Accounting Conservatism and Incentives:
Intertemporal Considerations

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Abstract. We study the intertemporal properties of conservatism with a focus on managerial incentives. In our main model, conservatism results in smaller expected payouts to the manager (agent) in early periods and larger expected payouts in later periods. Conservatism shifts (ambiguous) evidence that might be used to recognize good performance in early periods to later periods. In later periods, good performance is less informative, since good news might mean good current period performance and might also mean good prior period performance whose recognition was delayed. Because of the intertemporal shift in the information content of performance measures, incentives provided in future periods can spillback to early periods, making conservatism preferred by the principal (shareholders). We also study an extension in which the principal learns about the firm over time. In the learning model, conservatism is again optimal.

Keywords: accounting conservatism, multi-period incentives, incentive spillback
1. Introduction

Conservatism is a pervasive feature of accounting.\(^1\) Conservatism predates Paciolo and is used throughout the world (Basu 1995).\(^2\) Sanders, Hatfield, and Moore (1938) discuss conservatism as one of three general considerations in accounting.\(^3\) Sterling (1970) describes conservatism as accounting’s most influential valuation principle.

There are many definitions of accounting conservatism. Kohler’s dictionary defines conservatism as “a guideline which chooses between acceptable accounting alternatives … so that the least favorable immediate effect on assets, income, and owner’s equity is reported.” Bliss (1924) defines conservatism as: “anticipate no profit, but anticipate all losses.” According to Watts (2003) and Basu (1997), conservatism requires a “higher degree of verification to recognize good news as gains than to recognize bad news as losses.” As Sunder (1997) notes, “[t]he presence of uncertainty and the downward bias of measured current-period income, assets, and owner’s equity in the presence of uncertainty seems to be the essential aspects of conservatism.”\(^4,5\)

Conservatism is not without its critics. As Sanders, Hatfield, and Moore (1938, 12) put it, “[t]he common belief that less mischief is done by understatement than by overstatement is, in the hands of honest men probably true; but with dishonest men understatement may serve their turn as well as overstatement.” Paton was one of the strongest critics of conservatism, often emphasizing intertemporal reversals.\(^6\)

\(^1\) Conservatism is not a convention in the sense that it is not a matter of indifference to economic agents whether we adopt conservative, neutral, or liberal accounting (Sunder 1997).
\(^2\) Basu (1995) cites evidence in Penndorf (1933) that Francesco di Marco of Prato used lower of cost or market to value his inventory in 1406.
\(^3\) The other two general considerations discussed are: (i) capital and income and (ii) the form and terminology of financial statements.
\(^4\) The FASB (1980) also focuses on uncertainty in (briefly) discussing conservatism but adopts the awkward example of “equally likely estimates.”
\(^5\) Conservatism can also be viewed as a scaling issue, as in Demski and Sappington (1990).
\(^6\) Paton’s criticism was not with conservatism per se, but with its application in practice: “As a matter of fact, such a principle [lower-of-cost-or-market] does not insure conservatism. Instead, conservatism is
Standard setters have used intertemporal reversals as a justification for de-emphasizing conservatism. As early as 1980, in their Statement of Financial Accounting Concepts 2 (CON 2), the FASB seemed to view conservatism as an outdated idea that arose when balance sheets were the only readily available financial statement (CON 2, paragraph 93).

We study the intertemporal properties of conservatism with a focus on managerial incentives. The intertemporal reversals that Paton and others have so eloquently criticized turn out to have beneficial incentive properties. In our main model, conservatism results in smaller expected payouts to the manager (agent) in early periods and larger expected payouts to the manager in later periods. Conservatism shifts the information content of good performance. In early periods, good performance is more informative, since good performance is recognized only when we are sure performance is actually good. In later periods, good performance is less informative, since good news might mean good current period performance and might also mean good prior period performance whose recognition was delayed. Roughly stated, conservatism shifts (ambiguous) evidence that might be used to recognize good performance in early periods to later periods. Because of the intertemporal shift in the information content of performance measures, incentives provided in future periods can spillback to early periods, making conservatism preferred by shareholders represented by a principal.\(^7\)

Our modeling of conservatism is intended to capture two ideas. First, accounting conservatism is fundamentally a multi-period concept—in particular, good news (evidence) is deferred from the first period to the second period in order to subject it to enforcement only by sound reasoning, integrity, and governmental regulation (Paton and Stevenson 1920, 476).”

\(^7\) Although there are no debt-holders in our model, we note that accounting conservatism delays (expected) managerial payouts in our model. In other words, we identify an incentive benefit to what might otherwise appear (and is often described) as a feature of conservatism designed to protect debt-holders (e.g., Watts 2003).
additional verification. For example, we do not record appreciation in the value of unsold inventory. We wait until the inventory is sold in subsequent periods at the then prevailing market price. Second, conservatism is a reaction to uncertainty rather than an ex ante known shifting of earnings. The underlying true earnings is unknown when the accounting report is generated. Under conservative accounting, financial reports in early periods are produced with an under-reaction to potentially good (although uncertain) news relative to the reaction accorded to similar bad news.

In our model, the agent earns rents. Holding everything else constant, conservatism reduces the agent’s first-period rents and increases his second-period rents by the same amount. In our model, the rents are determined by likelihood ratios that compare the probability of obtaining a particular report under a high input supply to the probability of obtaining the same report under low input supply. Under conservatism, the likelihood ratios are improved in the first period, but the first-period improvement is countered by an exactly offsetting weakening in the second period. Once we introduce the possibility of changes in effort across time and/or the possibility of managerial replacement, a demand for conservatism emerges.

The result and intuition are particularly crisp when the principal has the option of firing the agent at the end of the first period. Under conservatism, the shift in rents from the first period to the second period is optimal because the second-period rents now “spill-back” to the first period (provide incentives for first-period effort). The agent wants to work hard in the first period to get the chance to continue his employment and enjoy the second-period rents.\(^8\) (If the same agent must be employed in all periods, then the spillback comes into play only if agent’s effort level varies intertemporally.) The broader perspective is (1) conservatism can be thought of as shifting the managers’ rewards and focus to the future and (2) the way in which intertemporal reversals of

\(^8\) The essential feature is the manager finds being fired costly (e.g., because of job search costs, lower future wages, etc.).
accruals play out in incentives is subtle and unlikely to coincide with the valuation perspective emphasized by the FASB.

We also study an extension in which the principal learns about the agent’s type as time goes by. In the learning model, conservatism is again optimal. The second-period incentive problem (information asymmetry) is less severe, so the principal finds conservatism an optimal way to focus on the first period. The learning result provides an insight about why conservatism may be of particular value in growth companies, where both learning and the impact of conservatism on the financial statements are the most pronounced.9

Our paper contributes to the now vast literature on the economic demand for accounting conservatism. For example, accounting conservatism’s properties for debt contracting have been studied by Gigler et al. (2009), Caskey and Hughes (2012), Li (2013), and others. Conservatism can facilitate trade in debt markets (Gox and Wagenhofer 2009) or in asset resale markets (Demski, Lin, and Sappington 2009). Gao (2013) formalizes conservatism as an ex ante reaction to ex post managerial opportunism. Accounting conservatism may also arise in equilibrium to improve managerial contracting efficiency even without reporting opportunism (Christensen and Demski 2002, 2004; Kwon, Newman, and Suh 2001). Our paper extends Kwon, Newman, and Suh (2001) by incorporating the intertemporal effect of accounting bias and, in particular, by showing that conservatism can be valuable because of its spillback effect. Somewhat surprisingly, the existing models of accounting conservatism focus on single-period (or essentially single-period) settings.

9 Our learning result is consistent with empirical evidence in LaFond and Watts (2008) and Francis, Hasan and Wu (2013), which find that conservatism is significantly associated with the extent of the information asymmetry between shareholders and managers. In our learning model, a large information asymmetry creates an opportunity for greater learning which increases the principal’s benefit to conservatism.
Like our paper, Drymiotes and Hemmer (2013) assume that probabilistic bias introduced in a first period is reversed in a second period. However, their focus is on discretionary accruals (chosen by the manager) and the stock market’s reaction to those discretionary accruals. Perhaps the most significant difference in our models is the spillback incentive effect in our paper, which gives rise to the demand for conservatism in our model and is not present in their paper. In their model, all accounting systems have the same incentive properties. Levine (1996), Bagnoli and Watts (2005), and Lin (2006) also study managerial accrual choices and show the choice of conservative accounting methods can serve as a signaling device.

The remainder of the paper is organized into four sections. Section 2 introduces the model. Section 3 presents our main result. Section 4 presents the learning model, and Section 5 concludes.

2. Model

A risk-neutral principal contracts with a risk-neutral agent to implement a two-period project. The agent sequentially selects two productive inputs, denoted by \( a_t \in \{a_L, a_H\}, t = 1, 2 \), with \( a_H > a_L \). With a slight abuse of notation, \( a_t \) also denotes the disutility of the agent’s act in period \( t \). An output, high or low, is produced in each period, denoted by \( x_t \in \{L, H\}, t = 1, 2 \). The technology is described by the conditional probability of a high output being produced, given the agent’s current period act. The first-period act does not affect the second-period technology, and the technologies are identical in both periods: \( p \equiv \Pr(x_t = H \, | \, a_H) \) and \( q \equiv \Pr(x_t = H \, | \, a_L) \), \( t = 1, 2 \), and \( p > q \).

The output cannot be contracted on, because it is observable only when the firm is liquidated. Instead, the contract is based on an accounting report, \( y_t \in \{L, H\}, t = 1, 2 \), generated at the end of each period. The periodic accounting report \( y_t \) is publicly observable and verifiable. Hence, the agent’s second-period input choice can be
conditioned on his observation of the first-period accounting report, 

\[ a_2(\cdot) : y_1 \in \{L, H\} \rightarrow \{a_L, a_H\} . \]

The accounting system is subject to bias, and the bias introduced in the first period is reversed in the second period, which is captured by a parameter \( \varepsilon \in [-d, d] \). The reporting technology is a probabilistic shift of the production technology.\(^{10} \)

\[
p_i \equiv \Pr(y_1 = H \mid \varepsilon, a_H) = p + \varepsilon \\
q_i \equiv \Pr(y_1 = H \mid \varepsilon, a_L) = q + \varepsilon \\
p_2 \equiv \Pr(y_2 = H \mid \varepsilon, a_H) = p - \varepsilon \\
q_2 \equiv \Pr(y_2 = H \mid \varepsilon, a_L) = q - \varepsilon
\]

To make this design meaningful, the boundary parameter \( d \) should satisfy:

\[ d = \min\{ p, q, 1 - p, 1 - q \} . \]

The principal chooses the parameter \( \varepsilon \in [-d, d] \) at the beginning of the first period. If \( \varepsilon = 0 \), there is no bias introduced by the accounting system ( \( p_1 = p_2 = p \) and \( q_1 = q_2 = q \)). The conditional probability of the accounting report being high or low is the same as for the underlying output. The accounting system is neutral. If \( \varepsilon \in [-d, 0] \), a conservative bias is introduced. The conditional probability of a high accounting report in the first period is shifted downwards ( \( p_1 < p, q_1 < q \) ). If \( \varepsilon \in (0, d] \), a liberal bias is introduced. The conditional probability of a high accounting report in the first period is shifted upwards ( \( p_1 > p, q_1 > q \) ).

One interpretation of the way we have modeled conservatism is as follows. A conservative accounting system defers less reliable income-increasing evidence from the

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\(^{10} \) In this formulation, financial reports are associated with the (unobservable) actual output through the underlying productive inputs. As we discuss later, a “tune up” in the third period ensures the sum of the reports equals the sum of the true output over the life of the firm—what Sunder (1997) calls the Law of Conservation of Income.
first period to the second period. After further verification brought about by the delay, the deferred evidence is used in determining second-period income. Since accounting involves judgment, the exclusion of evidence does not necessarily mean that more or less income will be reported in either period. Instead, the effect is a probabilistic one. In our model, conservatism is a reaction to uncertainty, not an ex ante known shifting of income. A modeling benefit of using an exactly offsetting probabilistic reversal in the second period is that it rigs the model against finding a demand for conservatism.

At the liquidation stage, a new agent takes over the firm. An output $x_3 \in \{L, H\}$ is realized. The probability of obtaining a high output is $q$. There is no productive input necessary at the liquidation stage, so the liquidating agent is paid zero. To preserve the conservation of income, $y_3 = x_1 + x_2 + x_3 - y_1 - y_2$.

The contract specifies an accounting report-contingent payment to be made at the end of the first and second periods, denoted by $s_1(y_1)$ and $s_2(y_1, y_2)$, respectively. The agent’s payoff is given by $s_1 + s_2 - a_1 - a_2$. The principal consumes the residual (output less payments to the agent) resulting in a payoff of $x_1 + x_2 + x_3 - s_1 - s_2$. The sequence of events is presented in Figure 1. Everything is common knowledge, except for the agent’s hidden (privately observed) supply of inputs.

Figure 1: Time-line
The principal’s problem is to maximize her expected residual subject to the following constraints. The individual rationality constraint (IR) requires the contract be sufficiently attractive to the agent. In particular, the contract must provide the agent with an expected utility of at least his 2-period reservation utility, \( \bar{U} \). The incentive compatibility constraints (IC) ensure the agent has incentives to choose the equilibrium inputs in each period. Finally, the payment to the agent must be non-negative in each period—the principal pays the agent, not the other way around (constraints NN).\(^{11}\)

Formally, we write the principal’s Program (P) as follows and denote its solution by \( \{ \varepsilon^*, s_1^*(\cdot), s_2^*(\cdot); a_1^*, a_2^*(L), a_2^*(H) \} \).

**Program P**

\[
\begin{align*}
\text{Max} & \sum_{\varepsilon, y_1} \Pr(y_1 \mid a_1) x_1 + \sum_{\varepsilon, y_2} \Pr(y_2 \mid a_2(y_1)) x_2 \\
& - \sum_{\varepsilon, y_1} \Pr(y_1 \mid a_1) \Pr(y_2 \mid a_2(y_1))[s_1(y_1) + s_2(y_1, y_2)]
\end{align*}
\]

Subject to

\[
\begin{align*}
\sum_{y_1} \Pr(y_1 \mid \varepsilon, a_1) \Pr(y_2 \mid \varepsilon, a_2(y_1))[s_1(y_1) + s_2(y_1, y_2) - a_1 - a_2] \geq \bar{U} & \quad \text{(IR)} \\
\sum_{y_1} \Pr(y_1 \mid \varepsilon, a_1^*) \Pr(y_2 \mid \varepsilon, a_2^*(y_1))[s_1(y_1) + s_2(y_1, y_2) - a_1^* - a_2^*] \geq \sum_{y_1} \Pr(y_1 \mid \varepsilon, a_1^*) \Pr(y_2 \mid \varepsilon, a_2^*(y_1))[s_1(y_1) + s_2(y_1, y_2) - a_1^* - a_2^*], \forall a_1^*, a_2^* \in \{a_L, a_H\} & \quad \text{(IC)} \\
s_1(\cdot), s_2(\cdot) \geq 0 & \quad \text{(NN)}
\end{align*}
\]

For simplicity, we assume \( \bar{U} = a_L = 0 \). This ensures the incentive compatibility and non-negativity constraints dominate the individual rationality constraints.

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\(^{11}\) See Innes (1990) and Sappington (1983) for standard models of limited liability in principal-agent relationships.
3. Results

3.1 Single-period setting

As a benchmark, consider a one-period setting. To make the problem interesting, we assume the following throughout the paper.

\[(A1) \quad H - L \geq \frac{p + d}{(p - q)(p - q)} a_H \]

Under (A1), the principal always prefers a high input supply from the agent in a one-period setting.\(^{12}\)

The optimal single-period contract is characterized in Observation 1. We characterize the optimal contract as a function of the accounting system in observations and the optimal accounting systems in propositions. All proofs are provided in an appendix.

Observation 1. For any accounting system \( \varepsilon \in [-d, +d] \), the optimal single-period contract is characterized as follows.

<table>
<thead>
<tr>
<th>Contract</th>
<th>( s^<em>(L) = 0 ), ( s^</em>(H) = \frac{a_H}{p - q} ).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective Function</td>
<td>((1 - p)L + pH - (p + \varepsilon) \frac{a_H}{p - q} )</td>
</tr>
</tbody>
</table>

The agent is paid a salary of 0 when the report is \( L \). He is paid a bonus of \( \frac{a_H}{p - q} \) if and only if the report is \( H \). Note that neither the incentive payment nor the expected output is affected by the accounting system, \( \varepsilon \). \( \varepsilon \) affects only the expected incentive

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\(^{12}\) In a risk-neutral single-period setting, the following condition ensures the principal always prefers the agent to supply a high input: \( H - L \geq \frac{p - d}{(p - q)(p - q)} a_H \), which is implied by (A1).
payment. Hence, the principal always prefers \( \varepsilon^* = -d \), a conservative accounting system. The principal is able to reduce the total expected incentive pay by reducing the probability of a high accounting report.

**Proposition 1.** A conservative accounting system \((\varepsilon^* = -d)\) is optimal in the single-period setting.

Proposition 1 captures the same trade-off documented in Kwon, Newman, and Suh (2001). That is, conservatism reduces the agent’s expected rent by reducing the probability that the agent will receive a bonus.

### 3.2 The Intertemporal Effect

We now turn to the two-period setting and solve Program P. The equilibrium contract under Program P depends on the desirable productive input level over the two periods. A natural starting point is to examine the case in which the output differential \((H - L)\) is sufficiently large that the principal finds it optimal to always induce high input from the agent in each period. Specifically, the following conditions are required to ensure that \( \{a_H; a_H, a_H\} \) is desirable in equilibrium, where \( \{a_k; a_m, a_n\} \) denotes \( \{a_i; a_2(L), a_2(H)\} \).

1. \( p + q \leq 1 \) and \( H - L \geq \frac{p + d - (p - d)(p - q)}{(1 - p + d)(p - q)(p - q)} a_H \), or
2. \( p + q > 1 \) and \( H - L \geq \frac{p - d - (p + d)(p - q)}{(1 - p - d)(p - q)(p - q)} a_H \)

We characterize the solution to Program P when \( \{a_H; a_H, a_H\} \) is motivated in Observation 2.
Observation 2. Assume (C1). For any accounting system $\varepsilon \in [-d, +d]$, the optimal contract can be characterized as follows.

<table>
<thead>
<tr>
<th>Contract</th>
<th>$s_1^<em>(L) = s_2^</em>(L, L) = 0, s_1^<em>(H) = s_2^</em>(L, H) = s_2^*(H, H) = \frac{a_H}{p-q}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective Function</td>
<td>$2L + 2p[H - L] - \frac{2p}{p-q}a_H$</td>
</tr>
</tbody>
</table>

As shown in Observation 2, the principal’s objective function value does not depend on the underlying choice of accounting system (denoted by the parameter $\varepsilon$). Any increase or decrease in expected incentive pay in the first period induced by accounting bias is exactly offset by a corresponding change in expected incentive pay in the second period. Consequently, the choice of accounting systems is irrelevant.

Proposition 2. If (C1) holds, the choice of accounting systems is irrelevant.

Proposition 2 implies that in steady state (i.e., when production levels/productive inputs are the same in each period), accounting does not play a role. Proposition 2 is a special case in that conservatism again emerges as optimal if either (i) the agent’s input supply is not always $a_H$ or (ii) a new agent can be hired for the second period. We analyze the first case next.

In Observation 3, we present necessary and sufficient conditions under which the principal prefers the strategy profile $\{a_H; a_L, a_H\}$ from the agent. That is, in equilibrium, the principal motivates the agent to exert low input in the second period if and only if a low accounting report is observed in the first period; otherwise, a high input is always desirable.

In contrast to Condition (C1) which requires the output differential $H - L$ to be large, either (C2) or (C3) in Observation 3 requires that $H - L$ not be too large. The principal weighs the incremental benefit of motivating high input supply from the agent.
and the incremental cost of the extra rent associated with motivating that input. Under (C2) or (C3), the rent needed to motivate high input is sufficiently high that the principal finds conditioning the second-period input on the first-period output optimal as a way of more efficiently motivating the agent. In particular, such conditioning creates a spillback of the second-period incentives to the first period, which reduces the cost of motivating effort in the first period. We characterize the optimal contract in Observation 3.

**Observation 3.** For any accounting system $\varepsilon \in [-d, d]$, the strategy $\{a_H; a_L, a_h\}$ is optimal if and only if either condition (C2) or condition (C3) holds:

(C2) $p + q > 1$ and $H - L > \frac{1 + p - q}{(p-q)(p-q)}$;

(C3) $p + q > 1$ and $H - L \leq \frac{1 + p - q}{(p-q)(p-q)} a_H$, or

$p + q \leq 1$ and $H - L < \frac{p + d - (p-d)(p-q)}{(1 - p + d)(p-q)(p-q)} a_H$.

The optimal contract can be characterized as follows.

<table>
<thead>
<tr>
<th>Contract</th>
<th>(s_1^<em>(L) = s_2^</em>(L, L) = 0, s_1^<em>(H) = \frac{1 - q + \varepsilon}{p - q} a_H, s_2^</em>(L, H) = 0,)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(s_2^*(H, H) = \frac{a_H}{p-q}.)</td>
</tr>
</tbody>
</table>

| Objective Function | \(2L + [p(1 + p - q) + q + (p - q)\varepsilon][H - L] - \frac{(p + \varepsilon)(1 + p - q)}{p - q} a_H\) |

Observation 3 suggests the choice of an optimal accounting system involves a tradeoff between expected output (recall the second-period input supply depends on the first-period accounting report) and the expected incentive payment.

**Proposition 3.** If (C2) holds, an aggressive accounting system ($\varepsilon^* = d$) is optimal. If (C3) holds, a conservative accounting system ($\varepsilon^* = -d$) is optimal.
Proposition 3 (combined with Observation 3) presents a setting in which the agency problem prevails in that it alters the principal’s dynamic operating decisions. In contrast, under the Condition (C1) of Proposition 2 (and Observation 2), the agency problem does not alter operating decisions.

Under the optimal contract in Observation 3, the agent earns rents only if high accounting reports are observed in both periods. Moreover, by design, the first-period incentive pay alone is not sufficient to motivate the agent to supply high input. The rents the agent earns in the second period help provide incentives for his first-period input—such a spillback of incentives from the second period to the first period gives rise to the demand for a biased accounting system.

Proposition 3 identifies conditions under which either conservative accounting system or aggressive accounting system arises in equilibrium. A conservative accounting system, modeled as downward bias, defers more of the incentive payment from the first-period to the second period and thus magnifies the spillback effect, which further reduces the cost of providing first-period incentives. When the marginal effect of an accounting bias on the expected incentive pay outweighs its effect on the gross output (the case identified by Condition (C3)), the spillback effect is more valuable to the principal and a conservative accounting system is optimal. An aggressive accounting system, on the other hand, reduces the spillback effect and, thus, increases the cost of providing first-period incentives. However, an aggressive accounting system also increases the probability of high input supply in the second period, since a high report is produced in the first period more often. An aggressive system is preferred as long as the increased probability of a high second-period input is more valuable to the principal than the increased cost of providing first-period incentives (Condition (C2)).
3.3 The principal’s firing decision

One might think that the driving force behind Proposition 3 is that the second-period incentive problem is less severe (a low input is sometime motivated in the second period), making conservatism optimal as a way of focusing the incentives on the first period. This is incorrect, or at least incomplete. It is not that the second-period incentive problem is less severe but rather that any rent earned in the second period can be used to reduce the first-period incentive payment if those rents are earned only when a high first-period accounting report is generated.

To make the spillback intuition even more transparent, consider an alternative setting in which the principal decides to hire a new agent (ex ante identical to the original agent) for the second period. Under (A1) (maintained throughout the paper), a new agent is hired if and only if the first-period accounting report is low. This makes it possible for the principal to take advantage of the spillback effect without sacrificing high input supply in the second period.

Denote by $D(y_1)$ the $y_1$-contingent decision to hire a new agent or retain the existing agent for period 2.

$$D(\cdot) = \begin{cases} 0 & \text{if a new agent is hired for period 2} \\ 1 & \text{if the same agent is hired for period 2} \end{cases}$$

If a new agent is hired, he is paid $t_2(y_2)$. The sequence of events is presented in Figure 2.
Figure 2: Time-line with the firing decision

<table>
<thead>
<tr>
<th>t = 0</th>
<th>t = 1</th>
<th>t = 2</th>
<th>t = 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal selects $\varepsilon$.</td>
<td>Principal and agent sign a contract; agent selects $a_i$.</td>
<td>$y_1$ is reported; agent is paid $s_1(y_1)$; principal makes firing decision.</td>
<td>If $D = 0$, a new agent is hired; employed agent selects $a(z_1(y_i))$ or $b_i$.</td>
</tr>
</tbody>
</table>
| New agent is hired; the firm is liquidated; $y_1 = \Sigma x - y_1 - y_2$ is reported; principal consumes $x_1 + x_2 - s_1(\cdot)$, $-D(y_1)s_2(\cdot)$, $-(1 - D(y))t_2(\cdot)$.

Denote the solution to principal’s revised problem by $\{\varepsilon^*, D^*(\cdot); s_1^*(\cdot), s_2^*(\cdot); t_2^*(\cdot)\}$.

$\{a_1^*, a_2^*(L), a_2^*(H); b_2^*\}$. The optimal contract is characterized in Observation 4.

**Observation 4.** Assume a new agent can be hired for period 2. For any accounting system $\varepsilon \in [-d, d]$, the optimal contract can be characterized as follows.

<table>
<thead>
<tr>
<th>Contract</th>
<th>$D^<em>(L) = 0$, $D^</em>(H) = 1$; $s_1^<em>(L) = s_1^</em>(H, L) = 0$, $s_1^*(H) = \frac{1-q+\varepsilon}{p-q}a_H$.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$s_2^<em>(H, H) = \frac{a_H}{p-q}$; $t_2^</em>(L) = 0$, $t_2^*(H) = \frac{a_H}{p-q}$.</td>
</tr>
<tr>
<td>Objective Function</td>
<td>$2L + 2p[H - L] - \frac{2p - (p + \varepsilon)(q - \varepsilon)}{p-q}a_H$</td>
</tr>
</tbody>
</table>

Observation 4 states that the principal optimally exercises her option to fire the agent whenever a low first-period accounting report is observed. The contract offered to the new agent replicates the optimal single-period contract (as described in Observation 1). Because the possibility of agent replacement allows the principal to incorporate the spillback effect for the first-period agent without distorting second-period production decisions (high managerial inputs are always supplied), a conservative accounting system ($\varepsilon^* = \max(-d, -\frac{p-q}{2})$) is always optimal. We summarize this result in Proposition 4.
Proposition 4. If a new agent can be hired for period 2, a conservative accounting system \((\varepsilon^* = \max\{-d, -\frac{p^* - q^*}{2}\})\) is optimal.

4. Learning

In addition to the hidden action problem studied in the earlier sections of the paper, suppose the agent also has hidden (private) information about the type of project that is to be implemented. In particular, assume the agent privately observes the realized project type after he signs the contract and is unable to communicate her private information to the principal. The blocked communication assumption is meant to capture a setting in which the principal (shareholders) know less about the firm’s technology than does the agent (manager), and the shareholders learn information over time that helps them fine-tune the contract to the environment. The first-period contract has to be robust to a variety of possible environments in the sense of Arya, Demski, Glover, and Liang (2009). Accounting conservatism will emerge as an optimal response to the robustness requirement.

There are two possible types of projects, good and bad, denoted by \(\theta \in \Theta = \{b, g\}\).

The principal has a prior belief about the type of the project implemented, denoted by \(\Pr(\theta), \theta \in \Theta\). In any period, the technology is described by the conditional probability of a high output being produced, given the realized state and the agent’s current act, denoted by \(p_\theta \equiv \Pr(x = H | \theta, a_H)\) (\(q_\theta \equiv \Pr(x = H | \theta, a_L)\)). Assume MLRP for each project type: \(p_g > q_g\) and \(p_b > q_b\). We also assume \(p_g - q_g > p_b - q_b\), i.e., the agent’s marginal productivity is greater if the project is good. The accounting system shifts the reported accounting income in the following fashion. For \(\varepsilon \in [-d, d]\),

\[
\begin{align*}
p_\theta^1 &\equiv \Pr(y_1 = H | \varepsilon, \theta, a_H) = p_\theta + \varepsilon \\
q_\theta^1 &\equiv \Pr(y_1 = H | \varepsilon, \theta, a_L) = q_\theta + \varepsilon \\
p_\theta^2 &\equiv \Pr(y_2 = H | \varepsilon, \theta, a_H) = p_\theta - \varepsilon \\
q_\theta^2 &\equiv \Pr(y_2 = H | \varepsilon, \theta, a_L) = q_\theta - \varepsilon
\end{align*}
\]
\[ q_0^2 \equiv \Pr(y_2 = H \mid \epsilon, \theta, a_L) = q_o - \epsilon \quad (8) \]

The principal learns the project type at the end of the first period. To make things interesting, the principal contracts with the agent period-by-period. If instead a long-term contract were allowed, the problem would effectively be one without hidden information.

The first-period payment is conditioned on only the first-period accounting report. The second-period payment is conditioned on the observable project type and the second-period accounting report. The sequence of events is present in Figure 3.

Figure 3: Time-line for the learning model

The principal’s problem is formalized in Program PL.

Program PL

\[
\text{Max} \sum_{\epsilon, \theta, a_L} \Pr(\theta) \left[ \sum_{y_1} \Pr(x_1 \mid \theta, a_1) x_1 + \sum_{y_1} \sum_{y_2} \Pr(y_1 \mid \epsilon, \theta, a_1) \Pr(x_2 \mid \theta, a_2(y_1)) x_2 \right. \\
\left. - \sum_{y_1} \sum_{y_2} \Pr(y_1 \mid \epsilon, \theta, a_1) \Pr(y_2 \mid \epsilon, \theta, a_2(y_1))(s_1(y_1) + s_2(\theta, y_2)) \right] \\
\text{Subject to} \\
\sum_{\theta} \sum_{y_1} \sum_{y_2} \Pr(\theta) \Pr(y_1 \mid \epsilon, a_1) \Pr(y_2 \mid \epsilon, a_2)(s_1(y_1) + s_2(\theta, y_2) - a_1 - a_2) \geq \bar{U} \quad (IR)
\]
\( \sum_{y_1} \sum_{y_2} \Pr(y_1 | \varepsilon, \theta, a_1) \Pr(y_2 | \varepsilon, \theta, a_2) [s_1(y_1) + s_2(\theta, y_2) - a_1 - a_2] \)

\[ \geq \sum_{y_1} \sum_{y_2} \Pr(y_1 | \varepsilon, a_1') \Pr(y_2 | \varepsilon, a_2') [s_1(y_1) + s_2(\theta, y_2) - a_1' - a_2'] \quad (IC) \]

\[ \forall \theta \in \{b, g\}, a_1', a_2' \in \{a_L, a_H\} \]

\[ s_1(), s_2() \geq 0 \quad (NN) \]

Denote the solution to Program PL by \( \{\varepsilon^*; s_{1H}^*, s_{1L}^*, s_{2H}^*, s_{2L}^*, a_1^*(\theta), a_2^*(\theta, y_1)\} \), which is characterized in Observation 5. Condition (C4), specified in the appendix, is necessary and sufficient to ensure the principal always motivates a high input supply from the agent.

**Observation 5.** Assume (C4). For any chosen accounting system \( \varepsilon \in [-d, d] \), the optimal contract can be characterized as follows.

<table>
<thead>
<tr>
<th>Contract</th>
<th>( s_1^<em>(L) = s_2^</em>(b, L) = s_2^*(g, L) = 0, )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( s_1^<em>(H) = s_2^</em>(b, H) = \frac{a_H}{p_b - q_b}, s_2^*(g, H) = \frac{a_H}{p_g - q_g} ).</td>
</tr>
<tr>
<td>Objective Function</td>
<td>( 2[\Pr(b)(1 - p_b) + \Pr(g)(1 - p_g)]L + 2[\Pr(b)p_b + \Pr(g)p_g]H )</td>
</tr>
<tr>
<td></td>
<td>(- \frac{\Pr(g)(p_g + \varepsilon) + 2 \Pr(b)p_b + \Pr(g)(p_g - \varepsilon)}{p_b - q_b} + \frac{\Pr(g)(p_g - \varepsilon)}{p_g - q_g})a_H )</td>
</tr>
</tbody>
</table>

Although the contract is myopic, the second-period contract is not the same as the first-period contract. Additional information (the realized project type) is used to fine-tune the second-period contract. The accounting system does not affect the total expected output but does affect the expected incentive payment. Conservatism focuses the rent-reducing role of the accounting system on the first period, in which the incentive problem is most severe.

**Proposition 5.** In the learning model, if (C4) holds, a conservative accounting system \( (\varepsilon^* = -d) \) is optimal.
5. Concluding Remarks

Our paper provides only a small insight into the demand for conservatism in the presence of bias reversals. Much additional work is needed, particularly theoretical research that views conservatism as a multi-period concept. We share the concern expressed in Watts (2003) and LaFond and Watts (2008) that regulators seem to be on quest to eliminate conservatism without first trying to understand it. We conclude by discussing other aspects of accounting conservatism that seem to be understudied in recent research.

An early attempt to codify accounting principles is Sanders, Hatfield, and Moore (1938), which can be viewed as an early example of positive accounting theory. Their positive approach is perhaps at its best in discussing conservatism: “It is therefore proper to inquire into the circumstances which have led to any bias which may exist in favor of understatement” (p. 12). Sanders, Hatfield, and Moore’s explanations include (1) auditor conservatism as a way of combating managerial optimism, (2) managerial conservatism as a way for management to signal its conservative orientation, and (3) earnings management under the guise of conservatism for the “purpose of averaging profits over the years “ in order to enhance “the company’s credit and prestige.”

As far as we are aware, there have been few studies on the role of auditor conservatism in combating managerial optimism (e.g., Antle and Lambert 1988, Antle and Nalebuff 1991, and Krishnan 1994). What are the necessary ingredients to make such conservatism optimal? What keeps the manager from anticipating the conservative response of auditors and overstating results so that the final result is the optimistic report he or she believes to be correct?

The idea that conservative accounting can signal conservative management may also be interesting to model. A related idea suggested to us by Yuji Ijiri is that conservative accounting may have a role in inducing managerial conservatism. That is,
conservative accounting may foster a culture of conservatism (a conservative way of thinking) within the corporation.

We might also model particular conservative accounting rules. Consider perhaps the most often discussed example of accounting conservatism: lower of cost or market (LOCM). Writing the asset down but not up to reflect market prices can be thought of as devoting additional attention to bad states. This additional attention comes in the form of resources devoted to detecting these bad states and the granularity of disclosure. When the market price is higher than cost, we are told no more. When the market price is lower than cost, we are given more information (or can recover it)—we know both the historical cost and the write-down. In this sense, traditional historical cost accounting subject to write-downs is honed on bad news, since the communication channels are expanded when there is bad news.

Another way to think of conservatism is as a description of a process rather than of an information system. For example, Arya and Glover (2008) compare a system that allows students to ask that individual exam questions be re-graded rather than insisting that only entire exams be re-graded. The selective (cherry-picked) approach is less conservative and turns out to be optimal only when the initial grading is of relative poor quality. That is, conservatism is optimal if the initial measurements generated by the accounting system are precise enough.

Arguably, the most important of the many recent information economics papers on accounting conservatism is Gigler et al. (2009). One interpretation of Gigler et al. (2009) is that it challenges the view of Watts (2003) and others that conservatism protects debt-holders. In our view, Gigler et al. is best viewed as a benchmark. We know that conservatism has a role in protecting debt-holders, for example, by protecting them from premature payouts to other parties. In the same spirit that Modigliani-Miller points us to deviations from their assumption to derive a demand for dividend policy, Gigler et al. (2009) can be interpreted as directing us to deviations from their model’s assumptions or
their definition of accounting conservatism rather than telling us to discard the idea that conservatism protects debt-holders. Gigler et al.’s (2009) definition seems to be intended to formalize notions espoused by Basu (1997), Watts (2003), and others. If the problem turns out to be with the (single-period) definition of conservatism, then is the challenge to the formalization adopted in information economics or instead with the underlying definitions given by others?
APPENDIX

A. Proof of Observation 1 and Proposition 1

In a single period risk-neutral setting, the agent gets paid only when a high accounting report is observed. The incentive compatibility constraint binds and yields 

\[ s^*(H) = \frac{a_H}{p-q} \] .

The objective function is 

\[ V = L + p(H - L) - (p + \varepsilon) \frac{a_H}{p-q} \] .

Taking the first-order derivative of the objective function with respect to \( \varepsilon \) yields 

\[ \frac{\partial V}{\partial \varepsilon} = -\frac{a_H}{p-q} < 0. \]

B. Proof of Observation 2, Proposition 2, Observation 3, and Proposition 3

There are eight possible strategy profiles for the agent. We solve Program P when each of the eight strategy profiles is motivated. In total, we solve eight programs.

**Step 1:** Given a prescribed accounting system \( \varepsilon \), solve Program P to motivate each of the eight strategy profiles. The solutions to the eight programs are as follows.

(i) \( \{a_H; a_H, a_H\} \) is motivated.

\[ V_{HHH} = 2L + 2p[H - L] - \frac{2p}{p-q} a_H. \]

(ii) \( \{a_H; a_L, a_H\} \) is motivated.

\[ V_{HLH} = 2L + [p(1 + p - q) + q + (p-q)\varepsilon][H-L] - \frac{(p+\varepsilon)(1+p-q)}{p-q} a_H. \]

(iii) \( \{a_H; a_H, a_L\} \) is motivated.

\[ V_{HHL} = 2L + [p(2 - p + q) - (p-q)\varepsilon][H-L] - \frac{2p - (p-q)(p+\varepsilon)}{p-q} a_H. \]

(iv) \( \{a_H; a_L, a_L\} \) is motivated.
\[ s_i^*(H) = \frac{a_H}{p-q}; \text{ and all other payments are zero.} \]
\[ V_{HLL} = 2L + [p+q][H-L] - \frac{p+\varepsilon}{p-q} a_H. \]

(v) \( \{a_L; a_H, a_H \} \) is motivated.
\[ s_2^*(L,H) = s_2^*(H,H) = \frac{a_H}{p-q}; \text{ and all other payments are zero.} \]
\[ V_{LHH} = 2L + [p+q][H-L] - \frac{p-\varepsilon}{p-q} a_H. \]

(vi) \( \{a_L; a_L, a_H \} \) is motivated.
\[ s_3^*(H,H) = \frac{a_H}{p-q}; \text{ and all other payments are zero.} \]
\[ V_{LHL} = 2L + [p+q][H-L] - \frac{(p-\varepsilon)(q+\varepsilon)}{p-q} a_H. \]

(vii) \( \{a_L; a_H, a_L \} \) is motivated.
\[ s_3^*(L,H) = \frac{a_H}{p-q}; \text{ and all other payments are zero.} \]
\[ V_{LHL} = 2L + [p+q(1-p+q) - (p-q)\varepsilon][H-L] - \frac{(p-\varepsilon)(1-q-\varepsilon)}{p-q} a_H. \]

(viii) \( \{a_L; a_L, a_L \} \) is motivated
All payments are zero. \( V_{LLL} = 2L + 2q[H-L]. \)

**Step 2:** Given any \( \varepsilon \), we compare the objective function of Program \( \{a_H; a_H, a_H \} \) with that of the other seven programs. Assumption (A1) ensures that Program (i) \( \{a_H; a_H, a_H \} \) is motivated) dominates Programs (iii) \( \sim \) (viii). Program (i) dominates Program (ii) if and only if the following condition holds:
\[ H - L \geq \frac{(p-\varepsilon) - (p + \varepsilon)(p-q)}{(p-q)(p-q)(1-p-\varepsilon)} a_H. \quad (E1) \]
Furthermore, the expression on the right-hand side of (E1) is increasing in \( \varepsilon \) if and only if \( p + q > 1 \).
Step 3: Given \( \{a_H; a_L, a_H\} \) is induced, \( \frac{\partial V_{HHH}}{\partial \varepsilon} = 0 \). Hence, \( \varepsilon_{HHH}^* \) does not affect the principal’s objective function, \( V_{HHH} = 2L + 2p[H - L] - \frac{2p}{p - q} a_H \).

Given \( \{a_H; a_L, a_H\} \) is induced, \( \frac{\partial V_{HHL}}{\partial \varepsilon} = (p - q)(H - L) - \frac{1 + p - q}{p - q} a_H \).

If \( H - L > \frac{1 + p - q}{(p - q)(p - q)} a_H \), \( \varepsilon_{HHH}^* = +d \). We write,

\[
V_{HLH}(d) = 2L + [p(1 + p - q) + q + (p - q)d][H - L] - \frac{(p + d)(1 + p - q)}{p - q} a_H. \tag{E2}
\]

If \( H - L \leq \frac{1 + p - q}{(p - q)(p - q)} a_H \), \( \varepsilon_{HHH}^* = -d \). We write

\[
V_{HLH}(-d) = 2L + [p(1 + p - q) + q - (p - q)d][H - L] - \frac{(p - d)(1 + p - q)}{p - q} a_H. \tag{E3}
\]

Step 4: Prove that under (C1), Program (i) dominates Program (ii).

Consider the case \( p + q > 1 \). Then the following inequality

\[
H - L \geq \frac{p - d - (p + d)(p - q)}{(p - q)(p - q)(1 - p - d)} a_H
\]

ensures (E1) always holds so that Program (i) dominates Program (ii).

Next consider the case \( p + q \leq 1 \). Then the following inequality

\[
H - L \geq \frac{p + d - (p - d)(p - q)}{(p - q)(p - q)(1 - p + d)} a_H
\]

ensures (E1) always holds so that Program (i) dominates Program (ii).

Step 5: Prove that under (C2) or (C3), Program (ii) dominates Program (i).

The following inequalities ensure that (E2) is greater than the objective function of Program (i):

\[
\frac{1 + p - q}{(p - q)(p - q)} a_H < H - L < \frac{p - d - (p + d)(p - q)}{(p - q)(p - q)(1 - p - d)} a_H. \tag{E4}
\]

In particular, the first inequality in (E4) ensures \( \varepsilon_{HHH}^* = +d \). There is nontrivial interval for \( [H - L] \) in (E4) if and only if \( p + q > 1 \).

The following inequalities ensure that (E3) is greater than the objective function of Program (i):

\[
H - L < \frac{p + d - (p - d)(p - q)}{(p - q)(p - q)(1 - p + d)} a_H. \tag{E5}
\]
To ensure $\epsilon_{HLH}^* = -d$, it must be $H - L \leq \frac{1 + p - q}{(p - q)(p - q)} a_H$. If $p + q \leq 1$, then
\[
\frac{1 + p - q}{(p - q)(p - q)} \geq \frac{p + d - (p - d)(p - q)}{(p - q)(p - q)(1 - p + d)}
\]
so that (E5) implies $\epsilon_{HLH}^* = -d$. If $p + q > 1$, then
\[
\frac{1 + p - q}{(p - q)(p - q)} < \frac{p + d - (p - d)(p - q)}{(p - q)(p - q)(1 - p + d)}
\]
so that $H - L \leq \frac{1 + p - q}{(p - q)(p - q)} a_H$ implies $\epsilon_{HLH}^* = -d$ and (E5).

\[\blacksquare\]

**C. Proof of Observation 4 and Proposition 4**

The principal has four possible strategies regarding the firing/retention decision, denoted by $\{D(y_1 = L), D(y_2 = H)\} = \{D(0, 0), D(0, 1), D(1, 0), D(1, 1)\}$. The strategy $D(0, 0)$ represents the case that the principal always fires the agent regardless of the first-period accounting report. The strategy $D(0, 1)$ (the strategy $D(1, 0)$) represents the case that the principal fires the agent only when a low (high) accounting report is generated at the end of the first period. The strategy $D(1, 1)$ represents Program P, in which the principal always retains the first-period agent.

Solve the principal’s program when $D(0, 1)$ is preferred. Denote the solution to the principal’s problem by $\{\epsilon^*, s_1^*(y_1), s_2^*(H, y_2), t_2^*(y_2); a_1^*(H); a_2^*(H); b_2^*(L)\}$. 

**Step 1**: Given a prescribed accounting system $\epsilon$, solve the principal’s problem to motivate $\{a_1^*(H), b_2^*(L), a_2^*(H)\}$. In total, we solve eight programs.

(i) $\{a_H^*, b_H^*, a_H\}$ is motivated
\[
s_2^*(H, H) = \frac{1 + p - q}{(p - q)(p - q)} a_H, \quad t_2^*(H) = \frac{a_H}{p - q}; \text{ and all other payments are zero.}
\]
\[
V_{HHH} = 2L + 2p[H - L] - \frac{2p - (p + \epsilon)(q - \epsilon)}{p - q} a_H.
\]

(ii) $\{a_H^*, b_L^*, a_H\}$ is motivated

$$s^*_2(H,H) = \frac{1+p-q}{(p-q)(p-\epsilon)}a_H,$$ and all other payments are zero.

$$V^{HH}_L = 2L + [p(1+p-q) + q + (p-q)\epsilon][H-L] - \frac{(p+\epsilon)(1+p-q)}{p-q}a_H.$$ 

(iii) \{a_H; b_H, a_L\} is motivated

$$s^*_1(H) = t^*_2(H) = \frac{a_H}{p-q};$$ and all other payments are zero.

$$V^{HH}_L = 2L + [p(2+p+q) - (p-q)\epsilon][H-L] - \frac{2p-(p-\epsilon)(p+\epsilon)}{p-q}a_H.$$ 

(iv) \{a_H; b_L, a_L\} is motivated.

$$s^*_2(H,H) = t^*_2(H) = \frac{a_H}{p-q};$$ and all other payments are zero.

$$V^{HL}_L = 2L + [p + q][H-L] - \frac{p+\epsilon}{p-q}a_H.$$ 

(v) \{a_L; b_H, a_H\} is motivated.

$$s^*_2(H,H) = t^*_2(H) = \frac{a_H}{p-q};$$ and all other payments are zero.

$$V^{LH}_L = 2L + [p + q][H-L] - \frac{p-\epsilon}{p-q}a_H.$$ 

(vi) \{a_L; b_L, a_H\} is motivated.

$$s^*_2(H,H) = \frac{a_H}{p-q};$$ and all other payments are zero.

$$V^{LL}_L = 2L + [q(2+p-q) + (p-q)\epsilon][H-L] - \frac{(p-\epsilon)(q+\epsilon)}{p-q}a_H.$$ 

(vii) \{a_L; b_h, a_L\} is motivated.

$$t^*_2(H) = \frac{a_H}{p-q};$$ and all other payments are zero.

$$V^{HL}_L = 2L + [p + q(1+p-q) - (p-q)\epsilon][H-L] - \frac{(p-\epsilon)(1-q-\epsilon)}{p-q}a_H.$$ 

(viii) \{a_L; b_h, a_L\} is motivated

All payments are zero. \( V^{LL}_L = 2L + 2q[H-L]. \)

**Step 2:** Choose the optimal \( \epsilon^* \) for each program so that the principal’s total expected payoff is maximized.
Step 3: Assumption A1 ensures that the Program (i) dominates Program (iii)–(viii). This is because the firing decision does not affect the objective function for Program (iii)–(viii) but increases the objective function for Program (i). Our claim is supported by Step 2 in Appendix B.

Step 4: Given \( \{a_h; b_h, a_H\} \) is motivated, we have,
\[
\frac{\partial V_{HHH}}{\partial \varepsilon} = -\frac{p - q + 2\varepsilon}{p - q} a_H.
\]
We have \( \varepsilon_{HHH}^* = \min(d, \frac{p - q}{2}) \). Given \( \{a_h; b_L, a_H\} \) is motivated, the optimal accounting system is characterized as that in Step 3 of Appendix B.

Step 5: It is readily to check that Program (i) dominates Program (ii). That is, if the following condition holds, \( H - L > \frac{1 + p - q}{(p - q)(p - q)} a_H \), then \( V_{HHH}(\varepsilon_{HHH}^*) > V_{HH}(d) \). Otherwise, \( V_{HHH}(\varepsilon_{HHH}^*) > V_{HH}(-d) \).

In a nutshell, we characterize the solution under the strategy \( D(0,1) \) as follows:
\[
\{a_h; b_h, a_H\} \text{ is optimal; } \varepsilon_{HHH}^* = \min(d, \frac{p - q}{2});
\]
\[
s_1^*(H, H) = \frac{1 + p - q}{(p - q)(p - \varepsilon)} a_H, \ t_2^*(H) = \frac{a_H}{p - q}; \text{ and all other payments are zero.}
\]

(2) By MLRP and (A1), the principal never prefers \( D(1,0) \) to \( D(1,1) \). In fact, the Program to motivate \( \{a_i^*; a_i^*(L), a_i^*(H)\} \) under \( D(1,0) \) produces lower objective function values than the program motivating the same act strategy under \( D(1,1) \).

(3) By A1, the optimal solution when the strategy \( D(0,0) \) is chosen is as follows:
\[
\{a_h; a_H, a_H\} \text{ is optimal; } \varepsilon_{HHH}^* \text{ does not matter;}
\]
\[
\text{The only nonzero payments are } s_1^*(H) = t_2^*(H) = \frac{a_H}{p - q};
\]
\[
V_{HHH}(D(0,0)) = 2L + 2p[H - L] - \frac{2p}{p - q} a_H.
\]

(4) Compare the solutions when the strategies \( D(0,0), D(0,1), \) and \( D(1,1) \) is adopted by the principal, respectively. Under Assumption A1, the principal finds it optimal to adopt the strategy \( D(0,1) \).
D. Proof of Observation 5 and Proposition 5

The agent has 64 strategies in total. Since $p_s - q_s > p_b - q_b$, the principal cannot never motivate the strategies $\{a_i(b) = a_H, a_i(g) = a_L; a_2(\theta, y_1) \mid \theta \in \{b, g\}, y_1 \in \{L, H\}\}$. Hence, there are 48 feasible strategies for the agent.

**Step 1:** In the second period, the principal prefers the agent to always supply a high input if and only if the following condition holds,

$$H - L \geq \max\left\{ \frac{p_s + d}{(p_s - q_s)(p_s - q_g)} a_H, \frac{p_b + d}{(p_b - q_b)(p_b - q_g)} a_H \right\}.$$

The principal prefers the agent with a good project to supply a high input in the second period if and only if $H - L \geq \frac{p_s + d}{(p_s - q_s)(p_s - q_g)} a_H$ holds. Similarly, the principal prefers the agent with a bad project to supply a high input if and only if

$$H - L \geq \frac{p_b + d}{(p_b - q_b)(p_b - q_g)} a_H.$$

Now, the remaining problem is to ensure the agent supplies a high input in the first period.

**Step 2:** Program $\langle a_H a_H; a_H a_H a_H a_H \rangle$ dominates $\langle a_L a_H; a_H a_H a_H a_H \rangle$ if and only if the following condition holds:

$$H - L \geq \frac{a_H}{\Pr(b)(p_b - q_b)} \left\{ \left[ \Pr(b) d + \Pr(g)(p_g - d) \right] \left( \frac{1}{p_b - q_b} - \frac{1}{p_g - q_g} \right) + \Pr(b) \left( \frac{p_b}{p_b - q_b} - \frac{q_b}{p_g - q_g} \right) \right\}.$$

**Step 3:** Program $\langle a_H a_H; a_H a_H a_H a_H \rangle$ dominates $\langle a_L a_L; a_H a_H a_H a_H \rangle$ if and only if the following condition holds:

$$[\Pr(b)(p_b - q_b) + \Pr(g)(p_g - q_g)] (H - L) \geq \frac{\Pr(b)(p_b + d) + \Pr(g)(p_g - d)}{p_b - q_b} a_H + \frac{2 \Pr(g)d}{p_g - q_g} a_H.$$

To summarize, the principal always prefers a high input supply if and only if the following condition (C4) holds:
(C4)

\[ H - L \geq \max \left\{ \frac{p_g + d}{(p_g - q_g)(p_g - q_g)} a_H, \frac{p_b + d}{(p_b - q_b)(p_b - q_b)} a_H \right\} \]

\[ \frac{a_H}{\Pr(b)(p_b - q_b)} \left\{ [\Pr(b)d + \Pr(g)(p_g - d)] \left( \frac{1}{p_b - q_b} - \frac{1}{p_g - q_g} \right) + \Pr(b) \left( \frac{p_b}{p_b - q_b} - \frac{q_b}{p_g - q_g} \right) \right\}, \]

\[ \frac{a_H}{\Pr(b)(p_b - q_b) + \Pr(g)(p_g - q_g)} \left[ \frac{\Pr(b)(p_b + d) + \Pr(g)(p_g - d)}{p_b - q_b} + \frac{2\Pr(g)d}{p_g - q_g} \right] \}

**Step 4:** Under Condition (C4), the solution to Program PL is:

\[ s_{1H}^* = \frac{a_H}{p_b - q_b}, \quad s_{2bH}^* = \frac{a_H}{p_b - q_b}, \quad s_{2gH}^* = \frac{a_H}{p_g - q_g} \]

\[ \text{Obj.} = 2[\Pr(b)(1 - p_b) + \Pr(g)(1 - p_g)L] + 2[\Pr(b)p_b + \Pr(g)p_g]H \]

\[ -\left( \frac{\Pr(g)(p_g + \varepsilon) + 2\Pr(b)p_b}{p_b - q_b} + \frac{\Pr(g)(p_g - \varepsilon)}{p_g - q_g} \right)a_H \]

Taking first-order derivative of the objective function with respect to \( \varepsilon \), we have

\[ \frac{\partial \text{Obj.}}{\partial \varepsilon} = -\left( \frac{\Pr(g)}{p_b - q_b} - \frac{\Pr(g)}{p_g - q_g} \right)a_H < 0. \]
REFERENCES


