Forced Labor Economic Model

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Goal

- Identify vessels that routinely behave in a way that indicates lower labor cost than other similar vessels

Assumptions

- For similar vessels (flag, gear, engine power, length, and tonnage) in a given time period (monthly), the fishery shares a common stock
- Individual vessels are profit maximizing, but for a given fishery and time period all points globally have a spatially uniform profitability. Points close to port will have smaller levels of the stock, but are less costly to travel to. Points further away from port will have higher levels of the stock, but are more costly to travel to.
- Based on certain vessel characteristics (flag, gear, engine power, length, and tonnage), vessel operators will travel an optimum distance from port to give them the same profitability as other vessels in the fishery.
- All similar vessels have the same variable labor cost, variable fuel cost, and variable subsidy benefits when not employing forced labor. These variable costs and benefits are assumed to be linearly proportional to both travel distance and fishing effort.
- Vessels employing forced labor will have lower variable labor costs

Equations

Revenue for a given fishing area, R_i is given as follows, where q is catchability, B_i is the biomass in each area fished, $\overline{E}$ is the total fishing effort across the fishing area, and p is price.

$$R_i = qB_i\overline{E}p$$

Cost for a given fishing area, C_i, is given as follows, where T_i is the travel distance from port to reach fishing ground i, c_{fuel} is the variable fuel cost, c_{labor} is the variable labor cost, and s is the variable subsidy cost:

$$C_i = (T_i + \overline{E})(c_{fuel} + c_{labor} - s)$$

Combining the equations for R_i and C_i, get we the profit equation:

$$\Pi_i = qB_i\overline{E}p - (T_i + \overline{E})(c_{fuel} + c_{labor} - s)$$

Solving for B_i yields the following:

$$B_i = \frac{\Pi_i + (T_i + \overline{E})(c_{fuel} + c_{labor} - s)}{q\overline{E}p}$$

This demonstrates that biomass will be higher in areas further from port. Next, we denote $\widetilde{\Pi}$ as the profit of vessels using forced labor. We can therefore write the following equation, where $c_{\tilde{labor}}$ is the cost of forced labor, which will be lower than c_{labor}.

$$\widetilde{\Pi} = qB_i\overline{E}p - (T_i + \overline{E})(c_{fuel} + c_{\tilde{labor}} - s)$$

Next, we can plug in B_i to this equation:

$$\widetilde{\Pi_i} = q\overline{E}p\left(\frac{\Pi_i + (T_i + \overline{E})(c_{fuel} + c_{labor} - s)}{q\overline{E}p}\right) - (T_i + \overline{E})(c_{fuel} + c_{\tilde{labor}} - s)$$

Which simplifies as follows:

$$\widetilde{\Pi_i} = \overline{\Pi} + (T_i + \overline{E})(c_{labor} - c_{\tilde{labor}})$$

Since c_{labor} will always be greater than $c_{\tilde{labor}}$, and vessels are assumed to be profit maximizing, vessels using forced labor will therefore maximize their distance from port T_i.

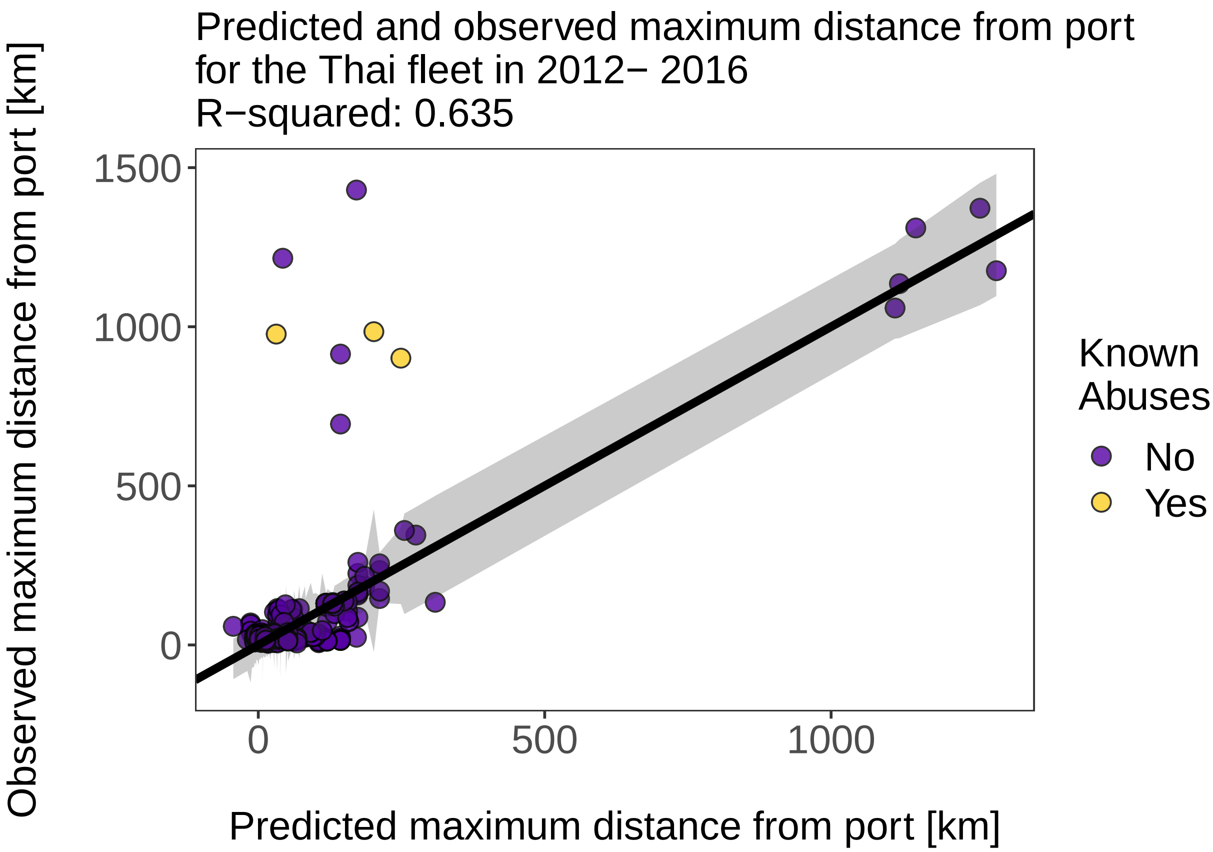
Examples

We use the following linear regression to predict total trip duration as a function of vessel characteristics:

$$max\_dist\_from\_port \sim length + tonnage + engine\_power + factor(gear) + factor(year) + factor(month)$$

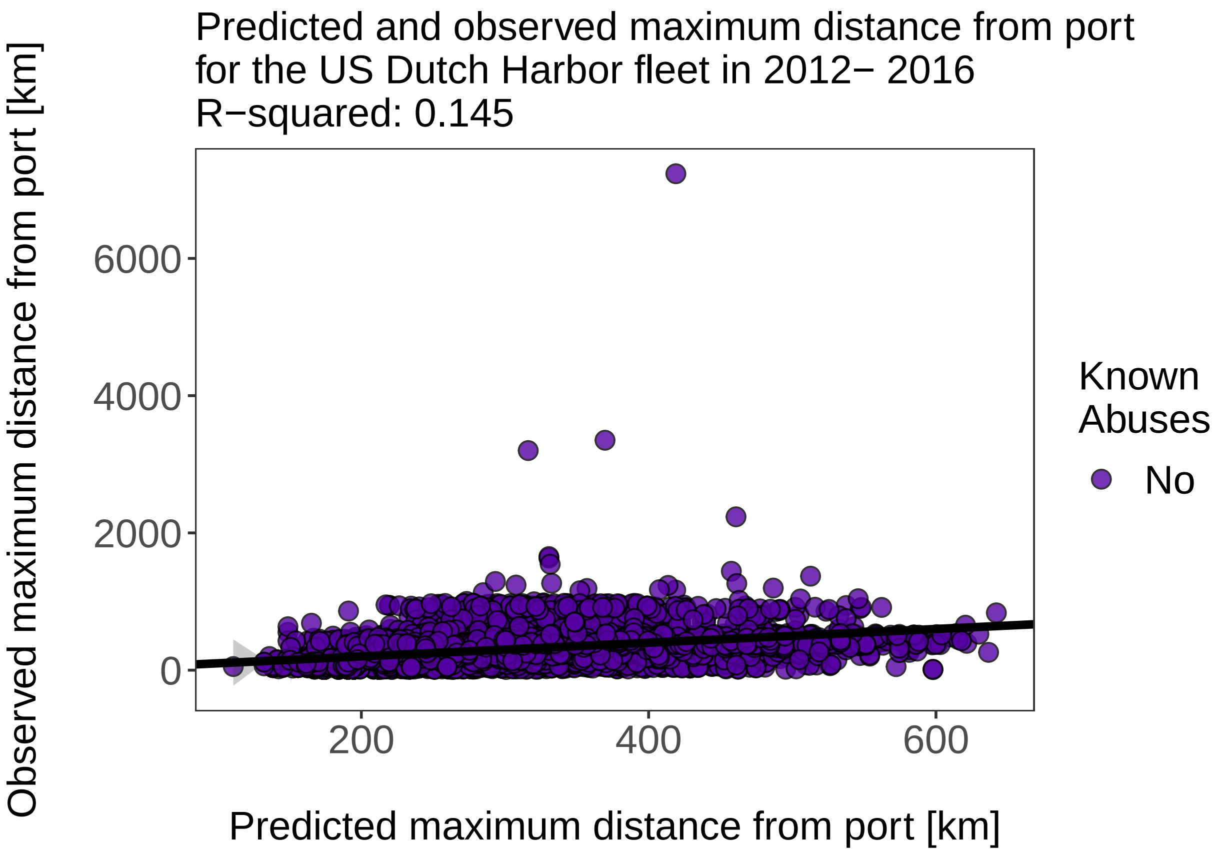
Thailand

The training data set is composed of all Thai-flagged fishing trips from 2012-2016. Importantly, we exclude any vessels from the training set that are known to be offenders. We use this model to predict maximum distance from port for all fishing trips, including those known to be offenders. The observed versus predicted model relationship is visualized as follows. Note that all known-offenders are significant outliers from the model, and exhibit higher than expected maximum distance from port.



United States - Dutch Harbor

Next, let's try the United States Dutch Harbor fleet, which we assume has little or no forced labor. This port has the most trips of any port in the US. We can see that the trips are more tightly grouped, but still with numerous outliers.


Predicted and observed maximum distance from port
for the US Dutch Harbor fleet in 2012− 2016
R−squared: 0.145
Observed maximum distance from port [km]
6000
4000
2000
0
200
400
600
Predicted maximum distance from port [km]
Known
Abuses
No