Appendix A. Ensemble forecasting methodology

The first step in forecasting the returns of a given stock of fall Chinook $y_{a,t}$ of age a in year t is to fit eight different models (Table 1) to observed returns in years 1964 through $t-1$. We omit subscripts for stock above and throughout for simplicity of notation and because stock groups are forecasted independently. The eight different models are variations of a sibling regression model fit on the log scale with time-varying intercept and slope:

Eq. 1
$$\begin{cases} \log\left(y_{a,t}\right) & = \alpha_t + \log\left(y_{a-1,t-1}\right)\beta_t + v_t, & v_t \sim \mathcal{N}(0, V_t) \\ \alpha_t & = \alpha_{t-1} + w_{\alpha,t}, & w_{\alpha,t} \sim \mathcal{N}\left(0, W_{\alpha,t}\right) \\ \beta_t & = \beta_{t-1} + w_{\beta,t}, & w_{\beta,t} \sim \mathcal{N}\left(0, W_{\beta,t}\right), \end{cases}$$

where α_t and β_t are an intercept and a slope for the log-transformed returns of the previous age in the previous year, respectively, and both are allowed to vary across years as random walks with process error variances $w_{\alpha,t}$ and $w_{\beta,t}$, respectively. The residual v_t is assumed to be normally distributed around zero with variance V_t. Together with a vague prior distribution for the values of α_0 and β_0 (the slope and intercept prior to the first year) Eq. 1 defines the "full" sibling regression model.

The seven other models are simplified versions of this full model where:

1) the slope is assumed to be constant through time (i.e., $w_{\beta,t} = 0$);

2) the intercept is assumed to be constant through time;

3) the slope and intercept are assumed to be constant through time;

4) the intercept is assumed to be zero (i.e., $\alpha_t = 0$);

5) the intercept is assumed to be zero and the slope is assumed to be constant through time;

6) the slope is assumed to be zero;

and, 7) the slope is assumed to be zero and the intercept is assumed to be constant through time.

Together with the full model, this list comprises the eight models considered in forecasting. The models are fit using the dlm package (Petris, 2010) in the R statistical computing environment (R Core Team, 2021).

Once the eight models have been fit, each is used to make a prediction of returns in the upcoming year and an ensemble forecast is generated by taking a weighted average of the predictions. The ensemble model weight w_m for each model m in the set ($\mathcal{M}$) of 8 models is calculated based on Akaike's Information Criterion with a correction for small sample size (AIC; Akaike, 1973; Burnham and Anderson, 2002) ,

Eq. 2
$$w_m = \frac{e^{-0.5(\mathrm{AIC}_m - \mathrm{AIC}_{\min})}}{\sum_{i \in \mathcal{M}} e^{-0.5(\mathrm{AIC}_i - \mathrm{AIC}_{\min})}},$$

For more information on this forecasting process, see the code in the GitHub repository at https://github.com/marksorel8/Cox_forecast_ensemble.

References

Akaike, H., 1973. Information theory as an extension of the maximum likelihood principle. Á In: Petrov, BN and Csaki, F, in: Second International Symposium on Information Theory. Akademiai Kiado, Budapest, Pp. 276Á281.

Burnham, K.P., Anderson, D.R. (Eds.), 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. Springer, New York, NY. https://doi.org/10.1007/978-0-387-22456-5_1

Petris, G., 2010. An R Package for Dynamic Linear Models. Journal of Statistical Software 36, 1–16.

R Core Team, 2021. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Table 1. A suite of 8 models run for each brood table. The full model is a sibling regression with time varying intercept and slope, while the 7 other models are simplified versions of the full model. A weighted average of the predictions of each of the 8 models, where weights are determined by AICc, is used as the forecast for an upcoming year.

Description	
Full)	Sibling regression with time-varying slope and intercept.
1)	Sibling regression with time-varying intercept.
2)	Sibling regression with time-varying slope.
3)	Sibling regression with constant slope and intercept.
4)	Time varying "cohort ratio" model. Time varying slope, Intercept=0.
5)	Constant "cohort ratio" model. Constant slope, Intercept=0
6)	Time-varying Intercept-only model. Random walk on return, no sibling predictor.
7)	Constant Intercept-only model. Long-term average, no sibling predictor.