Information Distortion, R&D, and Growth

Stephen J. Terry
Boston University

Toni M. Whited
Michigan Ross

Anastasia A. Zakolyukina
Chicago Booth
Managers continually report information while investing
Under high pressure from options compensation and elsewhere to manipulate reported profits in order to exploit asymmetric information

Misreporting profits vs messing with investment
If both forms of manipulation are costly at the margin, will engage in both activities, linking investment choices to the cost of misreporting.

After crises and scandals, a crackdown on misreporting occurred
Sarbanes-Oxley & Dodd Frank tightened regulation of information financial reporting considerably, with a stated goal of improving investor welfare.

Our question in this paper
Given manager incentives, is there a quantitatively meaningful tradeoff between the quality of reported information and the efficiency of investment?
# What We Do in This Paper

#1 Provide some context on manipulation  
Discussion of profit manipulation via accruals or intangible investment in practice plus an overview of US policy shifts

#2 Build a dynamic model of investment & distortion  
PE firm growth via R&D, firm-level profitability shocks, intermittent manipulation detection, manager option compensation, rational pricing with asymmetric info

#3 Exploit data on restatements to estimate the model  
Approach: SMM from data on restatements, exec comp, R&D  
Result: Satisfactory fit, match to untargeted R&D dynamics

#4 Quantify the information-investment tradeoff  
Managers bias profits + R&D jointly to distort short-term profits. Eliminating bias increases R&D vol. by 10%, reduces value by 0.5%.
Some context for profit manipulation

A model of information vs investment

Exploiting restatements to estimate the model

The quantitative tradeoff of information vs investment
What are Earnings, and How Can They Be Manipulated?

Earnings, profits, or net income, are a short-term measure meant to be more informative than cash flows. The basic idea is

\[ \text{Earnings} \approx \text{Sales} - \text{Expenses} - \text{Investment} \]

**Timing and accruals manipulation**
Accounting matches the timing of outflows and inflows. Discretion over the time of recognition for sales or expenses through “accruals” arises.

**Manipulation of long-term investment**
Tangible investment is depreciated (think “\( Y - WL - \delta K \)”), but R&D and intangible investments are expensed (think “\( Y - WL - I \)”). Long-term investment cuts lead directly to higher profits today.

**SEC regulation, investigations, and penalties**
The SEC regulates disclosure by public firms in the US according to “generally accepted accounting principles” (GAAP) and can impose penalties.
Some Practical Examples from SEC Investigations

Cardinal Health, Inc (pharmaceutical distributor, 2007 detection)

▶ “The Commission’s complaint alleges that, from September 2000 through March 2004, Cardinal engaged in this conduct in order to present a false picture of its operating results to the financial community and the investing public…”
▶ Premature recognition of $133 million in invoices to inflate sales, overestimation of inventory, penalties of around $36 million

Aspen Technology, Inc (software manufacturer, 2007 detection)

▶ “The SEC’s order finds that Aspen’s former senior management, motivated by a desire to boost revenues and meet securities analyst earnings expectations, was directly involved in negotiating and improperly recognizing revenue on transactions…”
▶ Premature recognition of 19 contracts which were not yet signed, no penalties

Point Blank Solutions, Inc (body armor manufacturer, 2011 detection)

▶ “The company overstated inventory values, failed to include appropriate charges for obsolete inventory, and falsified journal entries.”
▶ Inflated profits and fraudulent expense reports, criminal charges filed
US Disclosure Regulation Has Become Increasingly Strict

Sarbanes-Oxley Act (SOX, 2002)
After the dot-com crash and some famous scandals, SOX introduced changes such as direct manager certification of financial statements and internal control mechanisms, increased SEC enforcement power, etc...

Dodd Frank Act (DFA, 2010)
After the financial crisis, DFA introduced some more moderate changes such as more whistleblower protections

Explicitly stated goal of improving information on behalf of investors
“The overarching goals of the Act [SOX] are far-reaching and include restoring investor confidence and assuring the integrity of our markets…” (SEC Chair Donaldson, 2003)
Roadmap

Some context for profit manipulation

A model of information vs investment

Exploiting restatements to estimate the model

The quantitative tradeoff of information vs investment
Here’s the Model in Words

Piece 1: Real firm-level model of R&D and growth

▶ Firms face persistent, stationary fundamental shocks
▶ R&D drives growth through endogenous intangible quality
▶ Stationary in growth rates or ratios but not levels

Piece 2: Accounting and information

▶ Profits reflect real side + nonfundamental noise + intentional bias
▶ Investors rationally price firms with less information than managers
▶ Any nonzero bias is discovered with some probability each period

Piece 3: Manager incentives and decisions

▶ Managers are compensated with equity as well as options
▶ Suffer personal costs if bias is detected
▶ Determine all investment and bias choices

PE model with no labor, fixed interest rates, but rational pricing is a key fixed point imposing substantial discipline.
Firm-Level Fundamentals

A model with an infinitely lived firm in discrete time

**Sales** $Y$ **depend on shock** $\nu_y$ **and quality** $Q$

$$\log \nu_y' = \rho \log \nu_y + \eta_y', \quad \eta_y' \sim N(0, \sigma_y^2)$$

$$Y = \nu_y Q$$

**Endogenous quality** $Q$ **grows via R&D** $W$

$$\Delta Q' = Q' - Q = \xi W^\gamma Q^{1-\gamma}$$

**Dividends or free cash flows**

$$D = Y - p_w W$$
Profits and Information

Profits $\Pi$ deviate from fundamentals for two reasons

$$\Pi = Y - p_w W + \nu_\pi Q + (B - B_{-1})$$

Reason 1: noise $\nu_\pi$ in profits hits firms each period

$$\nu_\pi Q, \quad \nu_\pi \sim N(0, \sigma^2_\pi)$$

Reason 2: intentional shifts in bias $B$

$$B - B_{-1}$$

Rational price $P$ for the firm based on investor information $\mathcal{I}$

$$P(\mathcal{I}) = \mathbb{E} \left( \frac{1}{1 + r V'_F |\mathcal{I}} \right), \quad \Pi \in \mathcal{I}$$
Manager Incentives in the Model

Infinitely lived risk-neutral managers choose R&D and manipulation

Exogenous equity and options compensation

\[ D_M = \theta_d D + \theta_o \max \{ P - P_{-1}, 0 \} \]

Random detection of any bias \( B \neq 0 \) occurs with fixed probability

\[ \mathbb{P}(\text{Detection}|B \neq 0) = \lambda \]

If misreporting is discovered, managers face nonpecuniary costs

\[ MC(B, Q) = \left[ \kappa_f + \kappa_q \left( \frac{B}{Q} \right)^2 \right] Q \]
Firm & Manager Value

Manager optimization determines firm policies and value $V_M$

$$V_M(\nu_y, \nu_\pi, P_{-1}, B_{-1}, Q) =$$

$$\max_{W,B} \left\{ \begin{array}{l}
\mathbb{I}(B = 0) \left( D_M + \frac{1}{1+r} \mathbb{E}V_M(\nu'_y, \nu'_\pi, P, 0, Q') \right) \\
+ \mathbb{I}(B \neq 0)(1 - \lambda) \left( D_M + \frac{1}{1+r} \mathbb{E}V_M(\nu'_y, \nu'_\pi, P, B, Q') \right) \\
+ \mathbb{I}(B \neq 0)\lambda \left( D_M |_{B=0} - MC + \frac{1}{1+r} \mathbb{E}V_M(\nu'_y, \nu'_\pi, P |_{B=0}, 0, Q') \right) \\
\end{array} \right\}$$

Fundamental firm value $V_F$ is implied

$$V_F(\nu_y, \nu_\pi, P_{-1}, B_{-1}, Q) =$$

$$\left\{ \begin{array}{l}
\mathbb{I}(B^* = 0) \left( D^* + \frac{1}{1+r} \mathbb{E}V_F(\nu'_y, \nu'_\pi, P, 0, Q') \right) \\
+ \mathbb{I}(B^* \neq 0)(1 - \lambda) \left( D^* + \frac{1}{1+r} \mathbb{E}V_F(\nu'_y, \nu'_\pi, P, B^*, Q') \right) \\
+ \mathbb{I}(B^* \neq 0)\lambda \left( D^* + \frac{1}{1+r} \mathbb{E}V_F(\nu'_y, \nu'_\pi, P |_{B=0}, 0, Q') \right) \\
\end{array} \right\}$$

Nested value maximization

If no options compensation or costs of misreporting, then managers will choose value-maximizing investment
Scaling and Solving the Model

The model is nonstationary. We exploit homogeneity by rescaling all growing quantities by the endogenous quality $Q$, yielding lowercase variables.

$$V_M(\nu_y, \nu_\pi, P_{-1}, B_{-1}, Q) = Qv_M(\nu_y, \nu_\pi, p_{-1}, b_{-1})$$

Implement rational pricing using a polynomial rule with $\mathcal{I} = \Pi$

$$\hat{P}(\Pi) \approx \mathbb{E}\left( \frac{1}{1 + r} V'_F | \Pi \right)$$

Numerically solve the model with an iterative approach, akin to Krusell-Smith solution approach

1. Guess pricing rule coefficients
2. Solve for manager policies using discretization + policy iteration
3. Compute firm value implied by manager policies
4. Update pricing rule using the model’s ergodic distribution

When the pricing rule converges, the model is solved
Some context for profit manipulation

A model of information vs investment

Exploiting restatements to estimate the model

The quantitative tradeoff of information vs investment
We Use Three Sources of Data on US Public Firms

Audit Analytics data on restatements, bias
Focus on revenue restatements in the data related to SEC bulletin No. 101, considered serious by practitioners

Equilar data on executive compensation
Essentially the universe of US public firms, far broader than Execucomp

Compustat data on investment, free cash flow
Standard data on income statements and balance sheets for US firms

Our resulting panel dataset
Spans post-SOX pre-DFA period 2002-2009, with around 5K firms for about 25K firm-years. Includes earnings, free cash flow, intangible investment (SG&A or R&D), and restatements with bias amounts.
# Estimating the Model via SMM

We estimate 10 parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>Explanation</th>
<th>Name</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\xi$</td>
<td>Growth level</td>
<td>$\kappa_q$</td>
<td>Manipulation quad. cost</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Growth elasticity</td>
<td>$\kappa_f$</td>
<td>Manipulation fixed cost</td>
</tr>
<tr>
<td>$\rho_y$</td>
<td>Fundamental pers.</td>
<td>$p_w$</td>
<td>R&amp;D relative price</td>
</tr>
<tr>
<td>$\sigma^2_y$</td>
<td>Fundamental vol.</td>
<td>$\lambda$</td>
<td>Detection rate</td>
</tr>
<tr>
<td>$\sigma^2_\pi$</td>
<td>Profit noise vol.</td>
<td>$p_s$</td>
<td>Cash flow reshuffling</td>
</tr>
</tbody>
</table>

In addition, we externally fix the values of $\theta_d$, $\theta_o$, and $r$.

We target 17 moments

<table>
<thead>
<tr>
<th>Name</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mathbb{E}[\Delta_3 Y]$</td>
<td>Mean three-year weighted sales growth rate</td>
</tr>
<tr>
<td>$\mathbb{E}[\frac{W}{Y}]$</td>
<td>Mean ratio of R&amp;D to sales</td>
</tr>
<tr>
<td>$\mathbb{E}[I_d]$</td>
<td>Probability of detection</td>
</tr>
<tr>
<td>$\mathbb{E}[I_r]$</td>
<td>Probability of restatement</td>
</tr>
<tr>
<td>$\mathbb{E}\left(\left</td>
<td>\frac{B}{Y}\right</td>
</tr>
<tr>
<td>$\text{Cov}(\Delta \Pi, \Delta D, \Delta W)$</td>
<td>Cov. of profits, cash flows, R&amp;D growth</td>
</tr>
<tr>
<td>$\text{Cov}(\Delta \Pi, \Delta D, \Delta W \mid I_r)$</td>
<td>Cov. of profits, cash flows, R&amp;D growth upon $I_r$</td>
</tr>
</tbody>
</table>
## Our Model’s Fit

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean three-year weighted sales growth rate</td>
<td>0.1621</td>
<td>0.1067</td>
</tr>
<tr>
<td>Mean ratio of R&amp;D to sales</td>
<td>0.3398</td>
<td>0.3049</td>
</tr>
<tr>
<td>Mean bias to sales ratio, given restatement</td>
<td>0.0137</td>
<td>0.0088</td>
</tr>
<tr>
<td>Probability of detection</td>
<td>0.0141</td>
<td>0.0182</td>
</tr>
<tr>
<td>Probability of restatement</td>
<td>0.0317</td>
<td>0.0239</td>
</tr>
<tr>
<td>Variance of dividend growth</td>
<td>1.3594</td>
<td>1.0984</td>
</tr>
<tr>
<td>Covariance of dividend and earnings growth</td>
<td>0.2903</td>
<td>0.8272</td>
</tr>
<tr>
<td>Covariance of dividend and R&amp;D growth</td>
<td>-0.0107</td>
<td>-0.0230</td>
</tr>
<tr>
<td>Variance of earnings growth</td>
<td>1.1709</td>
<td>1.4193</td>
</tr>
<tr>
<td>Covariance of earnings and R&amp;D growth</td>
<td>-0.0104</td>
<td>-0.0282</td>
</tr>
<tr>
<td>Variance of R&amp;D growth</td>
<td>0.0596</td>
<td>0.0074</td>
</tr>
<tr>
<td>Variance of dividend growth, given restatement</td>
<td>1.5416</td>
<td>0.6695</td>
</tr>
<tr>
<td>Covariance of dividend and earnings growth, given restatement</td>
<td>0.4304</td>
<td>0.6837</td>
</tr>
<tr>
<td>Covariance of dividend and R&amp;D growth, given restatement</td>
<td>-0.0183</td>
<td>-0.1074</td>
</tr>
<tr>
<td>Variance of earnings growth, given restatement</td>
<td>1.4306</td>
<td>0.8171</td>
</tr>
<tr>
<td>Covariance of earnings and R&amp;D growth, given restatement</td>
<td>-0.0282</td>
<td>-0.1263</td>
</tr>
<tr>
<td>Variance of R&amp;D growth, given restatement</td>
<td>0.0743</td>
<td>0.0332</td>
</tr>
</tbody>
</table>
## Our Estimated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\xi$ multiplicative productivity shifter</td>
<td>0.0673</td>
<td>(0.0027)</td>
</tr>
<tr>
<td>$\gamma$ curvature of the innovation production function</td>
<td>0.3782</td>
<td>(0.0148)</td>
</tr>
<tr>
<td>$p_w$ price of R&amp;D relative to output</td>
<td>2.1972</td>
<td>(0.1456)</td>
</tr>
<tr>
<td>$\rho_y$ serial correlation of the persistent productivity shock</td>
<td>0.4938</td>
<td>(0.0202)</td>
</tr>
<tr>
<td>$\sigma_y$ volatility of the persistent productivity shock</td>
<td>0.2861</td>
<td>(0.0242)</td>
</tr>
<tr>
<td>$\sigma_\pi$ volatility of the i.i.d. shock to earnings</td>
<td>0.1824</td>
<td>(0.0067)</td>
</tr>
<tr>
<td>$\kappa_q$ quadratic cost of manipulation</td>
<td>21.3018</td>
<td>(1.9424)</td>
</tr>
<tr>
<td>$\kappa_f$ fixed cost of manipulation</td>
<td>0.001</td>
<td>(0.0006)</td>
</tr>
<tr>
<td>$\lambda$ probability of manipulation detection</td>
<td>0.1478</td>
<td>(0.0261)</td>
</tr>
<tr>
<td>$p_s$ probability of intertemporal earnings reshuffling</td>
<td>0.0207</td>
<td>(0.0057)</td>
</tr>
</tbody>
</table>

Based on Equilar averages, we also fix $\theta_d = 4.9\%$, $\theta_o = 1.1\%$. We choose $r = 6\%$ to reflect a realistic firm discount rate.
Roadmap

Some context for profit manipulation

A model of information vs investment

Exploiting restatements to estimate the model

The quantitative tradeoff of information vs investment
Mean R&D and Bias Choices

Low Profit Shock

High Profit Shock

Bias, % of Mean Sales

Fund. Shock, % from Mean

Investment, % from Mean

Fund. Shock, % from Mean

History Dependence
Plot the coefficients from the panel regression

\[ \log w_{jt} = \sum_{k=-K}^{K} \beta_k \mathbb{I}(\text{Upward Bias Restated})_{jt+k} + f_j + g_t + \varepsilon_{jt} \]
**Counterfactual Experiments**

**We first ask two questions**

- What would happen if misreporting was eliminated?
- What if managers were value maximizing with no options compensation?

Starting from baseline estimates, we examine the change in bias, investment volatility, and value in each case in the model stationary distribution.

<table>
<thead>
<tr>
<th>Percent</th>
<th>Baseline (Estimated)</th>
<th>No Bias ($\kappa_q = \kappa_f = \infty$)</th>
<th>Value Maximizing ($\theta_o = 0$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean bias to sales ratio</td>
<td>2.26</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Std dev. of R&amp;D growth</td>
<td>7.96</td>
<td>8.53</td>
<td>2.06</td>
</tr>
<tr>
<td>Mean $\Delta V_F$</td>
<td>-</td>
<td>-0.45</td>
<td>13.45</td>
</tr>
</tbody>
</table>
In a less extreme experiment, vary misreporting costs $\kappa_q$ over a range of parameterizations.

At estimated parameterization (circled), 1% bias reduction costs about 0.5% increased R&D growth volatility.
What We Do in This Paper

#1 Provide some context on manipulation
Discussion of profit manipulation via accruals or intangible investment in practice plus an overview of US policy shifts

#2 Build a dynamic model of investment & distortion
PE firm growth via R&D, firm-level profitability shocks, intermittent manipulation detection, manager option compensation, rational pricing with asymmetric info

#3 Exploit data on restatements to estimate the model
Approach: SMM from data on restatements, exec comp, R&D
Result: Satisfactory fit, match to untargeted R&D dynamics

#4 Quantify the information-investment tradeoff
Managers bias profits + R&D jointly to distort short-term profits. Eliminating bias increases R&D vol. by 10%, reduces value by 0.5%.
Backup Slides
Our Estimation Approach

Standard SMM objective

- Vector of model parameters $\theta$
- Vector of simulated model moments $m(\theta)$ and data moments $m(X)$
- Minimize weighted deviations of model and data moments

$$\hat{\theta} = \arg \min_{\theta} (m(\theta) - m(X))^\prime W (m(\theta) - m(X))$$

Implementation
We use an estimate of the efficient weighting matrix $W = Cov(m(X))^{-1}$, and we minimize the objective use particle swarm optimization. The standard errors follow the usual SMM formulas.
How Does Identification Work?

This is a joint and not one-to-one mapping, but some moments are particularly influential for some parameters.

**Fundamental parameters are familiar**

- Covariances and variances inform shock processes $\rho_y, \sigma_y^2, \sigma_\pi^2$
- Mean ratios, growth rates, and covariances inform relative price and quality growth parameters $p_w, \gamma, \xi$

**Detection and misreporting parameters are less familiar**

- Mean bias magnitude informs quadratic cost $\kappa_q$
- Covariances given restatement inform fixed cost $\kappa_f$
- Detection probability informs $\lambda$
- $\text{Cov}(\Delta \Pi, \Delta D)$ informs reshuffling in free cash flows $p_s$
History-Dependent R&D and Bias

![Graphs showing history-dependent R&D and bias](image-url)
Why Should We Care?

A meaningful quantitative tradeoff between info distortion and investment efficiency matters for at least two reasons.

**Reason 1: An equilibrium constraint on policy**
Given pervasive short-term options compensation, increasing info accuracy may lower average real efficiency.

**Reason 2: A new source of misallocation**
Executive incentives and info regulation generate misallocation of investment, in the same manner as financial frictions, adjustment costs, taxation, etc.
Related Strands of Literature

Quantitative investment frictions for firms and managers

Manipulation of profits with real activities or accruals

Endogenous growth and long-term investment

Executive compensation, short-term incentives