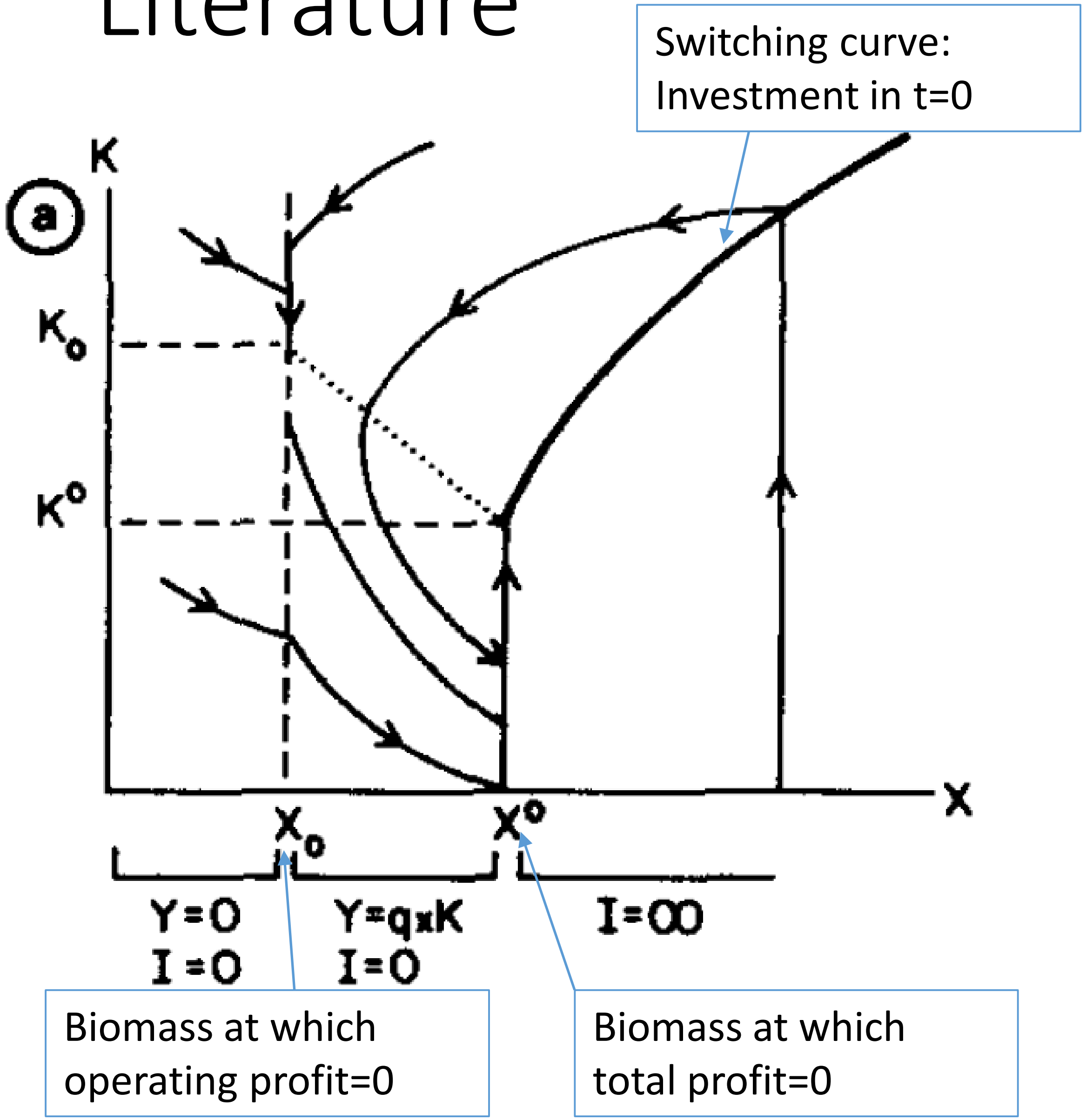
Research questions:

- What is the effect of seasonality on Senegalese fishing fleets‘ input decisions when capital is non-malleable?
- How do these effects differ between capital versus labor intensive fleets?
- What are the effects of the cultural sharing system and of fuel and capital subsidies?

Expected results:

- Capital is overemployed
- Capital intensive fleets more prone to seasonality
- Sharing system partly shifts seasonality impact from capital towards labor

Literature



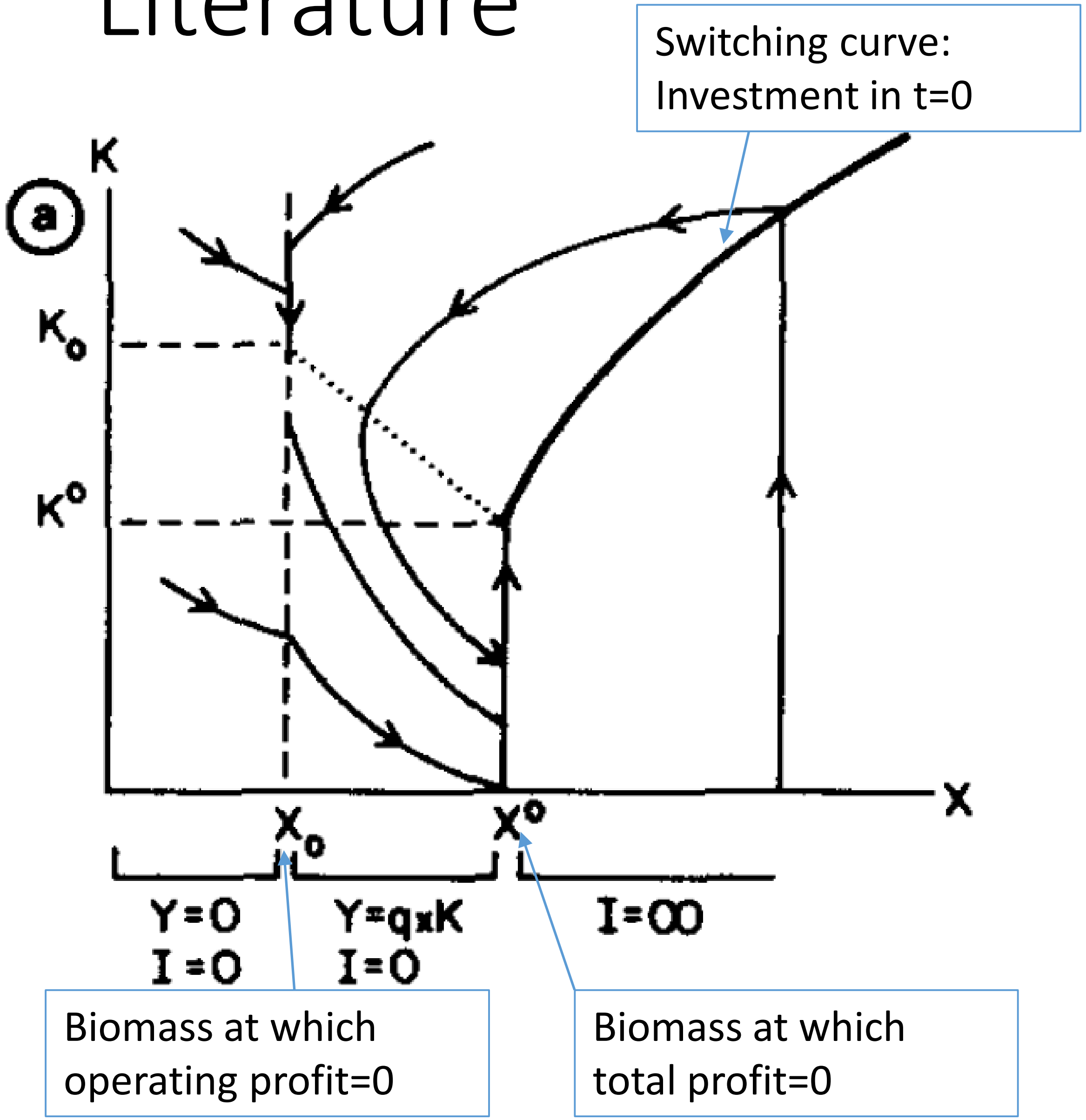
Open access case by McKelvey (1985):
(based on previous analysis of the optimal case by Clark, Clarke and Munroe (1979)

$$H_t = q x_t K_t \qquad C = \frac{c}{q x_t} H_t$$

- Phase plane portrait of capital K and biomass x

Mc Kelvey (1985): Decentralized regulation of a common Property Renewable Resource Industry with Irreversible Investment, Journal of Environmental Economics and Management, 12 (1985), pp. 287-307.

Literature



Open access case by McKelvey (1985):

$$H_t = q x_t K_t \qquad C = \frac{c}{q x_t} H_t$$

- Switching curve is determined by the usual investment rule (r is capital unit cost):

$$\int_0^\infty e^{-(\rho+\delta)t} \max\left\{ p q x_t - c, 0 \right\} = r$$

- Seasonality leads to cycles in steady state biomass:

$$x^0 = \frac{c + \rho r}{pq} \qquad x_0 = \frac{c}{pq}$$

Mc Kelvey (1985): Decentralized regulation of a common Property Renewable Resource Industry with Irreversible Investment, Journal of Environmental Economics and Management, 12 (1985), pp. 287-307.

The model: Setup

$G_{tf}\left(K_{tf}, L_{tf}, F_{tf}, B_{ti}\right) = q_{\mathrm{tf}} K_{tf}^{\alpha_f} L_{tf}^{\beta_f} F_{tf}^{\gamma_f} B_t$ Harvest production function (incl. cap., labor & fuel)

$\pi_{tf} = pG_{tf}\left(K_{tf}, L_{tf}, F_{tf}, B_t\right) - wL_{tf} - bF_{tf} - rI_{tf}$ Profit in period t

$\dot{K}_{tf} = I_{tf} - \delta K_{tf},\ \ I_{tf} \geq 0$ Capital dynamics (quasi malleable)

$\dot{B}_t = g\left(B_t\right) - H_{tf} = \mathrm{z}B_t\left(1 - \frac{B_t}{CC}\right) - H_{tf}$ Biomass dynamics

$q_{\mathrm{tf}} = \phi \sin(t) + \varepsilon$ Seasonality in catchable biomass $q_{\mathrm{tf}} B_t$

The model: Optimization

$$L_f = \int_0^\infty e^{-\rho t}\left(pG_{tf}\left(K_{tf}, L_{tf}, F_{tf}, B_t\right) - wL_{tf} - bF_{tf} + \left(\left(\upsilon_{tf} - r\right)\left(\delta + \rho\right) - \dot{\upsilon}_{tf}\right)K_{tf}\right)dt + e^{-\rho\infty}\upsilon_{\infty f}K_{\infty f} + \text{constant}$$

$$\left.\begin{aligned}
&p\frac{\partial G_{tf}\left(K_{tf}, L_{tf}, F_{tf}, B_t\right)}{\partial L_{tf}} = w \\
&p\frac{\partial G_{tf}\left(K_{tf}, L_{tf}, F_{tf}, B_t\right)}{\partial F_{tf}} = b \\
&p\frac{\partial G_{tf}\left(K_{tf}, L_{tf}, F_{tf}, B_t\right)}{\partial K_{tf}} = \left(r - \upsilon_{tf}\right)\left(\delta + \rho\right) + \dot{\upsilon}_{tf} \\
&KT : \dot{K}_{tf} + \delta K_{tf} \geq 0, \upsilon_{tf} \geq 0, \upsilon_{tf}\left(\dot{K}_{tf} + \delta K_{tf}\right) = 0
\end{aligned}\right\}$$

In general: Value of the marginal product equals marginal cost.

The model: Interpretation

$$p\frac{\partial G_{tf}\left(K_{tf},L_{tf},F_{tf},B_t\right)}{\partial K_{tf}}=\left(r-\upsilon_{tf}\right)\left(\delta+\rho\right)+\dot{\upsilon}_{tf}$$

$$KT:\dot{K}_{tf}+\delta K_{tf}\geq 0,\upsilon_{tf}\geq 0,\upsilon_{tf}\left(\dot{K}_{tf}+\delta K_{tf}\right)=0$$

- ν is the Lagrangian multiplier for the nonnegative-investment constraint
- Shadow value of disinvestment

Case 1: Investment is positive: ν is zero

- If catchable biomass shrinks, expect ν to increase → invest less (than with perfectly malleable cap.)
- If catchable biomass increases, expect ν to decrease → invest more

Case 2: Investment is negative: ν is positive

- Employ all capital available (efficiency) (Region II in the phase diagram)

Data & Estimation: The Production function

$$\log\left(\frac{H_{tf}}{B_t}\right) = \ln\left(q_{\text{basemonthf}}\right) + \alpha_f \log(\mathrm{K}_{tf}) + \beta_f \log(L_{tf}) + \gamma_f \log(F_{tf})$$

$$+ \sum_{i=1}^{12} \mathrm{d}^* Month_i + \psi \log\left(\frac{H_{t-1f}}{B_{t-1}}\right) + \varepsilon_{it}$$

- Capital, labor and fuel use in a classical CD estimation using OLS
- Adding monthly dummies to estimate seasonal catchabilities
- Introducing one lag to account for autocorrelation

Data & Estimation: Dataset

Time series of…	Unit	scale	Used as
Catch	Tons	Monthly, regional	Harvest
Effort	Days at sea	Monthly, regional	Labor
Fuel use	1000 l	Monthly, regional	Fuel input
Fuel price	FCFA/1000L	Monthly, regional	Fuel input/ dual
Fish price	FCFA/ton	Monthly, regional	Fuel input/ dual
Vessel number	Units	Yearly	Capital
Biomass	tons	Yearly	Biomass

In addition:

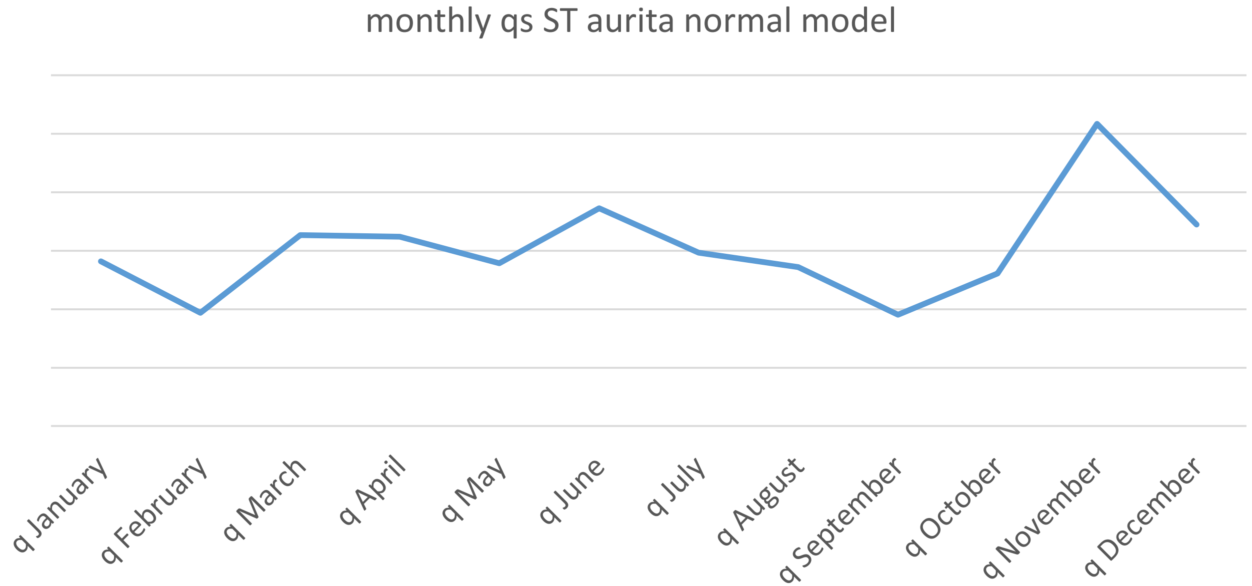
Data from the PREFACE survey on costs, depreciation, credit markets, crew size etc.

Data & Estimation: The Production function

log_Catch_per_B~s	Coef.	Std. Err.	t	P>|t|
log_No_vessels_ST	3.972428	1.036245	3.83	0.000
log_Effort	1.384167	.1161592	11.92	0.000
log_Fuel_Use	-.6918075	.4140111	-1.67	0.098

N: 108
R^2: 0.7388
Adj. R^2: 0.6995

Seasonal dummies estimated within same regression (but only some significant):



Data & Estimation: Production function with fuel price

Using the fact that the marginal product should be equal to the fuel price, and reinserting (where p/b is the ratio of fish price over fuel price):

$$\ln(H_{ft})$$

$$= \frac{1}{1-\gamma_f}\ln\left(q_{\text{basemonthf}}\right) + \frac{\gamma_f}{1-\gamma_f}\ln\left(\gamma_f\right) + \frac{\alpha_f}{1-\gamma_f} \mathrm{l}\log(\mathrm{K}_{tf}) + \frac{\beta_f}{1-\gamma_f}\ln(L_{tf})$$

$$+ \frac{\gamma_f}{1-\gamma_f}\ln\left[\frac{p_t}{b_t}\right] + \frac{1}{1-\gamma_f}\ln\left(B_t\right) + \sum_{i=1}^{12} \mathrm{d}^* \, Month_i + \psi\log(H_{t-1f}) + \varepsilon$$

Data & Estimation: Production function with fuel price

log_Catch	Coef.	Std. Err.	t	P>|t|
log_Effort	1.757089	.2287275	7.68	0.000
log_Price_ratio	-.3247083	.0718884	-4.52	0.000
log_No_vessels_ST	1.730146	.7661626	2.26	0.026
log_Catch_lag	.4164893	.0739711	5.63	0.000
log_Biomass	.093795	.1401043	0.67	0.505
_cons	-21.35938	5.325341	-4.01	0.000

$$\gamma_f = -0.479$$

$$\alpha_f = 2.559$$

$$\beta_f = 2.599$$

$$H_{tf} = q_{\mathrm{tf}} K_{tf}^{\alpha_f} L_{tf}^{\beta_f} F_{tf}^{\gamma_f} B_t$$

Data & Estimation: Production function with fuel price

log
log_N
l

0
0
6
0
5
0

Issue of endogeneity/ simultaneity?

Other methodological issue?

γ_f

$\alpha_f = 2.559$

$\beta_f = 2.599$

$$H_{tf} = q_{\text{tf}} K_{tf} L_{tf} F_{tf}^{\gamma_f} B_t$$

Conclusion:

- Senegalese artisanal fishery
- Characterized by seasonal species
- Capital is quasi-malleable/ not perfectly malleable
- Estimation of the production funciton: Likely endogeneity issue

- Steps ahead:
    - Estimate as panel, search for ways to account for endogeneity
    - simulation

References

- Clark C. W., Clarke, F. H. & Munroe, G. R. (1979): The Optimal Exploitation of Renewable Resource Stocks: Problems of Irreversible Investment, *Econometrica*, 47 (1), pp. 25-44.
- Corten et al (2012): *The Sardinella of Northwest Africa*, Commission Sous-Régionale de la Pêche, Dakar 2012.
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- Ndiaye, Y. D. (1996): Use of Capital Income in Artisanal Fisheries: the Case of Boat-Owners in Hann, Senegal, FAO 1996.