The Coherence Side of Rationality

Rules of Thumb, Narrow Bracketing, and Managerial Incoherence in Corporate Forecasts

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[Coherence:] "consistency of the elements of the person's judgment"
Hammond (2007), p. xvi

- A **pillar of rationality** of judgement and decision making, according to philosophers (at least since Aristotle), psychologists, and economists (e.g., Tversky and Kahneman (1981), Sen (1993), Becker (1996), Posner (2014)).
- One of the **two standards** to evaluate rationality, together **with accuracy** (e.g., Hammond (1990, 1996, 2000), Gigerenzer et al. (1999), Arks et al. (2016)).
- Large literature on **forecast accuracy**, centering on predictability of forecast errors given info at time of forecast (e.g., Tversky and Kahneman (1974) and Benjamin (2019)'s review). **Forecast coherence has received less attention**.
- **This paper** studies **forecast coherence in a firm setting**, providing **theory and evidence** on the extent to which chief financial executives make (in)coherent – and (in)accurate – forecasts of their own firm's output and input growth.

Motiv I: (In)Coherence May Be Consequential for Firms

- Firms' chief financial executives (CFO) routinely make detailed and explicit **corporate forecasts** ('plans') for several years.

- Presumably **taking into account firm's production technology and budget constraint**.
  - E.g., to double its output a firm will likely need to plan using a lot more of its input.
  - This paper's **'coherence benchmark'**.

- Ignoring budget and technological relationships may lead to a **suboptimal mix of inputs** (e.g., K and L) and **could be costly** to the firm.
  - In **static or stable environments** – our focus.
  - Dynamics or disruptions may require adaptation and incoherence relative to plans (e.g., Arks, Gigerenzer, and Hertwig (2016)) – interesting future research.

- A recent literature on **'behavioral firms'** has been concerned with firms making inefficient choices and leaving money on the table (e.g., DellaVigna (2018), DellaVigna and Gentzkow (2019), Strulov-Shlain (2022)).

- **Corporate planning and internal forecasting** underlie all firm decisions, but are **not yet well understood** (Graham, 2022).

Motiv II: Managerial Textbooks' Rules of Thumb (RoT) Have Not Been Evaluated

- Managerial textbooks acknowledge the difficulty of making plans about multiple firm's variables and provide **rules of thumb (RoT)** to aid CFOs (e.g., Ruback (2004), Titman and Martin (2016), Welch (2017), Holthausen and Zmijewski (2020), Koller et al. (2020)).
  - **These RoT have not been assessed theoretically or empirically** – we do so.

- **One rule** – called "plain growth forecast" (Welch (2017), p. 593) – is to forecast an input's growth rate (say, K's) by projecting its past growth into the future, without considering info on output and other inputs (say, L).
  - Reminiscent of **'narrow bracketing'** behavior of decision makers.
  - When considering multiple related choices (e.g., consumption bundles), narrow bracketers make each choice in isolation disregarding their relationships (e.g., via budget constraint and utility fn), possibly obtaining lower utility than broad bracketers (e.g., Thaler (1985) and Read et al. (1999)).

- Potential **parallel in production** context.
  - CFOs need to make detailed plans for several years about multiple firm's variables that are related via production fn and budget constraint.
  - Narrow bracketing could induce incoherent, suboptimal allocation of resources to capital expenditures while ignoring labor costs, or viceversa.

Motiv III: Firms May Be More Amenable to Study Coherence (Lack Thereof)

- Scholars have lamented the difficulty of studying coherence in judgment and decision.
  - * "(...) there is no way of determining whether a choice function is consistent or not *without* referring to something external to choice behavior (such as objectives, values, or norms)." Sen (1993), p. 495.
  - * "'[probability] judgments must be compatible with the entire web of beliefs held by the individual. Unfortunately, there can be no simple formal procedure for assessing the compatibility (...)" Tversky and Kahneman (1974), p. 1130.
  - This paper studies forecast coherence in a context where the **objective function (e.g., profit max) and technology (i.e., prod fn) should be uncontroversial and known to decision makers.**

- Behavioral/experimental research has focused on coherence ('consistency') benchmarks from propositional logic (e.g., modus tollens/ponens) and probability theory (e.g., Bayes' rule). These universal, domain-general criteria have been criticized by some scholars, who have proposed conceptualizing and assessing coherence in settings where it may serve an "organism's goals" (Arks, Gigerenzer, and Hertwig (2016), p. 31).
  - This paper studies forecast coherence (and accuracy) among **optimizing agents.**

Paper's Overview

- Introduces a **theory of forecast coherence** in a firm setting.
  - (i) **'Normative' version** $\Longrightarrow$ benchmark of 1st-best coherent forecasts & conditions on forecasts (*ex ante*) or forecast errors (*ex post*) to assess forecast coherence.
  - (ii) **'Positive' version** where CFOs observe noisy signals of input prices $\Longrightarrow$ conditions on 2nd-best optimality & testable predictions on firm outcomes (e.g., performance).
  - **(i)-(ii)** $\Longrightarrow$ Partial ranking of managerial rules of thumb (RoT) & RoT use as a **mechanism** whereby incoherence is due to 'narrow thinking' (bracketing).
- Implements **coherence (and accuracy) conditions** in linked **expectation-realization data** on multiple firm-level balance-sheet variables from the Duke Survey of large- and mid-size US corporations and from Compustat.
- Constructs a **continuous, ex ante measure of CFO (in)coherence** based on the model.
- Examines **extent to which CFO forecasts reflect RoT use** & **how RoT use is related to ex ante (in)coherence**.
- Investigates **relationships of (in)coherence and RoT use with firm's performance, investment, and debt policy** – all activities in which CFOs play a key role.

We Build On and Contribute to Three Strands of Lit

1. Coherence and Accuracy Sides of Rationality

   * Tversky and Kahneman (various), Hammond (various), Osherson, Shafir, and Smith (94), Wrightetal (94), Gigerenzer et al. (99), Rabin (02), Mandel (05), Newell (05), Reyna and Lloyd (06), Gigerenzer and Gaissmaier (11), Baron (12), Lee and Zhang (12), Wallin (13), Arks et al. (16), Benjamin, Rabin, and Raymond (16), Zhuetal (20, 22), Bergetal (22).

   - **By disentangling coherence and accuracy theoretically and empirically**.

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2. Bracketing

   * *Applied Theory*: Barberis et al. (06) (stock market participation), Rabin and Weizsacker (09) (gambling), **Lian (21) (consumption)**.
   * *Mental Accounting*: Tversky and Kahneman (81), Thaler (85), Kahneman and Lovallo (93), Read et al. (99), Rabin and Weizsacker (09), Hastings and Shapiro (13, 18), Farhi and Gabaix (20), Ellis and Freeman (20).
   * *Inattention and Sparsity*: Sims (03), Mackowiak and Wiederholt (09), Matejka and McKay (15), Mackowiak et al. (18), Koszegi and Matejka (20), Gabaix (14, 19).

   ▶ **By providing first theory and evidence of (narrow) bracketing in production**.

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3. Survey Expectations of Firms
   * **Top executives: Ben-David et al. (13), Boutros et al. (20), Campello et al. (10), Campello et al. (11, 12), Gennaioli et al. (16), Graham (22)**.
   * *Firm expectations*: Bachmann and Bayer (13, 14), Bachmann et al. (20), Bloom et al. (21), Altig et al. (22), Barrero (22), Born et al. (23), D'Acunto et al. (23), Candia et al. (23).
   - **By studying forecast heterogeneity, coherence, accuracy for multiple balance-sheet vars**.

Roadmap

- Data Essentials and Motivating Evidence
- Theory
  - Normative Benchmark of Ex Ante Optimal Coherent Forecast
  - Positive Model of Narrow Thinking in Corporate Forecast
- Empirical Analysis
  - Conditions and Tests of Coherence
  - Incoherence and RoT
  - Incoherence, RoT, and Corporate Performance
  - Incoherence, RoT, and Corporate Policies

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CFO Expectations Come from Duke Survey

- **Duke Survey** was co-launched by Michael Bradley and Campbell Harvey in 1996 and is currently run by John Graham and Campbell Harvey at Duke University.
  - Surveys 2-3K CFOs/quarter, asking their views about the US economy and corporate policies, and expectations of future firm performance and operational plans.
  - Usual response rate/quarter is 5-8% within a couple of days.
  - Since late 1990s, has been asking Rs' expectations of future 12-month growth rates of key corporate variables, including sale revenues ("Y"), capital expenditures ("K"), wages ("L"), etc.

- **Our data** comprises CFOs' point forecasts of multiple firm's variables for the period 2001q1-2018q4, elicited as follows:

4. Relative to the previous 12 months, what will be your company's PERCENTAGE CHANGE during the next 12 months? (e.g., +3%, -2%, etc.) [Leave blank if not applicable]

%	Prices of your products	%	Technology spending
%	Overtime	%	Earnings
%	Advertising/Marketing spending	%	Revenues
%	Number of employees	%	Inventory
%	Productivity (output per hour worked)	%	M&A activity
%	Wages/Salaries	%	Capital spending
%	Health care costs	%	Dividends

Firm Realizations Come from Compustat

- **Compustat** extracts the data from the Security and Exchange Commission (SEC)-required public filing of financial statements.
    - It covers all publicly traded firms across all sectors of the US economy since 1955.

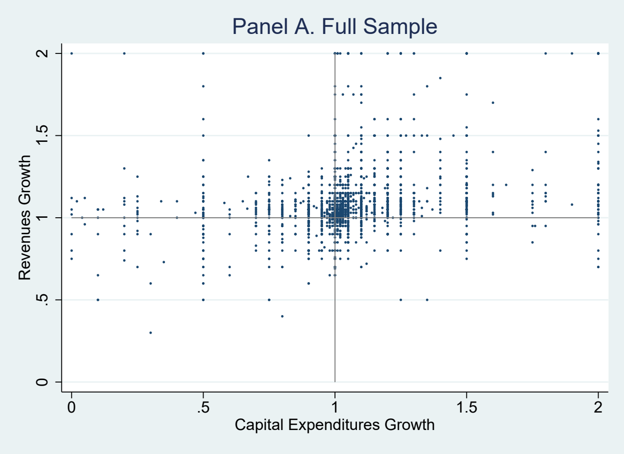
- **Compustat VS Duke** – Relative to Compustat firms, Duke-Study firms are on average:
    - larger in sales and assets, more profitable, and hoarding more cash;
    - similar in market-to-book ratio (avg. Tobin's q), investment (capital expenditures), and leverage (LT debt/assets)

  (e.g., Ben-David et al. (2013)).

- **Duke-Compustat Matching** – Subject to various sources of attrition, including:
    - Compustat's poor coverage of wages (about 90% missing) $\Longrightarrow$ **no forecast errors for labor**;
    - matches concentrated in early period (until 2011q4) $\Longrightarrow$ **focus on pre-financial crisis period**, consistent with stability assumption of model.

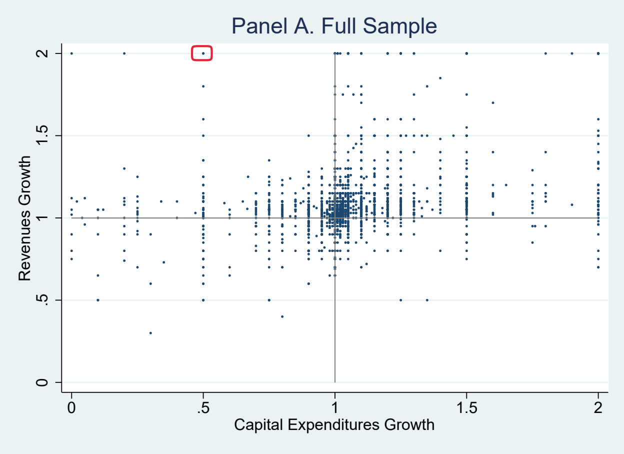
Details

Contemporaneous *Output-Capital Forecasts* in Duke



- Gross growth rates $(1 + r)$: 2 means 100% growth, 0.5 means -50% growth, etc.
- Slope of BLP (cond mean) $= 0.157$, but substantial heterogeneity.

Contemporaneous *Output-Capital Forecasts* in Duke



- ∼25% obs in the upper-left quadrant $\Longrightarrow$ increase output with decreased input.

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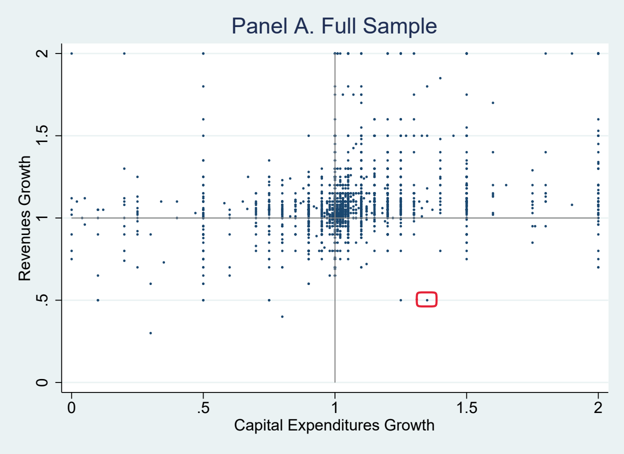

- ∼33% obs in the lower-right quadrant $\Longrightarrow$ decrease output with increased input.

(Similar patterns for output-input forecasts in matched sample, and for output-input realizations.)

Is This Simply Heterogeneity in (Rational) Forecast Pairs?

- Question is *Does cross-sectional dispersion in output-input forecast pairs simply reflect heterogeneity in realizations?*

- It could be. For example:
  - in ULQ, CFO may know the firm has a lot of inventory to sell;
  - in LRQ, CFO may plan to build K and expect it will take time to do so.

- Natural to **inspect forecast errors (FE)**, as a way to assess output's and input's forecasts and realizations *jointly*, at the *individual level*.
  - Any additive firm-level (f) component known or predictable at the time of forecast (t) should get differenced away in FEs.

$$
\begin{aligned}
y^f_{t+1} &= \alpha + \alpha^f + \sum_{i=1}^{n} \beta^f_i x^f_{i,t+1} + \sum_{i=1}^{n} \sum_{s=0}^{t} \delta^f_{i,t-s} x^f_{i,t-s} + \sum_{j=1}^{m} \sum_{s=0}^{t} \gamma^f_{j,t-s} z^f_{j,t-s} + \varepsilon^f_{t+1} \\
\mathbb{E}_t\left[y^f_{t+1}\right] &= \alpha + \alpha^f + \sum_{i=1}^{n} \beta^f_i \mathbb{E}_t\left[x^f_{i,t+1}\right] + \sum_{i=1}^{n} \sum_{s=0}^{t} \delta^f_{i,t-s} x^f_{i,t-s} + \sum_{j=1}^{m} \sum_{s=0}^{t} \gamma^f_{j,t-s} z^f_{j,t-s} \\
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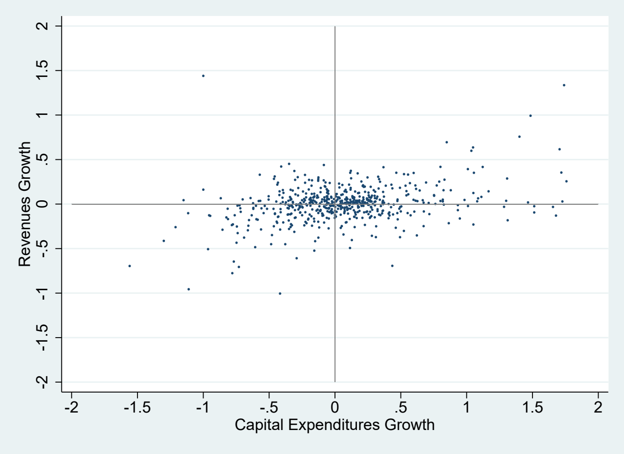
\end{aligned}
$$

Contemporaneous *Forecast Errors* in Matched Sample



- Slope of BLP (cond mean) = 0.149, and UL and LR quadrants' obs down to ∼42%.
- But ∼42% obs in UL-LR quadrants $\Longrightarrow$ **large fraction of output-input FEs with opposite sign**. (Applies to other pairs.)

Roadmap

Want to

Develop a theory of forecast coherence in production.

1. ‘Normative’ theory
   1.1 Provide a benchmark of ex ante coherent forecasts.
   1.2 Provide conditions for/tests of forecast coherence (ex ante/post).
2. ‘Positive’ theory
   2.1 Study forecasts coherence under imperfect information.
   2.2 Nest RoT and assess them: Do they emerge as 2nd-best optimal? If so, which ones and under what conditions?

Rules of Thumb from Welch (2017)'s Taxonomy

(R1) A **plain growth** forecast: each item (say, CapEx) forecasted individually by projecting into the future the item's past growth rates.

- Welch (2017) takes average of two most recent annual growth rates.

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(R3) An **economies-of-scale** forecast: each item's forecast has a fixed component and a variable component, the latter a proportion the sales' forecast.

- Welch (2017) estimates BLPs under square loss of each balance-sheet item's growth on contemporaneous sales' growth using Compustat data to obtain:
  - fixed component = intercept estimate;
  - variable component = slope estimate $\times$ sales' forecast.

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(R4) An **industry-based** forecast: an industry-specific economies-of-scale forecast.

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(R5) A **disaggregated** forecast: accounting for the fact that an item may comove with other items (beyond sales).

- Welch (2017) conditions on additional contemporaneous items (relative to (R3)-(R4)).

Roadmap

Model Setup

- Consider a CES production function and a budget constraint:

$$y = f(x_1, x_2) = \left(\frac{a}{a+b} x_1^{\xi} + \frac{b}{a+b} x_2^{\xi} \right)^{\frac{a+b}{\xi}}$$
$$p_1 x_1 + p_2 x_2 \leq Z,$$

where:

  - y is output, x_1, x_2 input quantities (say, K, L), and p_1, p_2 their prices;
  - denote $\log p_i = \pi_i$, with $i = 1, 2$;
  - Z is a real-valued budget constraint;
  - returns to scale are constant for $a + b = 1$, decreasing for $a + b < 1$;
  - elasticity of substitution between x_1 and x_2 is $\chi = \frac{1}{1-\xi}$;
  - factor-augmenting productivities constant and normalized to 1.

(A1) Prices i.i.d., $\{\pi_{i,t}\}_{t \geq 1} \sim \mathcal{N}(0, \sigma_i^2)$, with $corr(\pi_1, \pi_2) = \rho_{1,2}$.

(A2) Technology stable over time and no aggregate shocks.

- A forecaster issues forecast F_t at t of (generic) x_{t+1} by

$$\min_{F_t} \mathbb{E}\left[(x_{t+1} - F_t)^2 \,|\Omega_t \right],$$

where Ω_t is info set at t and at solution $F_t^* = \mathbb{E}[x_{t+1}|\Omega_t] \equiv \mathbb{E}_t[x_{t+1}]$.

Theory Results I

Proposition 1 (Inequality). *When $\xi \leq 1$ and $a+b \leq 1$, the CES function is concave; then forecast coherence requires that $\mathbb{E}_t[y_{t+1}]$, $\mathbb{E}_t[x_{1,t+1}]$, and $\mathbb{E}_t[x_{2,t+1}]$, satisfy*

$$\mathbb{E}_t[y_{t+1}] \leq \left(\frac{a}{a+b}\mathbb{E}_t[x_{1,t+1}]^{\xi} + \frac{b}{a+b}\mathbb{E}_t[x_{2,t+1}]^{\xi}\right)^{\frac{a+b}{\xi}}.$$

When $\xi \geq 1$ and $a+b \geq 1$, the CES function is convex and the inequality flipped.

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- Cobb-Douglas is linear in log, so Prop 1 holds with equality both for forecasts in levels and growth rates.

Corollary 1 (Cobb-Douglas). *In the limit for $\xi \to 0$,*

$$\mathbb{E}_t \log\left[y_{t+1}\right] = a \cdot \mathbb{E}_t \log\left[x_{1,t+1}\right] + b \cdot \mathbb{E}_t \log\left[x_{2,t+1}\right].$$

Similarly,

$$\mathbb{E}_t \log\left[\frac{y_{t+1}}{y_t}\right] = a \cdot \mathbb{E}_t \log\left[\frac{x_{1,t+1}}{x_{1,t}}\right] + b \cdot \mathbb{E}_t \log\left[\frac{x_{2,t+1}}{x_{2,t}}\right].$$

Theory Results II

- Assume AR(1) log-prices for inputs: $\pi_{i,t+1} = \gamma_i \pi_{i,t} + \epsilon_{i,t+1}$,

  with $0 < \gamma_i < 1$, $\left\{\epsilon_{i,t}\right\}_{t\geq 1} \sim \mathcal{N}\left(0, \sigma_i^2\right)$ for $i = 1, 2$, and $\left\{\epsilon_{1,t}\right\}_{t\geq 1} \perp \left\{\epsilon_{2,t}\right\}_{t\geq 1}$.

Proposition 2 (C-Statistics). *If $\xi \to 0$, under the null of coherence:*

$$\text{C1-stat} \equiv \frac{\frac{\mathbb{E}_t \log y_{t+1} - a\mathbb{E}_t \log x_{1,t+1}}{b} - \log \frac{b}{a+b} Z}{\gamma_2 \sigma_2} \sim \mathcal{N}(0,1)$$

and

$$\text{C2-stat} \equiv \frac{\mathbb{FE}_t \log y_{t+1} - a\mathbb{FE}_t \log x_{1,t+1}}{b\sigma_2} \sim \mathcal{N}\left(0,1\right),$$

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- Intuition: Under the null, FEs of output and input "not far" from each other.
  - Should hold beyond Cobb-Douglas. Cobb-Douglas gives a specific form, while requiring FEs for only $(n-1)$ inputs.

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  with $0 < \gamma_i < 1$, $\{\epsilon_{i,t}\}_{t\geq 1} \sim \mathcal{N}\left(0, \sigma_i^2\right)$ for $i = 1, 2$, and $\{\epsilon_{1,t}\}_{t\geq 1} \perp \{\epsilon_{2,t}\}_{t\geq 1}$.

Proposition 2 (C-Statistics). *If $\xi \to 0$, under the null of coherence:*

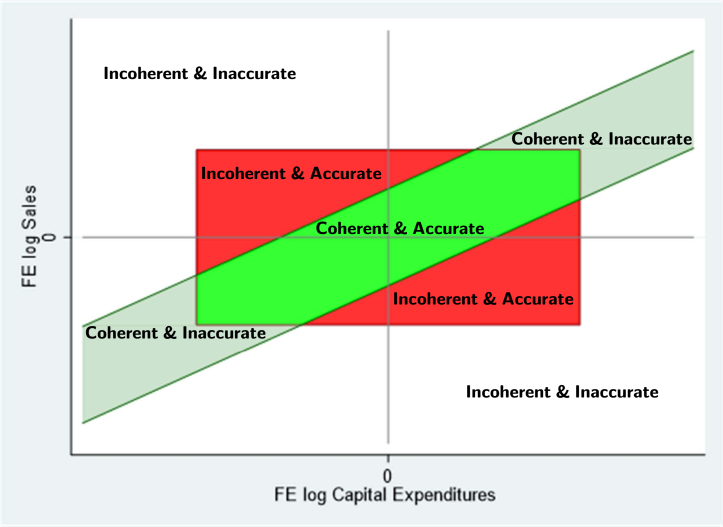
$$\text{C1-stat} \equiv \frac{\frac{\mathbb{E}_t \log y_{t+1} - a\mathbb{E}_t \log x_{1,t+1}}{b} - \log \frac{b}{a+b} Z}{\gamma_2 \sigma_2} \sim \mathcal{N}(0,1)$$

and

$$\text{C2-stat} \equiv \frac{\mathbb{FE}_t \log y_{t+1} - a\mathbb{FE}_t \log x_{1,t+1}}{b\sigma_2} \sim \mathcal{N}\left(0,1\right),$$

- Intuition: Under the null, FEs of output and input “not far” from each other.
  - Should hold beyond Cobb-Douglas. Cobb-Douglas gives a specific form, while requiring FEs for only $(n-1)$ inputs.
- *VS* Accuracy: $\mathbb{FE}_t \log x_{t+1}/\sigma \sim \mathcal{N}\left(0, \sigma^2\right)$ (for generic x).

(In)Coherence and (In)Accuracy



Some Notes

- Prop1 *VS* Prop2: P1 is more general (under CES) than P2 (under Cobb Douglas), but P2 does not require forecasts or FEs for the second input x_2.
  - P2 convenient in our application as 90% of obs on wages missing in Compustat.
- C1 *VS* C2: C1 requires Z, but not realizations. C2 requires realizations (for FEs), but not Z.
  - C2 convenient in our application as Z hardly measurable.
- Unknown params: If a, b unknown, the forecaster can estimate them using linear projections (in Proposition 3 and its corollaries).
- Ranking of RoT: Prop 3 and its corollaries imply that a version of (R5) is 1st-best optimal, and that (R5) $\succeq$ (R3)-(R4) $\succeq$ (R1)-(R2).

Roadmap

A Model of Narrow Thinking in Firm Forecasts

- In reality, CFO may be better informed about capital than labor, or viceversa; about physical than intangible assets, or vicecersa; etc.
  - Forecasts maybe in between broad bracketing and narrow bracketing.
  - Narrow bracketing could be 2nd-best optimal (i.e., under imperfect info).
- To capture these possibilities, we introduce noisy signals following Lian (2021), and recast the forecasting problem as multiple selves playing an incomplete info, common interest game.
  - "CFO K-self" forecasts K growth by observing imprecise signals of Y and L growth.
  - "CFO L-self" forecasts L growth by observing imprecise signals of Y and K growth.
- In equilibrium, each self's forecast is made with imperfect knowledge of other selves' forecasts (signals, states of mind).
  - **Narrow thinking in forecasting of related variables as intra-personal frictions in coordinating multiple forecasts**.

Noisy Signals and Optimal Forecast

- Consider a CFO forecasting input 1 ($i = 1$), $\log x_1$, by $\min_{F \log x_1} \mathbb{E}\left(\log x_1 - F \log x_1\right)^2$,

  where t dropped (by stationarity), $y = x_1^a x_2^b$, and $p_1 x_1 + p_2 x_2 = Z$.

- Assume the CFO observes noisy signals for y and x_2 (i.e., $\neg i = 2$), $\eta_y = \log y + \epsilon_y$ and $\eta_2 = \log x_2 + \epsilon_2$, where $\epsilon_y \sim \mathcal{N}\left(\mu_y, s_y^2\right)$ and $\epsilon_2 \sim \mathcal{N}\left(\mu_2, s_2^2\right)$.

Proposition 4. *The optimal forecast of* $\log x_1$ *given* η_y *and* η_2 *is*

$$\mathbb{E}\left[\log x_1 | \eta_y, \eta_2\right] = \mu_1 + \beta_y\left(\eta_y - \mu_y\right) + \beta_2\left(\eta_2 - \mu_2\right),$$

where

$$\beta_y = \frac{a\sigma_1^2}{a^2\sigma_1^2 + b^2\sigma_2^2 + s_y^2 - \frac{b^2\sigma_2^4}{\sigma_2^2 + s_2^2}}; \beta_2 = \frac{ab\sigma_1^2\sigma_2^2}{b^2\sigma_2^4 - \left(\sigma_2^2 + s_2^2\right)\left(a^2\sigma_1^2 + b^2\sigma_2^2 + s_y^2\right)}.$$

- Optimal forecast for "x_1" is a linear projection of (deviations of signals from prior means of) "y" and "x_2", where intercept is prior mean for "x_1" and slopes are fns of fundamental uncertainty and precision of signals $\Longrightarrow$ rationalizes (R5).

Rationalizing (R1) and (R3)-(R4)

Corollary 6 (Narrow Bracketing). *When $s_y^2, s_2^2 \to +\infty$, the optimal forecast is*

$$\mathbb{E}\left[\log x_1 | \eta_y, \eta_2\right] = \mu_1.$$

$\implies$ (R1) is 2nd-best optimal when both signals are infinitely noisy.

Corollary 7 (Univariate Projections). *When $s_2^2 \to +\infty$ and $0 < s_y^2 < +\infty$, the optimal forecast is*

$$\mathbb{E}\left[\log x_1 | \eta_y, \eta_2\right] = \mu_1 + \beta_y \left(\eta_y - \mu_y\right),$$

where

$$\beta_y = \frac{a\sigma_1^2}{a^2\sigma_1^2 + b^2\sigma_2^2 + s_y^2}.$$

$\implies$ (R3)-(R4) 2nd-best optimal when other input's signal is infinitely noisy and output's signal is noisy but informative.

Taking Stock

- RoT Ranking: Model yields a partial ranking of RoT,

$$(R5) \succeq (R3)\text{-}(R4) \succeq (R1)\text{-}(R2),$$

  where:

  (R5) is the ex ante optimal multivariate rule;
  (R1) is the narrow bracketing rule, most distant from (R5);
  (R2) uses info on output, but suboptimally;
  (R3) and (R4) are the univariate rules, lying between (R1) and (R5).

- (R3) *VS* (R4):
  - Parameters may be industry-specific $(a_j, b_j) \Longrightarrow$ (R4).
  - Using industry-specific sub-samples may reduce precision $\Longrightarrow$ (R3).

- Prediction: If incoherence implies a suboptimal mix of inputs in production, firm's profits will decrease with extent of deviation from optimal forecast.

- Mechanism: Narrow thinking may generate incoherence via use of suboptimal rules of thumb.

Roadmap

First, We Implement the Inequality of Prop 1 ($\leq$ Case)

▸ Implementation

	$\chi = 0.5$	$\chi = 0.7$	$\chi = 0.9$
Inequality in Levels			
% Incoherent	100.00	100.00	99.07
% Coherent	0.00	0.00	0.93
% Total	100.00	100.00	100.00
N Obs	107	107	107
Inequality in Growth Rates			
% Incoherent	73.31	73.14	72.96
% Coherent	26.69	26.86	27.04
% Total	100.00	100.00	100.00
N Obs	577	577	577

- Most CFOs violate the inequality, as they forecast higher sales growth than implied by feeding into the CES their capital and labor growth forecasts.
- Extent of violations is heterogeneous. (Different conditions? Uncertainty?)
- $\chi \to 1$ gives CFOs a better chance to coherence? (MBA teaching examples are about Cobb-Douglas.)

Next, the Coherence and Accuracy Stats of Prop 2

Implementation Bootstrap

Panel A – % **Rejections** *of Null HP Across CFOs*

Confidence $(1-\alpha)$	Coherence Sales-CapEx	Accuracy Sales	Accuracy CapEx	Accuracy Both
	(1)	(2)	(3)	(4)
95%	55.7%	27.2%	47.9%	57.0%
99%	7.7%	1.8%	6.4%	7.1%

Panel B – % **Coherence-Accuracy Combinations** *Across CFOs*

Confidence $(1-\alpha)$	Coherent & Accurate	Coherent & Inaccurate	Incoherent & Accurate	Incoherent & Inaccurate
	(1)	(2)	(3)	(4)
95%	31.1%	13.2%	12.0%	43.7%
99%	89.4%	2.9%	3.4%	4.3%

Roadmap

We Implement (R1)-(R5) Following Welch (2017)

- We focus on forecasts about output (Sale Revs) and capital input (CapEx), as they have a clear mapping with theory and high coverage in Compustat.

(R1) **Plain growth**: Avg of two most recent annual growth rates of each item.

(R2) **Proportion of sales**: BLP under square loss of Sales Growth given CapEx Growth, with zero const and unit slope.

(R3) **Economies-of-scale**: BLP under square loss of Sales Growth given CapEx Growth, estimated with all Compustat firms.

(R4) **Industry-based**: Like (R3), but by industry. We do it for 9 sectors, based on SIC 1-digit codes.

(R5) **Disaggregated**: Would like BLP under square loss of Sales Growth given CapEx Growth & Labor Cost Growth. In practice:

  - *Main version*: Sales Growth on CapEx Growth & Earnings Growth.
  - *App version*: Sales Growth on CapEx Growth & Advertising Expend Growth.

Min Dist of CFO Forecasts from RoT ⇒ CFO 'Type'

- For each CFO, we determine a 'type' in two steps:

  1. Compute orthogonal distance between CFO's actual forecast (of CapEx) and that implied by each of the five RoT.

  2. Compute min distance among those five $\Longrightarrow$ CFO's 'type' is RoT to which CFO's forecast is closest.

	All	R1	R2	R3	R4	R5
Mean	0.033	0.058	0.030	0.019	0.031	0.043
Std Dev	0.059	0.100	0.064	0.017	0.035	0.069
Frac Zeros	0.106	0.000	**0.268**	0.000	0.000	0.000
P10	0.000	0.008	0.000	0.005	0.002	0.003
P25	0.007	0.015	0.000	0.006	0.007	0.008
P50	0.019	0.028	0.014	0.010	0.023	0.023
P75	0.036	0.064	0.035	0.028	0.048	0.043
P90	0.071	0.114	0.071	0.048	0.072	0.089
P95	0.106	0.143	0.106	0.048	0.100	0.140
N Obs	396	30	157	43	107	59
Fraction	1.000	**0.076**	**0.396**	**0.109**	**0.270**	**0.149**

$\Longrightarrow$ ∼40% of CFOs give a forecast closest to that implied by (R2); ∼27% exactly (R2).

$\Longrightarrow$ ∼8% of CFOs give a forecast closest to that implied by (R1), i.e., are 'narrow bracketers'.

$\Longrightarrow$ ∼15% of CFOs give a forecast closest to that implied by (R5), i.e., are 'broad bracketers'.

Ex Ante *VS* Ex Post Incoherence

- **Ex Ante Incoherence:** Orthogonal distance between actual forecast and (R5),

$$\text{Incoherence}_{i,t} = \frac{\left| F_{i,t}\left[y_{i,t+1}\right] - \widehat{\beta_1} F_{i,t}\left[x_{1i,t+1}\right] - \widehat{\beta_2} F_{i,t}\left[x_{2i,t+1}\right] - \widehat{\beta_0} \right|}{\sqrt{1^2 + \widehat{\beta_1}^2 + \widehat{\beta_2}^2}},$$

  where $\widehat{\beta_0}$, $\widehat{\beta_1}$, $\widehat{\beta_2}$ are estimated coeffs of (R5), using Compustat data and alternative measures for $x_{2i,t}$:

  - Earnings Growth (here);
  - Advertisement Growth (appendix);
  - Wages Growth (too few obs).

- **Validation:** Ex ante incoherence measure predicts ex post C2 stat:

$$\widehat{|C2|} = \underset{(0.022)}{0.229} + \underset{(0.197)}{0.629} \cdot \text{Incoherence},$$

  where SEs are in parentheses under the point estimates.

- **Incoherence by personal CFO characteristics:** Regs

Incoherence and CFO Type (RoT)

- The model predicts (R5) $\succeq$ (R3)-(R4) $\succeq$ (R1)-(R2).
- We regress Ex Ante Incoherence on CFO Type dummies (for CapEx), where (R5) is used as a reference group.

	(1)	(2)	(3)	(4)	(5)
Rule 1 (CapEx)	0.081				0.104
	(0.014)				(0.016)
Rule 2 (CapEx)		0.039			0.053
		(0.008)			(0.011)
Rule 3 (CapEx)			-0.055		-0.020
			(0.012)		(0.014)
Rule 4 (CapEx)				-0.027	0.010
				(0.009)	(0.012)
Constant	0.066	0.057	0.079	0.080	0.043
	(0.004)	(0.005)	(0.004)	(0.005)	(0.009)
N Obs	396	396	396	396	396

$\Longrightarrow$ (R1) & (R2) CFOs have largest Ex Ante Incoherence relative to (R5) CFOs.

Roadmap

Data Essentials and Motivating Evidence

Theory

- Normative Benchmark of Ex Ante Optimal Coherent Forecast
- Positive Model of Narrow Thinking in Corporate Forecast

▶ Empirical Analysis

- Conditions and Tests of Coherence
- Incoherence and RoT
- Incoherence, RoT, and Corporate Performance
- Incoherence, RoT, and Corporate Policies

CFO Incoherence – or Type (RoT) – and Firm Outcomes

- We investigate relationship between firm's outcomes and CFO's incoherence by:

$$\text{Outcome}_{ijt} = \alpha + \lambda_j + \delta_t + \beta \cdot \text{Incoherence}_{ijt} \left[\text{or RoT}_{ijt}\right] + \theta \cdot X_{ijt} + \varepsilon_{ijt},$$

  where i is CFO-firm pair, j is industry, and t is time.

- Outcome_{ijt} is alternatively:
  i. ROA = percent return on firm's assets.
     - If incoherence implies suboptimal inputs mix, expect $\beta < 0$ for incoherence, and also for types (R1), (R2), (R3) relative to (R5).

  ii. I/A = capital expenditures divided by assets.
     - If incoherent CFOs invest less than required to achieve planned output growth, expect $\beta < 0$ for incoherence / suboptimal RoT.

  iii. D/A = LT book debt divided by assets.

- X_{ijt} includes:
  - CFO-level variables: Short-term and long-term miscalibration and optimism from Ben-David et al. (2013).
  - Firm-level variables: Firm size, market-to-book, dividends.

Ex Ante Incoherence and Firm Performance (ROA)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Incoherence	-0.377	-0.378	-0.360	-0.396	-0.399	-0.386	-0.317	-0.307
	(0.157)	(0.179)	(0.162)	(0.162)	(0.186)	(0.169)	(0.192)	(0.181)
Misc ST		0.003			0.001		-0.001	
		(0.005)			(0.005)		(0.004)	
Optm ST		0.000			0.000		0.001	
		(0.006)			(0.006)		(0.005)	
Misc LT			0.004			0.002		0.001
			(0.005)			(0.005)		(0.005)
Optm LT			0.008			0.007		0.009
			(0.006)			(0.006)		(0.006)
Firm size							0.009	0.009
							(0.003)	(0.003)
Mkt-to-Book							0.028	0.027
							(0.014)	(0.015)
Dividends							0.022	0.023
							(0.012)	(0.013)
Const	0.069	0.069	0.068	0.054	0.056	0.057	-0.131	-0.123
	(0.011)	(0.011)	(0.011)	(0.014)	(0.020)	(0.019)	(0.047)	(0.0471)
Industry FE	N	N	N	Y	Y	Y	Y	Y
Survey FE	N	N	N	Y	Y	Y	Y	Y
N Obs	468	423	428	468	423	428	396	401

CFO Type (RoT) and Firm Performance (ROA)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rule 1	-0.057	-0.061	-0.059	-0.051	-0.059	-0.055	-0.053	-0.051
	(0.022)	(0.025)	(0.024)	(0.023)	(0.025)	(0.025)	(0.026)	(0.025)
Rule 2	-0.026	-0.027	-0.023	-0.023	-0.028	-0.024	-0.034	-0.031
	(0.014)	(0.015)	(0.015)	(0.015)	(0.017)	(0.016)	(0.021)	(0.019)
Rule 3	-0.031	-0.036	-0.034	-0.027	-0.037	-0.034	-0.047	-0.045
	(0.017)	(0.019)	(0.019)	(0.019)	(0.020)	(0.021)	(0.023)	(0.022)
Rule 4	-0.012	-0.010	-0.010	-0.008	-0.008	-0.007	-0.012	-0.011
	(0.012)	(0.014)	(0.014)	(0.013)	(0.014)	(0.015)	(0.015)	(0.015)
Misc ST		0.001			-0.001		-0.002	
		(0.005)			(0.005)		(0.004)	
Optm ST		0.001			0.000		0.001	
		(0.006)			(0.005)		(0.005)	
Misc LT			0.003			0.002		0.001
			(0.006)			(0.005)		(0.004)
Optm LT			0.007			0.006		0.008
			(0.006)			(0.006)		(0.005)
Firm characts	N	N	N	N	N	N	Y	Y
Industry FE	N	N	N	Y	Y	Y	Y	Y
Survey FE	N	N	N	Y	Y	Y	Y	Y
N Obs	468	423	428	468	423	428	396	401

CFO Type (RoT) and Corporate Policies

	Investment			Leverage		
	(1)	(2)	(3)	(4)	(5)	(6)
Rule 1	-0.016	-0.014	-0.015	0.055	0.041	0.047
	(0.011)	(0.011)	(0.012)	(0.092)	(0.101)	(0.092)
Rule 2	-0.013	-0.015	-0.012	0.093	0.098	0.092
	(0.006)	(0.007)	(0.008)	(0.053)	(0.060)	(0.053)
Rule 3	-0.007	-0.011	-0.010	-0.023	-0.015	-0.027
	(0.008)	(0.010)	(0.010)	(0.073)	(0.091)	(0.084)
Rule 4	-0.003	-0.003	-0.003	-0.004	0.005	0.001
	(0.007)	(0.008)	(0.008)	(0.045)	(0.050)	(0.046)
Misc ST		0.001			0.012	
		(0.003)			(0.024)	
Optm ST		0.002			-0.006	
		(0.003)			(0.019)	
Misc LT			0.002			0.013
			(0.002)			(0.018)
Optm LT			0.004			-0.010
			(0.002)			(0.017)
Firm characts	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y
Survey FE	Y	Y	Y	Y	Y	Y
N Obs	437	397	402	437	397	402

Conclusion

- We develop a theory of forecast coherence in production, which yields conditions (tests) of forecast coherence.
- Large fractions of CFOs taking the Duke Survey report seemingly incoherent forecasts of output and input growth, but empirical implementation is not straightforward.
- The baseline model provides a benchmark of an ex ante coherent forecast that is 1st-best optimal. When CFOs observe noisy signals about output/inputs, some RoT emerge as 2nd-best optimal. E.g., the "narrow-bracketing rule" (R1) is 2nd-best optimal when signals of output and other input are infinitely noisy.
- The model implies a partial ranking of the managerial RoT, and predictions on firm outcomes.
- Consistent with the model, in the data we find:
    1. forecasts implied by the narrow-bracketing rule (R1) are most distant from those implied by the (R5) benchmark;
    2. firm performance correlates negatively with ex ante incoherence, and is lowest for CFOs giving forecasts closest to (R1) or (R2).
- Firms whose CFOs give forecasts closest to (R1) or (R2) have lower investment (CapEx) and higher leverage on average.

Thank You!

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Duke-Compustat Matching

Bck

- **Duke-Compustat matching** is done via firm ID and has 4 main sources of **attrition**:

  (1) Due to privacy restrictions, not all Duke Rs report their firm ID needed for matching.

  (2) Not all Duke Rs give forecasts on all variables.

  $\Longrightarrow$ **Likely selection, potentially positive**.

  (3) Some variables forecasted in Duke do not have precise counterparts in Compustat: technology spending, outsourced employees, health spending, productivity, product prices, and share repurchases.

  (4) Among variables with precise counterparts, a few important ones don't have full coverage in Compustat: wages (about 90% missing), R&D expenditures, and advertising expenditures.

  $\Longrightarrow$ (-) **Analysis involving forecast errors (FE) limited to variables with full coverage in both datasets**.

  $\Longrightarrow$ (+) **Main coherence restriction (statistic) will not require FEs on all variables**.

- Matched sample mostly refers to early period (until 2011q4).

  $\Longrightarrow$ Empirical analysis will focus on **pre-financial crisis period**, consistent with stability assumption of model.

Implementing Inequality of Prop 1 Bck

- We begin with the relevant inequality from Proposition 1 (concave case):

$$\begin{aligned}\mathbb{E}_t\left[y_{t+1}\right] &\leq f\left(\mathbb{E}_t\left[x_{1,t+1}\right], \mathbb{E}_t\left[x_{2,t+1}\right]\right) \\ &\leq \left(\frac{a}{a+b}\mathbb{E}_t\left[x_{1,t+1}\right]^{\xi} + \frac{b}{a+b}\mathbb{E}_t\left[x_{2,t+1}\right]^{\xi}\right)^{\frac{a+b}{\xi}} .\end{aligned}$$

- We implement it both in levels and in growth rates.
  - We observe CFO forecasts of growth rates, not of levels. We back out the latter as $\mathbb{E}_t\left[x_{i,t+1}\right] = x_{i,t} \cdot \mathbb{E}_t\left[\frac{x_{i,t+1}}{x_{i,t}}\right]$ for $i = 1, 2$.
  - As most realizations on labor expenditures (i.e., $x_{2,t}$) are missing in Compustat, we end with fewer observations in levels than in growth rates.

- We compute industry-level a_j and b_j, using data on the universe of industries from the Bureau of Economic Analysis.

- We present results for $\chi = 0.5, 0.7, 0.9$, informed by the macro/IO literature (e.g., Berndt (1976), Oberfield and Raval (2021), and others).

Implementing Coherence and Accuracy Stats of Prop 2

Bck

- We proceed with the coherence statistic based on FEs:

$$\text{C2-stat} \equiv \frac{\mathbb{FE}_t \log y_{t+1} - a\mathbb{FE}_t \log x_{1,t+1}}{\sigma_2 b} \sim \mathcal{N}(0,1),$$

and the accuracy statistics for output (i.e., Sales) and input 1 (i.e., CapEx):

$$\text{Accu-Y} \equiv \frac{\mathbb{FE}_t \log y_{t+1}}{\sigma_y} \sim \mathcal{N}(0,1)$$

and

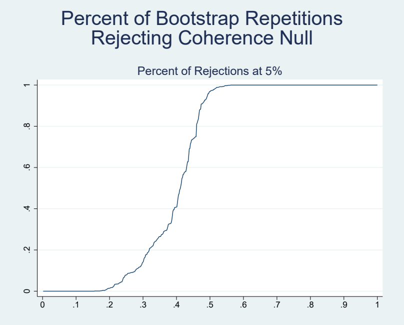
$$\text{Accu-X}_1 \equiv \frac{\mathbb{FE}_t \log x_{1,t+1}}{\sigma_1} \sim \mathcal{N}(0,1).$$

- They cannot be implemented directly using survey forecasts (not about log-variables). So, we use $\mathbb{E}_t \log x_{t+1} = \log \mathbb{E}_t x_{t+1} - \frac{1}{2} V_t \log x_{t+1}$ (for generic x) and relationships between cond and uncond variance for capital input and output (recall AR(1) log-prices for inputs).
- With estimated parameters (a, b, σ's), $\sim$ Student t (with 1 dof).

Bootstrapped C2

Bck

- To account for estimation uncertainty, we obtain bootstrap estimates of C2 (1,000 repetitions per CFO).
- For each CFO, we compute the fraction of bootstrap repetitions for which the coherence null is rejected at 95% and 99% CL. This stat ranges between 0 and 1.
- We plot this stat (on the y-axis) against its empirical cdf (on the x-axis). Here shown for the 95% CL case.
- For $\sim$15% of CFOs, the null is never rejected. For $\sim$40% of CFOs, the null is always rejected. For $\sim$45% of CFOs, the fraction of rejections across bootstrap reps is strictly between 0 and 1.
- The null is rejected more than 1/2 of the times for $\sim$55% of CFOs.



Ex Ante Incoherence and Personal CFO Characteristics

Bck

	(1)	(2)	(3)	(4)	(5)	(6)
CFO has MBA	0.004			0.005		
	(0.009)			(0.009)		
Age 40-		-0.011		-0.011		
		(0.022)		(0.022)		
Age 41-50		-0.026		-0.027		
		(0.015)		(0.016)		
Age 51-60		-0.024		-0.024		
		(0.017)		(0.017)		
Gender			-0.000	0.002		
			(0.011)	(0.010)		
Miscalibration ST					-0.012	
					(0.008)	
Optimism ST					-0.012	
					(0.007)	
Miscalibration LT						-0.005
						(0.004)
Optimism LT						0.001
						(0.004)
Constant	0.050	0.078	0.053	0.075	0.052	0.046
	(0.021)	(0.025)	(0.019)	(0.026)	(0.027)	(0.021)
Industry FE	Y	Y	Y	Y	Y	Y
Survey FE	Y	Y	Y	Y	Y	Y
N Obs	396	396	396	396	360	362

Note: CFOs' characteristics: 45% with MBA; mean age 50.4; 9% female; on the job 4.3y.