Dynamic Oligopoly with a Managerial Labor Market: Ships and Captains in 19th Century American Whaling

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June 3, 2025

1 Introduction

...

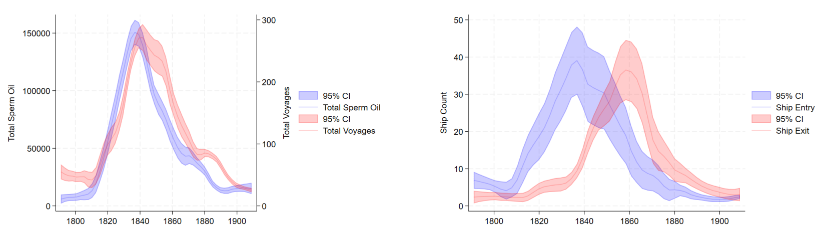
2 Setting and Data

Cut off data in 1880 - ignore bone production

2.1 19th Century American Whaling Data

2.2 Aggregate Patterns

Figure 1: Voyages, Output, Entry and Exit



Total Voyages and Output

Ship Entry and Exit

INDUSTRY TRANSITIONS TO SMALLER SHIPS

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Figure 2: Product Prices

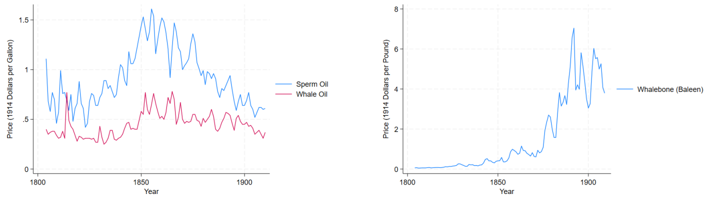
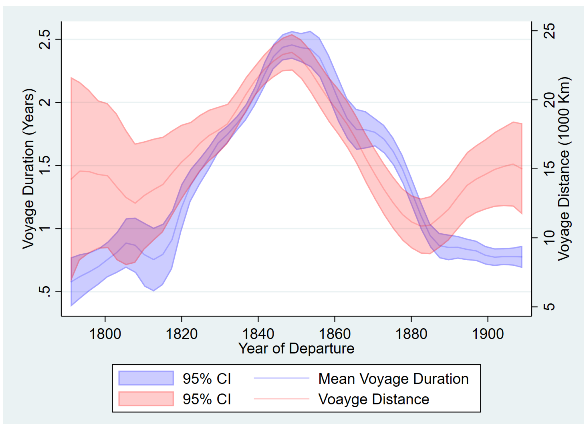
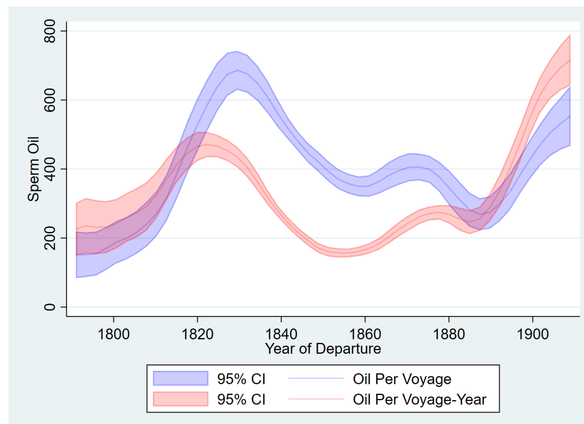


Figure 3: Voyage Duration and Output per Voyage



Voyage Duration and Distance



Output per Voyage

Distance???

2.3 Voyages and Captains

2.4 Production, Selection, and Experience

Basic Facts about production

... captains selected on output over voyages: first voyage output

... some people just really like whaling

.... experience and past catch doesnt seem to matter - > no learning?

... duration and distance matters for output

... competition matters for output

... oil bone and sperm correlations

Table 1: Summary Statistics: Voyages

	Mean	Median	SD	Min	Max	N
Year Out	1847.49	1846	24.405	1790	1910	13745
Duration (Years)	1.93	2	1.41	0	12	12630
Distance (1000 km)	19.84	21.70	9.24	0.46	31.72	1356
Lost	0.07	0	0.25	0	1	13745
Sperm Oil (1000 bbl)	0.53	0.20	0.70	0	4.80	11540
Whale Oil (1000 bbl)	0.77	0.20	1.02	0	8.49	11540
Whalebone (1000 lbs)	5.45	0	111.99	0	106	11540
Output ($1000)	42.83	34.16	35.99	0	49.28	10997
Ship Size (Tonnage)	267.35	285	111.94	27	907	12482
Ship Voyage #	5.84	4	5.24	1	37	13745
N	13745					

Table 2: Summary Statistics: Captains

			Captains			
	Mean	Median	SD	Min	Max	N
Total Voyages	2.68	2	2.64	1	34	5134
Total Ships	1.93	1	1.45	1	14	5134
N	5134					
			Captain-Voyages			
	Mean	Median	SD	Min	Max	N
Same Ship	0.42	0	0.49	0	1	8611
Lay	0.068	0.067	0.010	0.038	0.125	1522
N	13745					

Table 3: Correlation of Outputs

	Sperm Oil	Whale Oil	Whalebone
Sperm Oil	1.000		
Whale Oil	-0.307	1.000	
Whalebone	-0.218	0.712	1.000

Figure 4: Selection into Employment

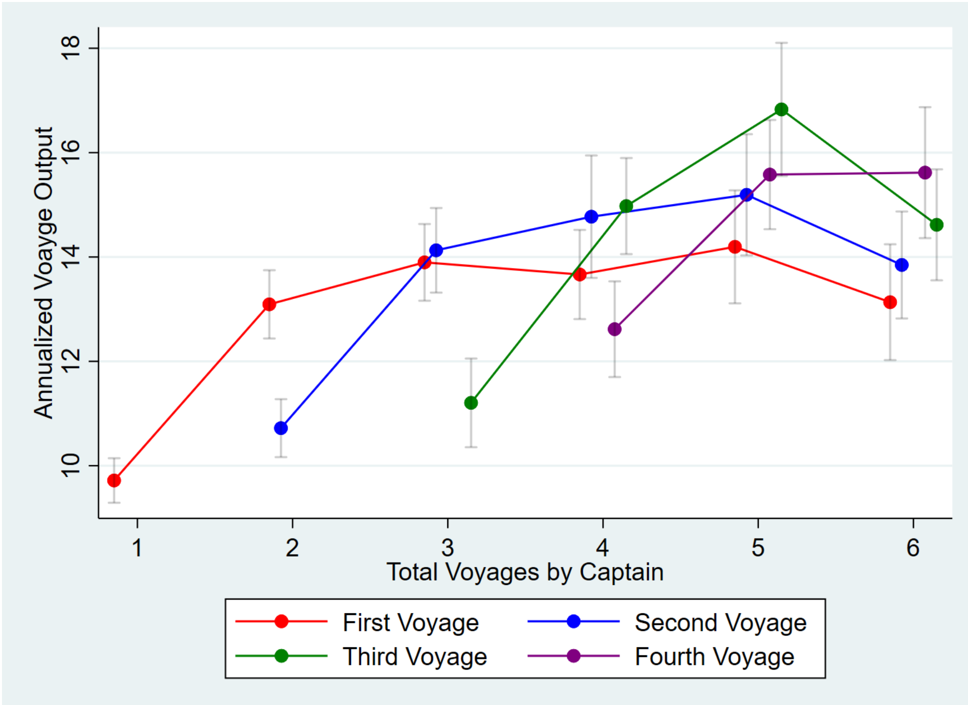


Figure 5: Experience Shares

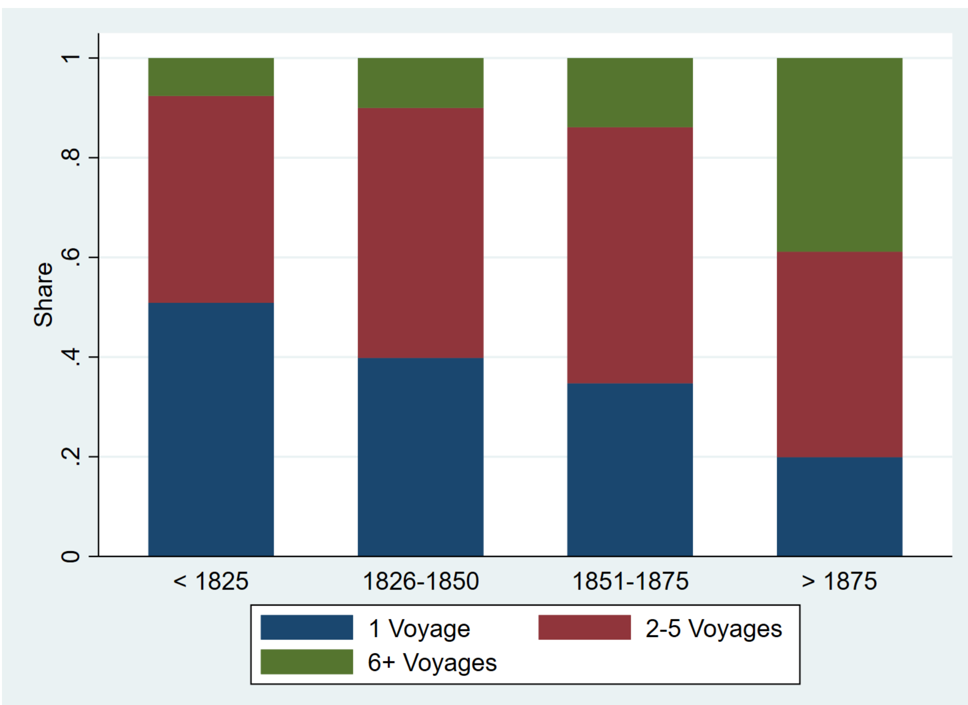


Table 4: Determinants of Output

	Output	Output	Output	Output
Average Past Output	0.036***	-0.108***		-0.107***
	(0.008)	(0.010)		(0.010)
First Voyage	0.025	-0.167***	0.026	-0.160***
	(0.019)	(0.027)	(0.020)	(0.025)
Voyage Number	0.008	-0.038	-0.009	0.008
	(0.009))	(0.022)	(0.022)	(0.017)
Duration	0.449***	0.501***	0.504***	0.509***
	(0.010)	(0.014)	(0.014)	(0.012)
Competition	-0.522***	-0.250**	-0.318***	-0.436***
	(0.081)	(0.110)	(0.111)	(0.098)
Tonnage				0.350***
				(0.016)
Full Rig Ship				0.031
				(0.026)
Schooner				0.059
				(0.040)
Year In FE	X	X	X	X
Ship FE	X	X	X	
Captain FE		X	X	X
R^2	0.704	0.827	0.823	0.751
N	10997	10997	10997	10698

Table 5: Employment and Pay

	Final Voyage	Same Ship	Lay	Lay	Lay
Output	-0.079***				
	(0.007)				
Previous Voyage Output	0.032***	0.048***	0.436***	0.271***	0.290***
	(0.008)	(0.015)	(0.077)	(0.038)	(0.048)
Average Past Output	0.004	-0.048***	-0.163***	-0.029	-0.106***
	(0.007)	(0.012)	(0.061)	(0.029)	(0.040)
First Voyage	0.059***		-0.192	-0.182**	-0.203
	(0.016)		(0.168)	(0.088)	(0.127)
Voyage Number	-0.003	0.245***	0.716**	0.099**	0.128
	(0.007)	(0.023	(0.324)	(0.049)	(0.193)
Duration			-0.095	-0.191***	-0.181***
			(0.081)	(0.035)	(0.051)
Tonnage					-0.400***
					(0.055)
Year In FE	X	X	X	X	X
Ship FE	X	X	X	X	
Captain FE		X	X		X
R^2	0.241	0.531	0.942	0.731	0.798
N	10318	7115	1474	1474	1474

... reversion to the mean

... retention

...experience -> duration?

Lay facts

...experience matters for lay

2.5 Entry and Exit

???

3 Model

3.1 Demand

Let j index the three products, $j \in \{sperm, oil, bone\}$. Demand for product j in year t is given by,

$$Q_{jt} = \xi_{jt} - \alpha_j \log p_t \tag{1}$$

Where Q_{jt} is total quantity, p_{jt} is price, and ξ_{jt} is a year-product specific demand shock. p_t is the 3x1 vector of prices and ξ_t is the 3x1 vector of demand shocks. I assume that ξ_t evolves accordiong to the following VAR process:

$$\xi_t = \Sigma\xi_{t-1\tau(t)} + \delta_{\tau(t)} + \nu_t \tag{2}$$

Where $\Sigma_{\tau(t)}$ is a symmetric 3x3 matrix, $\delta_{\tau(t)}$ is a 3x1 verctor, and $\nu_{jt} \sim N(0, \sigma_{\nu\tau(t)})$ iid over j and t. $\tau(t)$ is an indicator for $t \geq 1859$. The VAR parameters are therefore allowed to differ across the two periods, reflecting the structural change in demand from the development of the petroleum industry and the rise in popularity of whalebone corsets.

3.2 Firm's Problem

number of potential entrants drawn from poisson random variable....identified? or just fix the number of potential entrants? Fixed number of potential entrants identified by cost of building a ship

- choose to enter (large or small)

- if active and at port, choose duration and targeting

– match and negotiate lay

- output realized, tau periods later...

exit or continue...

3.3 Production

Not captured here: different voyages target different species within the same year...

NEED: higher tonnage ships go away for longer...

Consider a voyage v with captain c and ship $f$in year t. The voyage lasts τ_v years, and a share of time s_{vj} is devoted to targeting each product, $j \in \{sperm, oil, bone\}$. Total output is given by

$$O_v = \sum_j p_{jt+\tau v} Y_{vj},$$

where Y_{vj} is the quantity of product j harvested on voyage v. The production function for each product is

$$Y_{vj} = \begin{cases} (\tau_v s_{vj} w_{vj})^{\alpha_j} & if \log w_{vj} > \log \underline{w}_{vj} \\ 0 & otherwise \end{cases},$$

where $\tau_v s_{vj}$ is the amount of time devoted to targeting product j, w_{vj} is a product-voyage specific productivity, $\alpha_j \in [0,1]$, and $\underline{w}_{vj} \sim N(\underline{w}, \sigma_{\underline{w}})$. The productivity term can be further decomposed as

$$\log w_{vj} = X_f\beta + a_c + \omega_{vj}$$

Where a_c is the captain's ability, X_f are ship characteristics, and ω_{vj} is a productivity shock. We asusme that $\omega_{vj} \sim N(0, \Sigma_\omega)$. For instance, the productivity shock to $j = oil$ and $j = bone$ are likely to be positively correlated.

3.4 Simpler Version

$$Y_{vj} = \begin{cases} (\tau_v w_{vj})^{\alpha_j} & with\, P = \frac{1}{1+\exp(\gamma_0 - \gamma \log(w_{1vj}))} \\ 0 & otherwise \end{cases},$$

Independence across outputs. No targeting.

$$\log w_{vj} = X_f \beta_j + \delta_j a_c + \omega_{vj}$$

Where $a_c \sim N(0, \sigma_a)$ and $\omega_{vj} \sim N(0, \Sigma_\omega)$.

This can be esitmated using maximum likelihood separately form any dynamic game or matching part.

Identification: σ_a identified by the extent to which some captains perform better on average than others. β is standard. γ_0 is the average prob of non-zero output. γ_1 is identfied by the extent to which zero output is more likely for low-productivity captains. Σ_ω is variance of output and correlation between outputs. α_j is effect of duration on output. $\delta_j = 1$ for a reference porduct and captures relative importance of captain's skill for other products.

Note $\frac{logY_j}{\alpha_j} = log(\tau_v) + X_f\beta + a_c + \omega_{vj}$ for positive output

Expect $\alpha_{oil} < \alpha_{sperm}$because of geography.

Include dummies for ship type in X. including tonnage as a continuous variable seems problematic.

Actuall, there is selection of a conditional on tau if tau is chosen with knowledge of a.... Need to jointly estimate duration choice and output.

Assume a is known, then optimal duration is

$$O_v = \sum_j p_{jt+\tau v} Y_{vj},$$

3.5 Labor Market

correlation between ability and outside option...

... learning? limited information?

Captains have ability drawn from $a_c \sim N(a, \sigma_a)$. Ability is unobserved, but can be learned about through signals generated by whaling outcomes.

Let n_{ct} be the number of whaling voyages a captain has completed up to year t. When a captain and an owner match to negotate a contract, the owner observes the prior distribution of abilities, $N(a, \sigma_a)$, an initial signal about the capitain, $s_c \sim N(a_c, \sigma_s)$, and the output of the captain's past voyages. In particular, the owner ovserves $\alpha_c + \omega_{vj}$ for each j for the catptain's last voyage, and $\alpha_c + \omega_{vj}$ for previous voayges with probability δ. This can be thought of as a "forgetting" parameter that rationalizes over-reliance on recent performance. Finally, the owner observes n_{ct}. Given all of this information, the owner has a posterior beleif , $G(a_c)$ about the captain's ability.

- Every period, previously matched pairs decide whether to continue to be matched. If it id worth it for both sides they match, otherwise they separate

- all unmatched ships draw a captain from the distribution of available captains

- all matched pairs negotiate a lay

- Ships keep track of includive value of available captains?

– includive value: expected value of drawing a new captain. Assume it evolves 1st order markov.

—-

every available worker gets a shock - order of matching randomized among firms - match from highest expected value to lowest expected value.

If number of ships exceeds number of workers... draw from “new” captains.

What about new captains joining when the market is in decline?

— retirements etc...

THE BETTER A CAPTIAN PERFORMS THE MORE LIKELY THEY ARE TO JUMP SHIP

UPGRADING TO BIGGER SHIPS!

SIZE -> PRODUCTIVITY

Separation process....

captain quit if u_quit + cost> u_stay + eps

captain fired if V_fire + cost > V_not_fire +eps

Matching process... assortative matching

captains prefer larger ships

ships prefer captains according to value function + shock (friction)

assortative match

4 Estimation

4.1 Demand

.. use landings from departures from previous years as instrument -> seems to work

4.2 Production

This is really an identification argument:

Consider the first voyage so all captains look the same. Note that the duration choice is therefore independent of captain ability. We write:

$$E\left(\log Y_{\nu j}\right) = \alpha\tau_v + \delta_{t(v)} + \alpha X_f \beta + correction$$

We can then estimate the joint distribution of omegas + a ...

5 Results

Table 6: Demand Parameters

	α_j			Σ_0			Σ_1						
Product	Sperm	Oil	Bone	Sperm	Oil	Bone	Sperm	Oil	Bone	δ_0	δ_1	$\sigma_{\nu 0}$	$\sigma_{\nu 1}$
Sperm													
Oil													
Bone													

Figure 6: Demand Residuals ξ_{jt}

...

6 Conclusion

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