Optimal vessel speed and weather effects

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NHH

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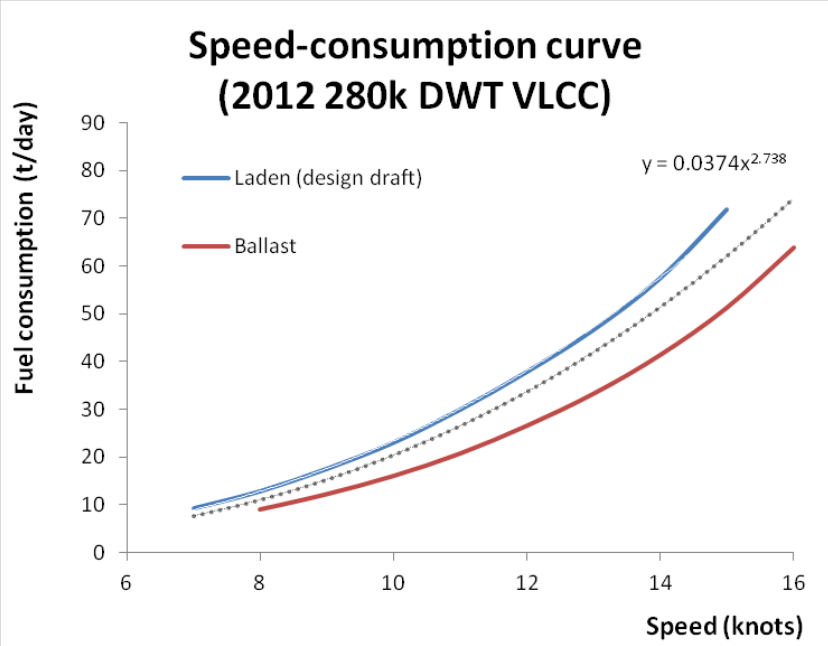
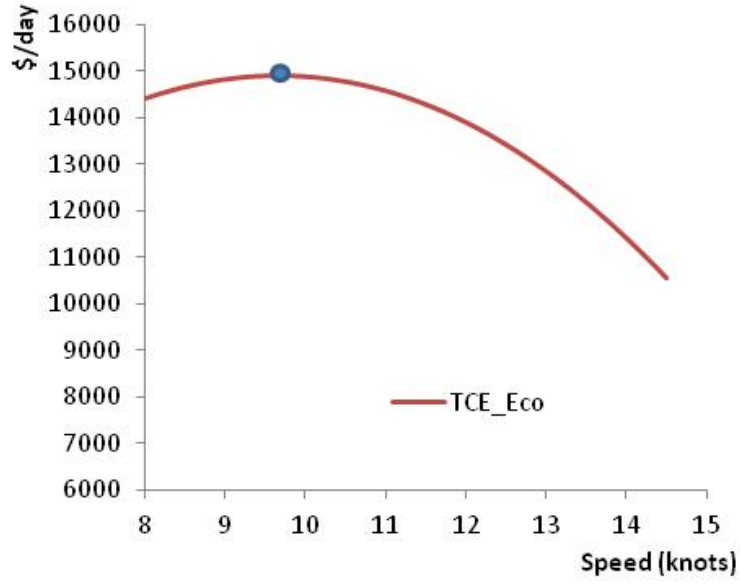
Background

- Optimal speed reflects a tradeoff between the value of time (freight rates) and the cost of fuel
- In most economic analysis we rely on the classical "cubic rule" relationship between speed and consumption

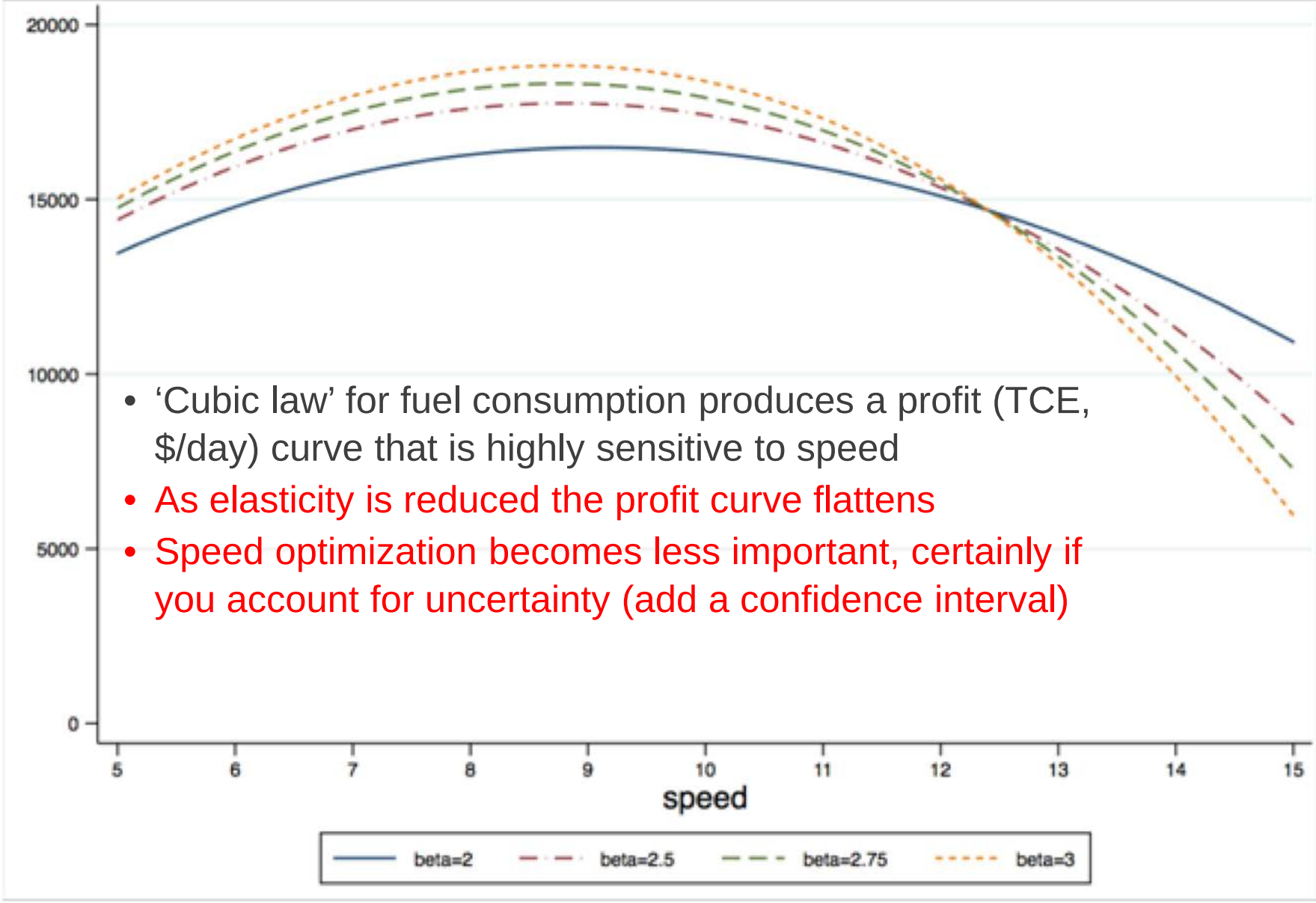




Challenges

- 'Cubic law' represents an idealized relationship between vessel speed and fuel consumption
  - Flat-water conditions
  - New ship hull, no fouling
  - To account for weather you add a fixed «weather margin» of 10 – 15%
- What is the true fuel consumption curve at low speeds?
  - Often no trial, model test data in this range. Yards only warrant design conditions
- What is the impact of weather?
- ***In reality, the optimal speed depends on both the true fuel consumption-speed elasticity and weather effects***

Impact of changing elasticity



- 'Cubic law' for fuel consumption produces a profit (TCE, $/day) curve that is highly sensitive to speed
- As elasticity is reduced the profit curve flattens
- Speed optimization becomes less important, certainly if you account for uncertainty (add a confidence interval)

Empirical analysis

- Objective: To extract elasticities from vessel performance data directly
- “Reverse engineer” naval architecture theory for operations in the real, complex seaway
- Use vessel performance data for a fleet of sister vessels
  - 10 Aframax crude tankers and 6 Suezmax crude tankers
  - Period of observation: January 2012 – December 2016
- Use daily noon reports
  - Fuel consumption since last observation (usually 24 hours)
  - Sailed distance, GPS speed and log speed
  - Weather conditions: wave, wind, swell direction and magnitude
- Relatively large sample size: 18,422 reports before cleaning

Data-driven elasticities (and inflection points)

- Generally a decreasing function of speed

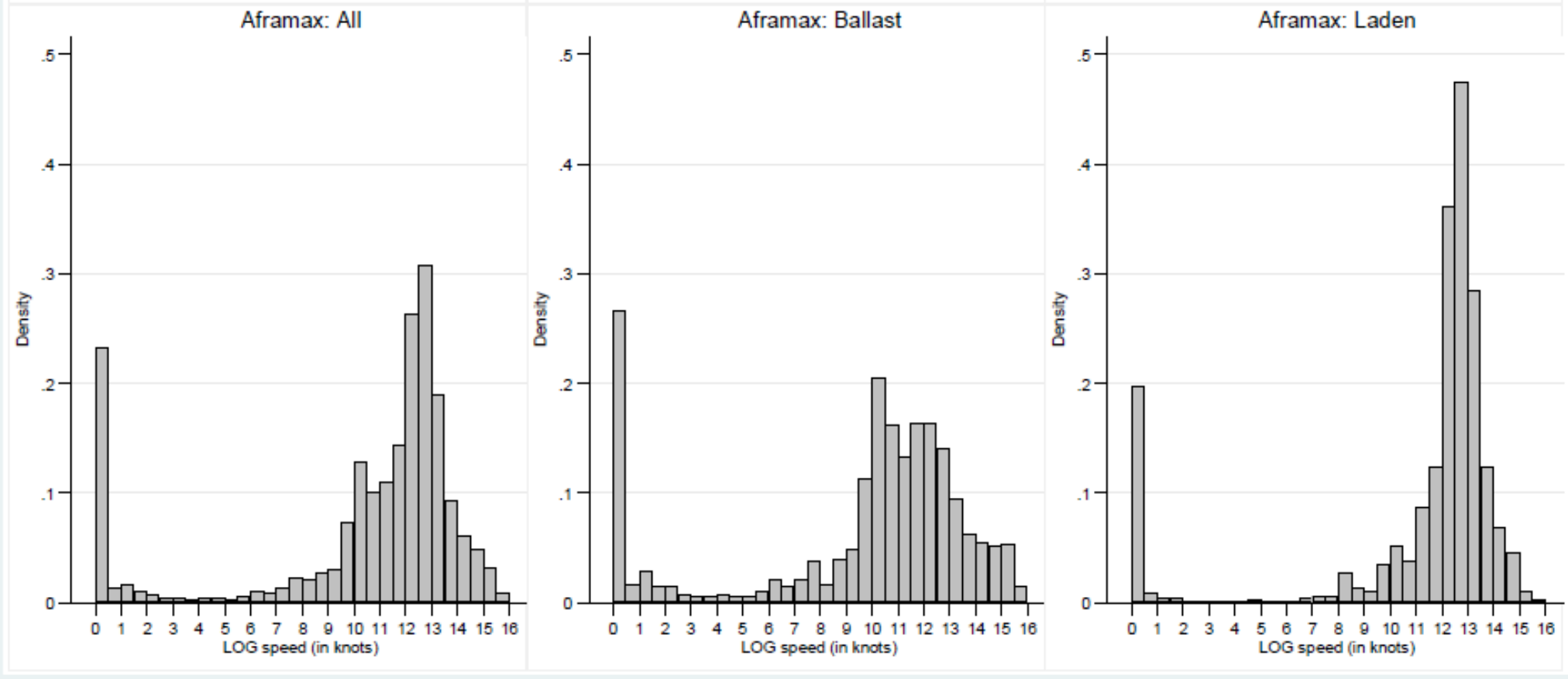
Table 3. Estimates of the logarithm of fuel consumption with endogenous knots

Variables		Aframax			Suezmax		
		(1A) All	(1B) Ballast	(1C) Laden	(2A) All	(2B) Ballast	(2C) Laden
Panel C. Two endogenous knots							
Estimated knot K_1		9.89	8.51	10.50	7.30	7.76	8.49
Estimated knot K_2		11.61	9.99	14.32	10.68	11.45	12.53
LOG speed (log)	Speed < K_1	0.349***	0.081	0.415***	-0.180	0.327*	1.262***
		(8.25)	(0.59)	(9.38)	(-0.85)	(1.85)	(8.18)
LOG speed (log)	K_1 ≤ Speed < K_2	2.576***	1.092***	2.099***	1.624***	1.749***	1.984***
		(57.01)	(9.93)	(75.09)	(40.33)	(35.74)	(54.62)
LOG speed (log)	K_2 ≤ Speed	2.242***	2.626***	3.036***	2.417***	2.623***	2.216***
		(72.35)	(72.47)	(14.11)	(80.39)	(43.22)	(32.37)
Test of equal elasticity	F-test	797.06	351.05	487.42	220.37	128.14	17.40
	Prob-value	0.000	0.000	0.000	0.000	0.000	0.000
Extended controls		YES	YES	YES	YES	YES	YES
Observations		7,600	2,575	5,025	4,325	2,068	2,257
R^2		0.855	0.842	0.739	0.885	0.857	0.864

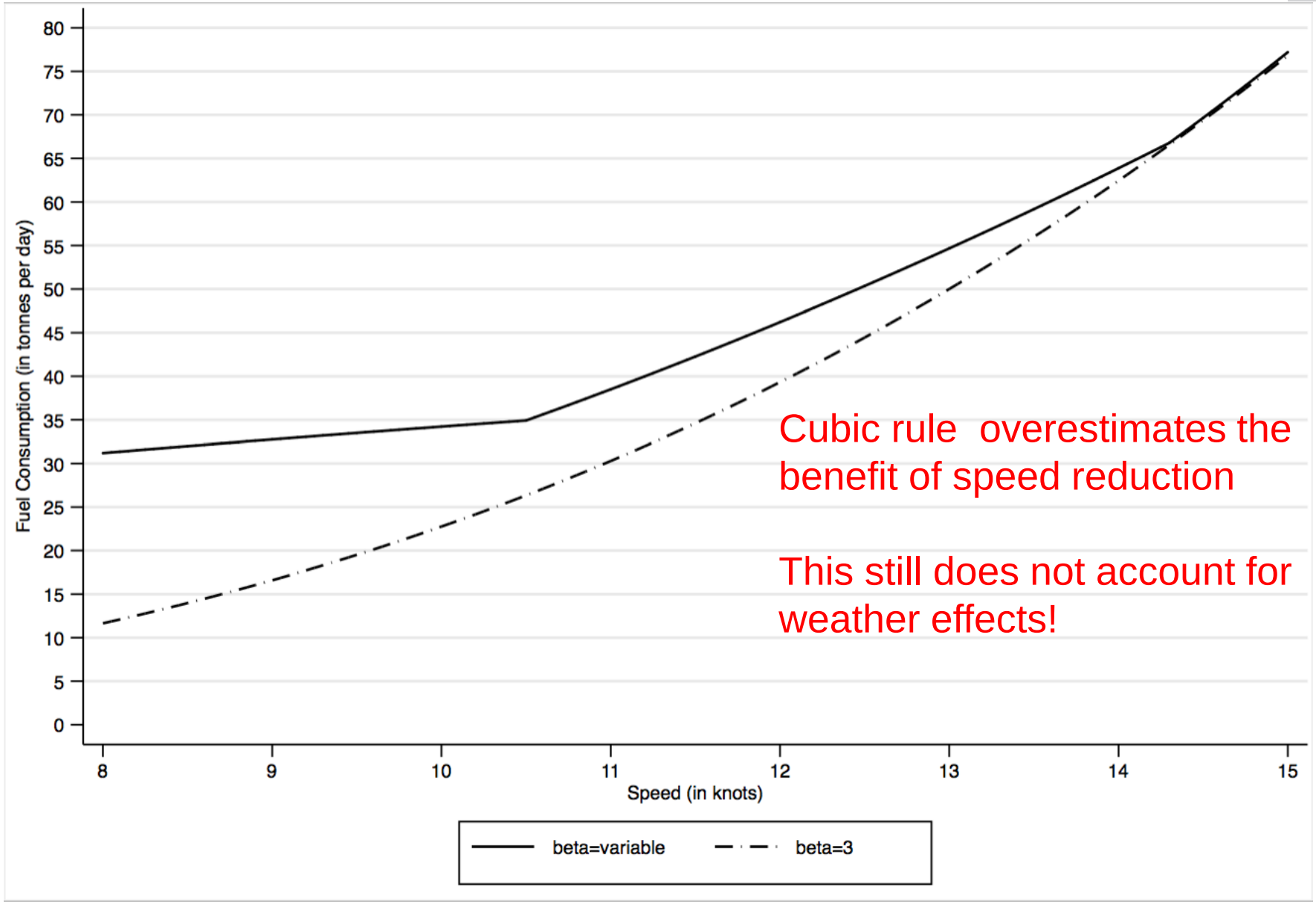
Source: data from a tanker company, authors' calculations.

Note: the reported estimates are obtained from linear regressions with robust standard errors. Significance levels are 1% (***), 5% (**) and 10% (***). The sample is restricted to average daily speeds comprised between 6 and 16 knots.

Speeds are typically not near design speed

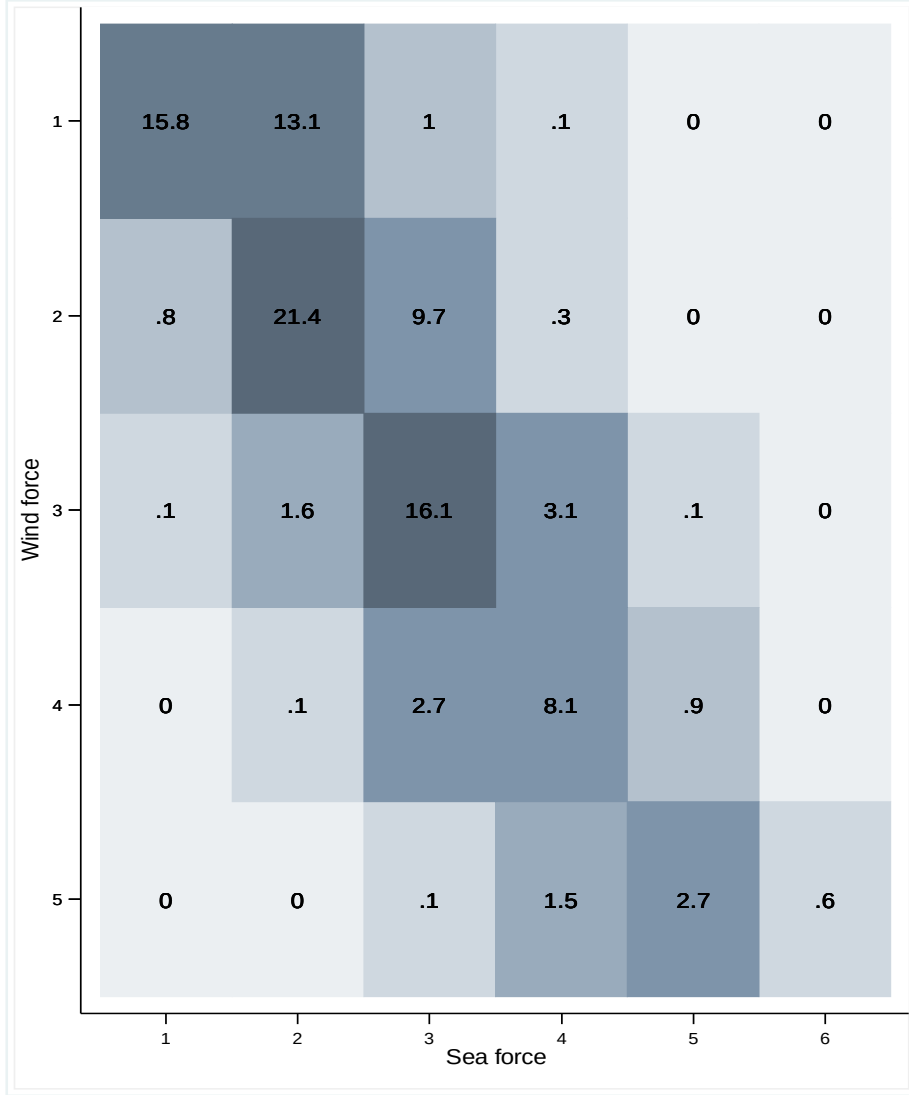


Impact of varying elasticity on fuel consumption

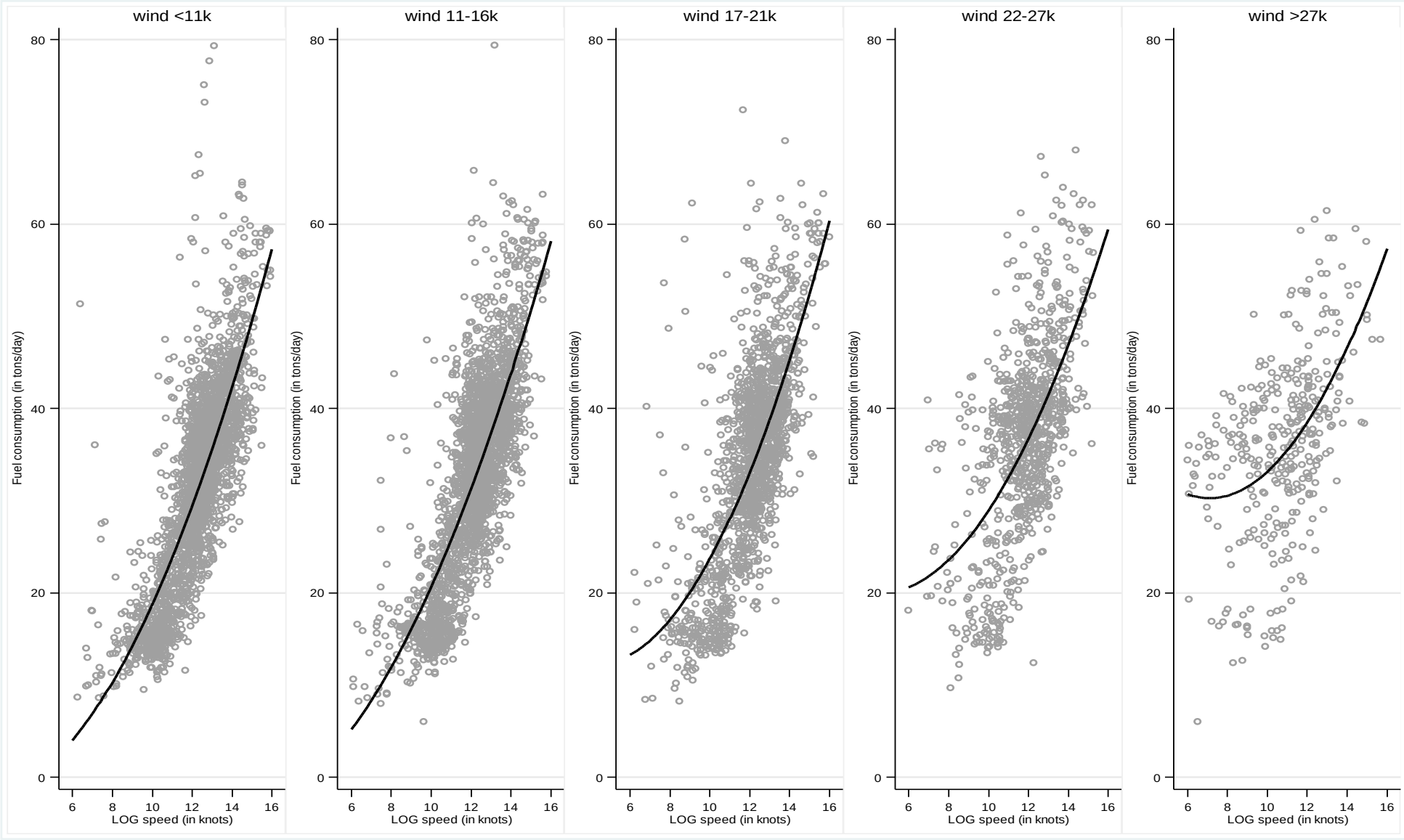


Accounting for weather

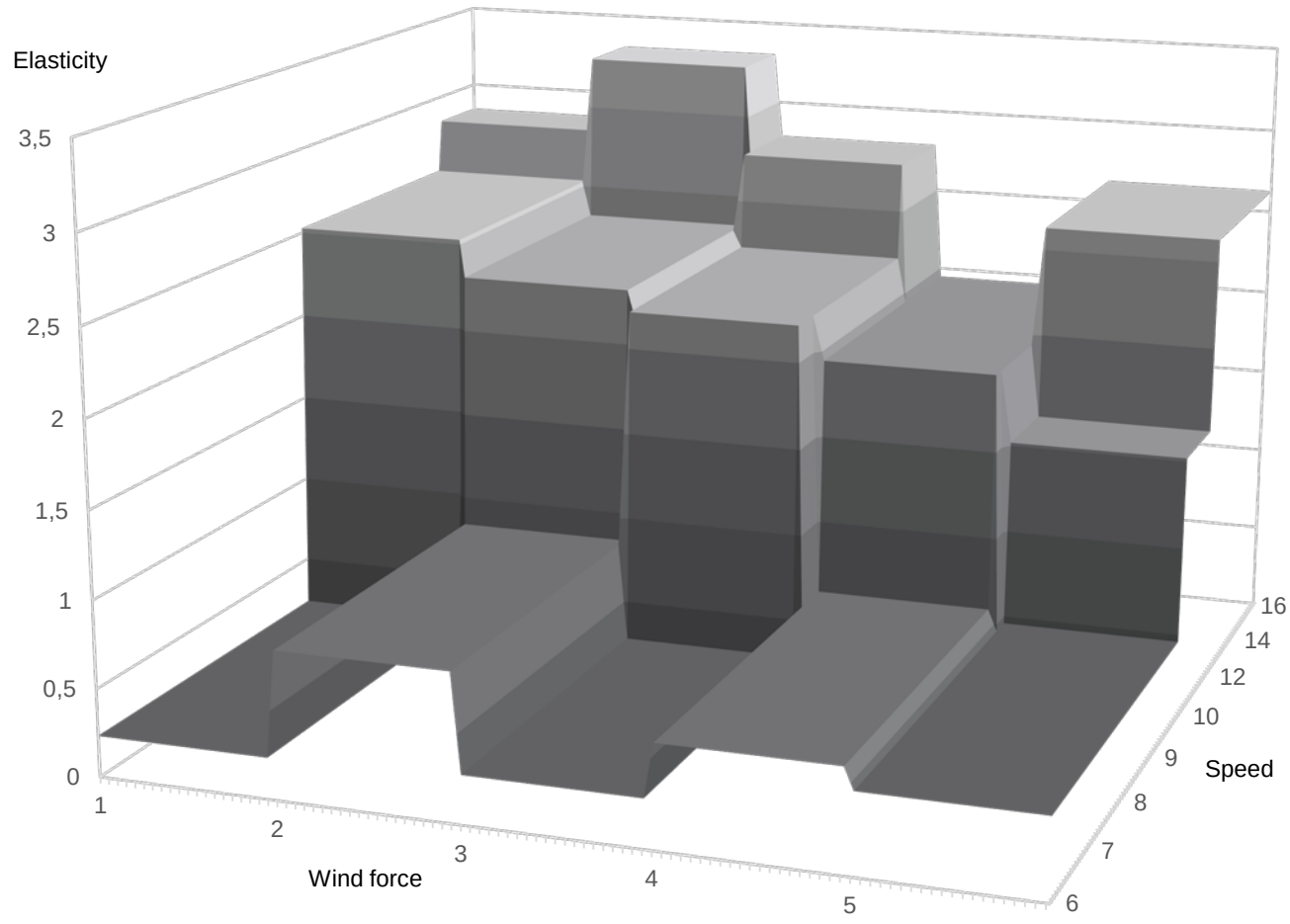
- Need to simplify a complex physical environment for the purpose of visualization (reducing the dimension)
- Wind force is highly correlated to the other phenomena (swell, sea state) – c.f. Beaufort scale



Correlation between fuel consumption and speed by wind force



Fuel consumption elasticities as a function of sailing speed and wind speed



Concluding remarks

- On the speed-consumption relationship:
  - "Cubic rule" holds only at near-design speeds and not at observed sailing speeds
  - The true elasticity is lower at reduced speeds and dependent on both speed itself and weather conditions
  - Bad weather further reduces the elasticity of fuel consumption with regards to speed
- Implications are potentially very important:
  - The positive environmental impact of speed reduction is probably much less than assumed!
  - Add uncertainty in the estimates and it could easily be that speed optimization does not matter (economically)