# A teaching note on the controllability "Principle" and performance measurement

Steven T. Schwartz
*School of Management, Binghamton University, Binghamton, New York, USA, and*
Eric E. Spires and Richard A. Young
*Fisher College of Business, The Ohio State University, Columbus, Ohio, USA*

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## Abstract

**Purpose** – The purpose of this note is to expose accounting students and others to recent findings in management control, specifically to the relationship between the informativeness of a performance measure and its usefulness in performance evaluation.

**Design/methodology/approach** – Numerical examples illuminate key ideas and are easy to follow and replicate by students.

**Findings** – Seemingly in contradiction to the controllability principle, performance measures that are informative about actions taken by employees are not necessarily useful for performance evaluation. This occurs when the performance being measured is related to an intermediate task, such as prepping items prior to final assembly. If prepping is an important factor in the quality of not only the intermediate good but also the finished good, and the quality of the finished good can be reasonably measured, it may not be useful to measure the prepping performance. This result holds even if obtaining the intermediate measure is costless and the intermediate measure provides unique information on the effort given to the intermediate task.

**Originality/value** – Opportunities to measure employees' intermediate outputs are ubiquitous; therefore, judicious decisions should be made regarding the use of limited monitoring resources. This note contains intuitive, easy-to-follow illustrations (based on recent findings) that will help students and others identify situations where such evaluations are more and less useful.

**Keywords** Management control, Informativeness, Performance measurement, Responsibility accounting

**Paper type** Case study

## 1. Introduction

Double-entry accounting was developed in the late Middle Ages not only for the purpose of measuring enterprise value but also for evaluating the effectiveness of the agents and employees of a business, or *stewardship*[1]. Accounting systems continue to be a source of information for measuring and promoting stewardship, often referred to as *management control*. For this reason, it is important that accounting students recognize the multiple roles played by accounting information, rather than focusing exclusively on accounting as an input in valuing entities traded in capital markets. In this vein, this note adds to a growing pedagogy on the role of accounting in management control (Antle and Demski, 1988, Arya *et al.*, 1996, 2005; Schwartz *et al.*, 2007).

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In this note, numerical examples are used to illustrate a situation where an accounting datum that is clearly informative about the actions of an employee is not useful for evaluating that employee. The examples are developed from Arya *et al.* (2005). They consider situations wherein an employer wishes to motivate an employee to devote “effort” to an intermediate and a subsequent task[2]. Contrary to casual intuition, the employer may receive no benefit at all from utilizing the intermediate output to evaluate the employee, even though the intermediate output is informative about the employee’s intermediate task effort. If it is costly to measure the intermediate output, the employer is actually worse off using it. The intuition for the numerical results and analogies to business settings are discussed. The important implication of the analyses is that accountants should not measure things for the sake of measurement, even if the measurements contain unique information. Attempting to use such information for performance evaluation purposes can be costly both in terms of resources expended to collect superfluous data and in terms of the potential for reducing employee morale due to unnecessarily heavy-handed oversight.

The contribution of this note is that it presents these potentially complicated ideas in a simple and easily digestible format (relative to the proofs and theorems found in rigorous analyses) that can fit well into any intermediate-level undergraduate or graduate course on management accounting. The solutions to the examples can be replicated by students using spreadsheet software and are therefore useful in the classroom as a unifying approach to focus discussions on potential inefficiencies that can result from an excessive use of performance measures.

The rest of this note is organized as follows. Section 2 presents materials to be given to students. Section 3 discusses classroom implementation. Section 4 concludes the note.

## 2. Case materials

It is common sense that employees should be evaluated only on things that they control. In managerial accounting textbooks, this is referred to as the *controllability principle*. At first blush, a batting coach should not be evaluated on the basis of the team’s pitching numbers, a sales manager should not be evaluated on the basis of the frequency with which production equipment gets jammed, and an army general should not be evaluated on the basis of the gunnery on naval ships. However, common-sense thinking can lead to fallacies.

Antle and Demski (1988) present numerical illustrations to demonstrate that controllability is neither necessary nor sufficient for a measure to be useful in performance evaluation. As an example, consider the manager of a ski resort. Clearly, the manager cannot control the amount of snow that falls in a given year; nevertheless, such information could easily be helpful in evaluating the manager. Achieving profitability in lean snow years is an indicator that the manager is skillful, while a ski resort manager who cannot turn a profit even in plentiful snow years might need to be replaced. Therefore, controllability of a measure is not a *necessary* condition for it to be useful in performance evaluation.

Now, consider the general manager of a sports team responsible for the selection of players and coaches. There is no doubt that the more successful, exciting and appealing (in terms of player personalities) the team is, the higher is the attendance. Therefore, the general manager clearly has control over a performance measure such as parking revenue. However, parking revenue may be just a noisy substitute for the information gained from ticket sales and, hence, should not be used in evaluating the general manager. Therefore, controllability of a measure is not a *sufficient* condition for usefulness in evaluation, either.

The key to evaluating the usefulness of a measure is *conditional informativeness*. A measure is conditionally informative if it provides additional information about the actions of the individual being evaluated, given the other measures already available. Assuming that the employer and employee objectives are not already aligned, the conditional informativeness of a measure implies that it is valuable for performance evaluation, assuming of course that it can be obtained at no cost. Returning to the above example, the profitability of a ski resort is valuable as a performance measure, but profitability plus snowfall is even more valuable. A manager who can turn a profit despite poor natural snow is more valuable than a manager who can make money only in heavy snow seasons. On the other hand, parking revenue for the sports team may be informative (unconditionally) about the performance of the general manager, but not if one already possesses data on ticket sales. The point is that the consideration of multiple performance measures leads to a modified version of the controllability principle.

The link between the informativeness of an accounting measure and its usefulness in performance evaluation is investigated further by using Arya *et al.*'s (2005) model. The key feature of their setting is that the employee performs two types of tasks. It is assumed that the employer wishes to motivate high input on both tasks. There are two measures of performance. The first performance measure is affected only by the first task and a random element. The second measure is affected by both the first and the second tasks as well as a random element. Given these assumptions, the first performance measure provides information about the first task that is not contained in the second performance measure; hence, it is conditionally informative. However, it is possible that the first measure is not useful for evaluating the overall performance. Perhaps even more surprising, this occurs not when the first action is nearly irrelevant, but when it significantly impacts the second performance measure.

While not the interpretation in Arya *et al.* (2005) per se, it is both natural and insightful to think of one of the tasks as preceding the other. For example, an attorney must first prepare research that will be compiled into a report. Next, she must prepare oral arguments for her case, partially based on the research conducted. There are two measureable outputs: the research report and the outcome of the trial. Note that the second action, the oral arguments, does not affect the quality of the research report, while the first action, the research, clearly affects the outcome of the trial. The law partners, could, if they wished, evaluate the lawyer on both the quality of the research report and the outcome of the trial. In fact, it may be optimal to do this. However, it may also be optimal to evaluate the lawyer solely on the outcome of the trial, even though the partners wish to motivate high effort on research and the research report is conditionally informative on the effort put into research. Consider also the example of a product manager. He/she is responsible for developing a stylish product and for placing the product in retail outlets. Stylishness can be measured through focus groups, while availability can be measured by the number of outlets carrying the product. Note that focus group measures are not affected by market penetration (especially if taken before the product is released), but both stylishness and the marketing efforts of the manager contribute to market penetration. Again, this example illustrates that it is possible that evaluating only market penetration can motivate high effort on both tasks.

Our model is designed to be rich enough to capture the basic ingredients of an incentive contracting setting without burdening the exercise with details that can distract from the main effects of interest. In this simplified model of the firm, there is a risk-neutral employee (hereafter, the agent) who performs two tasks, one after the other, and a risk-neutral employer (hereafter, the principal) who is the residual claimant[3]. The agent's input on each task is denoted as H (high) or L (low). Assume that the benefits of high input on both tasks are so great that the principal wishes to motivate the agent to choose high input on both tasks (Using our vignette involving the attorney, it is best for the law firm if the attorney works hard at both researching the case and developing a compelling case to present to the jury). The agent's utility depends on his compensation and his input. The agent's disutility from high input is greater than the disutility from low input; hence, there exists a potentially interesting management control problem. Finally, the agent is assumed to have no resources and therefore cannot be assigned a negative payment.

The agent's first task results in a measure that is naturally not affected by the agent's input on the second task. This outcome is referred to as the "intermediate" performance measure. For simplicity, assume that the intermediate measure is either "good" or "bad," denoted as G or B. Because the intermediate measure is also affected by factors beyond the agent's control, high input on this task does not necessarily result in a good measure. Naturally, however, high input is more likely to lead to a good measure than low input. The probability of G on the intermediate measure given input level i is $p_i$, i = H, L, where $p_H > p_L$. The probability of B on the intermediate measure given input i is 1- $p_i$.

The employee's second task combined with his first task results in the "final" performance measure. That is, the outcome of the final measure is affected by both the first and second task inputs and is also, for simplicity, either "good" or "bad". This allows for interdependence in the two tasks. That is, choosing high input on the first task may make the second task easier for the agent. We denote the probability of a good outcome on the second measure given the input combination (i, j) by $p_{ij}$, i, j = H, L. Naturally, we assume that $p_{HH}$ is greater and $p_{LL}$ is less than both $p_{HL}$ and $p_{LH}$. Similar to the intermediate performance measure, high input on both tasks is more likely to produce a good final measure than any other combination of task inputs, justifying our use of the labels of good and bad, G and B, for the second performance measure. Finally, we assume statistical independence, so the joint probability of any combination of measures on the first and the second task is equal to the product of the first and the second task probabilities. For example, the probability of a G on both measures given input i on the first task and j on the second task is equal to $p_i(p_{ij})$.

The risk-neutral principal's objective can be described as choosing non-negative payments to the agent that minimize the expected compensation while ensuring that the agent is both willing to work for the principal (as opposed to taking a job elsewhere) and to choose high input on both tasks. Logically, the payments are contingent on the outcome of one or both of the performance measures – they are denoted as $s_{ij}$, where i and j refer to the intermediate and the final measures, respectively, and i and j = G or B. A performance measure is considered useful if the optimal payments to the agent are contingent on that measure in a non-trivial fashion. For example, $s_{Bj}$ not equal to $s_{Gj}$ for some j indicates that the intermediate measure is useful for contracting. Similarly, $s_{iB}$ not equal to $s_{iG}$ for some i indicates that the final measure is useful for contracting.

As mentioned, the agent is also a risk-neutral expected utility-maximizer. Further, the agent's utility is the sum of his compensation and his personal cost of inputs. Denote the personal cost of input on task k by $c(a_k)$, where c(H) > c(L) and k = 1, 2. Formally, the agent's utility function is $u(s_{ij}, a_1, a_2) = s_{ij} - c(a_1) - c(a_2)$, where i, j = G, B, $a_k$ = L, H, and k = 1, 2.

Table I presents the parameters, principal's program and solution to Example 1. It shows for the intermediate measure, the probability of a good and a bad outcome, conditional on the agent's choosing high or low input (H or L) on the first task. It also presents the probabilities of good and bad outcomes on the final measure, conditional on the level of input on both the first and the second task. Given statistical independence across measures, the probability of a given combination of outputs is equal to the product of the respective input-conditional probabilities. The program minimizes expected payments to the agent while ensuring that high input on both tasks is at least as good for the agent as any other input combination (constraints LH, HL and LL) and that high input on both tasks provides an expected net utility at least as great as the agent's next best alternative (constraint P).

| Intermediate task (1) outcome probabilities | | | Final task (2) outcome probabilities | | |
|---|---|---|---|---|---|
| $a_1$ | Good | Bad | $a_1$, $a_2$ | Good | Bad |
| H | 0.90 | 0.10 | H, H | 0.90 | 0.10 |
| L | 0.45 | 0.55 | H, L | 0.45 | 0.55 |
| | | | L, H | 0.45 | 0.55 |
| | | | L, L | 0.20 | 0.80 |

$a_1$ = input on task 1; $a_2$ = input on task 2; H = high input; L = low input cost of high input on each task = 1; cost of low input on each task = 0 net expected utility to the agent from the next best opportunity is 0

*Program*:

Let $s_{12}$ be the payment to the agent for outcome measures 1 and 2. The program to solve for the optimal contract in Example 1 is as follows:

$$\min_{s_{GG}, s_{GB}, s_{BG}, s_{BB}} \quad 0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB}$$

*Subject to*:

$$0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB} - 2 \;\; \geq 0 \qquad \text{(P)}$$

$$0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB} - 2 \;\; \geq 0.9(0.45)s_{GG} + 0.9(0.55)s_{GB} + 0.1(0.45)s_{BG} + 0.1(0.55)s_{BB} - 1 \qquad \text{(HL)}$$

$$0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB} - 2 \geq 0.45(0.45)s_{GG} + 0.45(0.55)s_{GB} + 0.55(0.45)s_{BG} + 0.55(0.55)s_{BB} - 1 \qquad \text{(LH)}$$

$$0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB} - 2 \geq 0.45(0.2)s_{GG} + 0.45(0.8)s_{GB} + 0.55(0.2)s_{BG} + 0.55(0.8)s_{BB} \qquad \text{(LL)}$$

$$s_{GG}, s_{GB}, s_{BG}, s_{BB} \geq 0 \qquad \text{(NN)}$$

*Constraints*: P (participation constraint) ensures that the agent is willing to participate. LH, HL and LL (incentive compatibility constraints)
ensure that the agent prefers high input on both tasks to any other input combination. NN (non-negativity constraint) ensures that all payments are non-negative.

*Solution*:

$$s_{GG} = \frac{25}{9} \approx 2.78 \;\; s_{GB} = 0 s_{BG} = 0 s_{BB} = 0$$

| | |
|---|---|
| Expected cost to principal | 2.25 |
| Expected net utility to the agent for high input on task 1, high input on task 2 (HH) | 0.25 |
| Expected net utility to the agent for high input on task 1, low input on task 2 (HL) | 0.13 |
| Expected net utility to the agent for low input on task 1, high input on task 2 (LH) | −0.44 |
| Expected net utility to the agent for low input on task 1, low input on task 2 (LL; the binding constraint) | 0.25 |

**Table I.**
Example 1

The left side of the constraints is the agent's expected utility if he puts in high input on both tasks. To explain further, given high input on both tasks, the probability of realizing two good measures is equal to .9(.9) = .81, so the agent's payment for a good on both measures, $s_{GG}$, is multiplied by this amount. The "−2" on the left-hand side of the constraints is the total cost to the agent of providing high input on both tasks, as high input has a cost of 1 for each task. In the "participation constraint" (P), the right-hand side is the agent's expected utility from his next best alternative, assumed for simplicity to be zero. In the "incentive compatibility constraints" (LH), (HL) and (LL), the right-hand sides are his/her expected utility from the corresponding combination of inputs. For example, in (LL), the agent's payment for a good on both measures, $s_{GG}$, is multiplied by 1.45(1.2) = 1.09 because this is the probability that a good outcome will be obtained on both measures given low input on both tasks. The "non-negativity constraint" (NN) assures that the principal makes payments to the agent, not the other way around.

Table I presents the optimal solution to Example 1: $s_{GG} = 25/9 \approx 2.78$ and $s_{GB} = s_{BG} = s_{BB} = 0$, leading to an expected cost of compensating the agent of 2.25 and an expected utility for the agent of 0.25[4]. Thus, in the optimal solution, the agent strictly prefers working for the firm, as $0.25 > 0$.

The key to developing intuition about the optimal solution is to analyze what happens with the constraints. In Example 1, the only binding incentive constraint is (LL). The term "binding" means that the constraint is satisfied as an equality and, further, if the constraint were relaxed, the solution would improve. Hence, at the optimal solution, low input on both tasks is just as desirable for the agent as high input on both tasks[5]. However, the agent strictly prefers high input on both tasks to low on one and high on the other. It is useful to substitute the optimal solution into the constraints to verify that only the (LL) constraint is binding. Doing so, one can see that if the agent puts in low input on both tasks, he receives $0.45(0.2)25/9 - 0 - 0 = 0.25$, so the agent is indifferent between high input on both tasks and low input on both tasks. If the agent puts in high input on the first task and low input on the second task, he receives $0.9(0.45)25/9 - 1 - 0 \approx 0.13$, which is strictly worse than high input on both tasks. Low input on the first task and high input on the second task is even worse for the agent.

Importantly, in this example, the solution is unique, meaning that in an optimal contract, both task outcomes, not just the final outcome, must be measured. Most noteworthy for our purposes is that $s_{GG} > 0$ but $s_{BG} = 0$. Thus, from the agent's perspective, it is not good enough to obtain a good outcome on the final measure; to receive the "bonus", a good outcome must be obtained on both measures. With respect to accounting, this implies that both outcomes must be observed or the principal will pay unnecessary compensation to the agent.

The key to designing the contract is to place the incentives where the agent is least inclined to follow the wishes of the principal. In Example 1, the agent is most tempted by the option of providing low input on both tasks; therefore, the (LL) constraint determines how much is paid for the outcome GG. Therefore, the principal is better off designing a contract that uses the information on both measures, because the agent is tempted to choose low input on both tasks.

Table II presents the details for Example 2, leading to the expected cost of compensating the agent of 3 and the expected utility for the agent of 1. Importantly, Example 2 illustrates the case where an optimal contract can rely solely upon the outcome of the final measure. In particular, one solution is $s_{GG} = s_{BG} = 10/3 \approx 3.33 > s_{GB} = s_{BB} = 0$. Irrespective of the outcome on the intermediate measure, the agent receives 3.33 in compensation for a good outcome on the final measure and zero otherwise.

In Example II, the only binding constraint is (HL). Hence, high input on the first task and low input on the second task are just as desirable for the agent as high input on both tasks. The agent strictly prefers high input on both tasks to low input on the first task and high input on the second task and to low input on both tasks. Again, it is useful to substitute the optimal solution into the constraints to verify that the (HL) constraint is binding. Doing so,

| Intermediate task (1) outcome probabilities | | | Final task (2) outcome probabilities | | |
|---|---|---|---|---|---|
| $a_1$ | Good | Bad | $a_1, a_2$ | Good | Bad |
| H | 0.90 | 0.10 | H, H | 0.90 | 0.10 |
| L | 0.45 | 0.55 | H, L | 0.60 | 0.40 |
| | | | L, H | 0.45 | 0.55 |
| | | | L, L | 0.20 | 0.80 |

$a_1$ = input on task 1; $a_2$ = input on task 2; H = high input; L = low input cost of high input on each task = 1; cost of low input on each task = 0 net expected utility to the agent from the next best opportunity is 0

*Program:*

Let $s_{12}$ be the payment to the agent for outcome measures 1 and 2. The program to solve for the optimal contract in Example 2 is as follows:

$$\min_{s_{GG},s_{GB},s_{BG},s_{BB}} \quad 0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB}$$

*Subject to*:

$$0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB} - 2 \geq 0 \qquad \text{(P)}$$

$$0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB} - 2 \geq 0.9(0.6)s_{GG} + 0.9(0.4)s_{GB} + 0.1(0.6)s_{BG} + 0.1(0.4)s_{BB} - 1 \qquad \text{(HL)}$$

$$0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB} - 2 \geq 0.45(0.45)s_{GG} + 0.45(0.55)s_{GB} + 0.55(0.45)s_{BG} + 0.55(0.55)s_{BB} - 1 \qquad \text{(LH)}$$

$$0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB} - 2 \geq 0.45(0.2)s_{GG} + 0.45(0.8)s_{GB} + 0.55(0.2)s_{BG} + 0.55(0.8)s_{BB} \qquad \text{(LL)}$$

$$s_{GG}, s_{GB}, s_{BG}, s_{BB} \geq 0 \qquad \text{(NN)}$$

*Constraints*: P (participation constraint) ensures that the agent is willing to participate. LH, HL and LL (incentive compatibility constraints) ensure that the agent prefers high input on both tasks to any other input combination. NN (non-negativity constraint) ensures that all payments are non-negative

*Solution*:

$$s_{GG} = \frac{10}{3} \approx 3.33 \quad s_{GB} = 0 \qquad s_{BG} = \frac{10}{3} \approx 3.33 \quad s_{BB} = 0$$

| | |
|---|---|
| Expected cost to principal | 3.00 |
| Expected net utility to the agent for high input on task 1, high input on task 2 (HH) | 1.00 |
| Expected net utility to the agent for high input on task 1, low input on task 2 (HL is binding constraint) | 1.00 |
| Expected net utility to the agent for low input on task 1, high input on task 2 (LH) | 0.50 |
| Expected net utility to the agent for low input on task 1, low input on task 2 (LL) | 0.67 |

**Table II.** Example 2

one can see that if the agent puts in high input on the first task and low input on the second task, he receives $0.6\,10/3 - 1 - 0 = 1$, so the agent is indifferent between high input on both tasks and choosing high input on the first task and low input on the second task. If the agent puts in low input on both tasks, he receives $0.2\,10/3 - 0 - 0 = 2/3 \approx 0.67$, which is strictly worse than high input on both tasks.

We see here that the agent is tempted to provide low input only on the second task, not on the first. Therefore, it may not come as a complete surprise that the incentives can be placed entirely on the final measure (affected by both tasks) and not the intermediate measure (affected by only the first task). However, it is a little more nuanced than that. For one, there are other solutions, one of which is to set $s_{GG} \approx 3.70 > s_{GB} = s_{BG} = s_{BB} = 0$, which also leads to an expected cost of 3. So, while it is true that the principal may observe and use the

**Table III.**
Example 3

| Intermediate task (1) outcome probabilities | | | Final task (2) outcome probabilities | | |
|---|---|---|---|---|---|
| $a_1$ | Good | Bad | $a_1$, $a_2$ | Good | Bad |
| H | 0.90 | 0.10 | H, H | 0.90 | 0.10 |
| L | 0.45 | 0.55 | H, L | 0.60 | 0.40 |
| | | | L, H | 0.45 | 0.55 |
| | | | L, L | 0.20 | 0.80 |

$a_1$ = input on task 1; $a_2$ = input on task 2; H = high input; L = low input
cost of high input on task 1 = 2; cost of high input on task 2 = 1; cost of low input on each task = 0
net expected utility to the agent from the next best opportunity is 0

*Program*:

Let s12 be the payment to the agent for outcome measures 1 and 2. The program to solve for the optimal contract in Example 3 is as follows:

$$\min_{s_{GG},s_{GB},s_{BG},s_{BB}} \quad 0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB}$$

*Subject to*:

$$0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB} - 3 \geq 0 \quad \text{(P)}$$

$$0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB} - 3 \geq 0.9(0.6)s_{GG} + 0.9(0.4)s_{GB} + 0.1(0.6)s_{BG} + 0.1(0.4)s_{BB} - 2 \quad \text{(HL)}$$

$$0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB} - 3 \geq 0.45(0.45)s_{GG} + 0.45(0.55)s_{GB} + 0.55(0.45)s_{BG} + 0.55(0.55)s_{BB} - 1 \quad \text{(LH)}$$

$$0.9(0.9)s_{GG} + 0.9(0.1)s_{GB} + 0.1(0.9)s_{BG} + 0.1(0.1)s_{BB} - 3 \geq 0.45(0.2)s_{GG} + 0.45(0.8)s_{GB} + 0.55(0.2)s_{BG} + 0.55(0.8)s_{BB} \quad \text{(LL)}$$

$$s_{GG}, s_{GB}, s_{BG}, s_{BB} \geq 0 \quad \text{(NN)}$$

*Constraints*: P (participation constraint) ensures that the agent is willing to participate. LH, HL and LL (incentive compatibility constraints) ensure that the agent prefers high input on both tasks to any other input combination. NN (non-negativity constraint) ensures that all payments are non-negative

*Solution*:

$$s_{GG} = \frac{300}{72} \approx 4.17 \quad s_{GB} = 0 \quad s_{BG} = 0 \quad s_{BB} = 0$$

| | |
|---|---|
| Expected cost to principal | 3.375 |
| Expected net utility to the agent for high input on task 1, high input on task 2 (HH) | 0.375 |
| Expected net utility to the agent for high input on task 1, low input on task 2 (HL) | 0.250 |
| Expected net utility to the agent for low input on task 1, high input on task 2 (LH) | −0.156 |
| Expected net utility to the agent for low input on task 1, low input on task 2 (LL; the binding constraint) | 0.375 |

outcome of the intermediate measure, there is no benefit to doing so – it is just as good to only measure the second task. If it is costly to observe the intermediate output, then the principal would be made worse off doing so because she would pay the cost without any offsetting benefits[6].

The intuition for why it is unnecessary to measure the intermediate task in Example 2 is aided by a careful comparison of Examples 1 and 2. In Example 1, the conditional probability structures of the first and the second tasks are identical, and hence, both are equally important in generating a good outcome on the final measure. However, in Example 2, what matters more in generating a good outcome on the final measure is high input on the first task (moving the conditional probability from .45 to .90) as opposed to high input on the second task (which only moves the conditional probability from .6 to .9). Therefore, any sufficient incentives placed on the final measure to motivate high input on the second task would be more than enough to motivate high input on the first task. As a result, the (HL) constraint is binding, and in this particular example, there is an optimal contract in which the contract ignores the intermediate outcome. In Example 2, one might say the control problem of motivating high input on the second task "spills back" into motivating high input on the first task (Arya *et al.*, 2005).

As an analogy, suppose that a municipality is trying to get a coal-powered electricity generating plant to use more efficient scrubbers and a cleaner variety of coal. The municipality can monitor air quality in the local vicinity, which would be affected by both the use of scrubbers and the variety of coal used, as well as coal residues, which would be affected only by the variety of coal used. If air quality is much more affected by the variety of coal used than by the scrubbers, then, all else being equal, any incentives strong enough to motivate more efficient scrubbers are likely to have a large impact on the variety of coal used. The municipality may not need to monitor coal residues and yet have the power plant use the preferred variety of coal. This is the idea of Example 2. The second task has relatively weak impact on the final measure, so incentives must be ramped up to motivate high input on the second task. As a result, when the final measure is sufficient to motivate high input on the second task, it will be sufficient to motivate high input on the first task.

Table III presents Example 3, which uses the same probability structure as Example 2. However, in this example, the optimal payments must be conditioned on both the intermediate and the final measure, rather than on just the final measure, as in Example 2. In Example 3, the cost of high input on the first task has been increased from 1 to 2. With a higher cost on the first task, it is no longer true that providing incentives on the second task ensures that the first task is not costly to motivate. Therefore, it now becomes important to make the compensation depend on the first task as well. What this final example illustrates is that information interacts with the other attributes, such as the disutility of input, in determining the optimal incentive scheme. Returning to the example regarding a power

| Intermediate task (1) outcome probabilities | | | Final task (2) outcome probabilities | | |
|---|---|---|---|---|---|
| $a_1$ | Good | Bad | $a_1, a_2$ | Good | Bad |
| H | 0.90 | 0.10 | H, H | 0.75 | 0.25 |
| L | 0.40 | 0.60 | H, L | 0.50 | 0.50 |
| | | | L, H | 0.20 | 0.80 |
| | | | L, L | 0.10 | 0.90 |

$a_1$ = input on task 1; $a_2$ = input on task 2; H = high input; L = low input
cost of high input on task 1 = 1; cost of high input on task 2 = 1; cost of low input on each task = 0
net expected utility to the agent from the next best opportunity is 0

**Table IV.**
Take-home assignment

plant, if the desired variety of coal is sufficiently more expensive than the alternative, it will take direct monitoring to provide incentives for its use.

Finally, we make the following general observations about the model and its implications. First, if (LL) is binding, the intermediate outcome must be measured, because $s_{GG}$ will not be equal to $s_{BG}$ in an optimal contract. Second, (HL) binding is a necessary but not sufficient condition to be able to ignore the intermediate outcome. This is because if (HL) is binding, there are multiple solutions, but it is not necessarily true that $s_{GG} = s_{BG}$ is one of them. In fact, there are situations where (HL) is binding, but (LL) would be violated if $s_{GG}$ were set to $s_{BG}$.[7]

## 3. Implementation

This teaching note is suitable for any accounting class that covers topics on managerial accounting beyond the survey level. We have used it in core master's level and honor's undergraduate level classes. The note is presented as part of a module on management control along with similarly themed teaching notes such as Antle and Demski (1988), Arya *et al.* (1996) and Nikias *et al.* (2009).

Students are expected to read Section 2 of the note before attending class and are given a short pre-quiz prior to the lesson. The purpose of the pre-quiz is to ensure that the note is read, not to test for deep comprehension. During the lesson, the instructor and students work together through the numerical examples and discuss their practical relevance. Finally, as an assurance of learning, students are given an assignment similar to the examples, but with different parameters. Answers are either delivered as a presentation by one student to the class or in the written form. Table IV presents parameters for a take-home assignment. Students should be asked to arrive at a solution that motivates high input on both tasks but does not use the intermediate performance measure (solution available from the authors). For variety, the instructor can change the cost of the high input on the first task from 1 to 2, which causes the intermediate measure to become useful.

## 4. Conclusion

The use of accounting numbers in performance evaluation is a mainstay of managerial accounting practice. However, monitoring and evaluation activities are costly. Through the use of a simple model, we explore situations where accounting numbers may be informative on performance but not needed for performance evaluation, and hence, costly measurement activities might be avoided. Students can easily work through the illustrations with an instructor and a take-home assignment using spreadsheet software capable of solving constrained optimization programs. Our teaching note adds to a growing pedagogy on managerial accounting and management control.

### Notes

1. In presenting his case for teaching double-entry bookkeeping, Sangster (2010) recounts, "His [Pacioli's] treatise also enabled merchants to audit their own books and to ensure that the entries in the accounting records made by their bookkeepers complied with the methods he described. Without such a system, all merchants who did not maintain their own records were at greater risk of theft by their employees and agents: it is not by accident that the first and last items described in his treatise concern maintenance of an accurate inventory".
2. While here we refer to the employee's input as "effort", there are other interpretations. The main point is that the employer wishes the employee to choose an input level that the employee would rather not choose, *ceteris paribus*.

3. Simply put, risk neutrality implies that the individual neither seeks nor avoids risk. Such an individual would be completely indifferent between receiving $50 for certain or flipping a fair coin where heads yielded $100 and tails yielded $0.

4. Throughout the examples, rounding occurs for expositional convenience.

5. One should not be concerned about the agent's indifference between actions, because at an arbitrarily small cost to the principal, the "tie" can be broken by adding a small amount to $s_{GG}$.

6. Under the natural assumptions that $p_H$ is greater than $p_L$ and that $p_{HH}$ is greater than $p_{HL}$, $p_{LH}$ and $p_{LL}$, it is always optimal to make $s_{GG}$ positive; it is never necessary that any other payments be positive. However, under some circumstances, there may exist an equally good solution where $s_{GG} = s_{BG}$. This is illustrated by Example 2. However, with other parameters where HL is the only binding constraint, setting $s_{GG} = s_{BG}$ will violate LL. In such a case, $s_{GG}$ may be the only payment that is positive, or both $s_{GG}$ and $s_{BG}$ may be positive, but they cannot be made equal without the principal incurring an additional cost (and hence, it would not be an "optimal" contract). We thank the reviewer for pointing this out.

7. In Example 1, wherein $p_{HL} = 0.45$, LL is binding and only $s_{GG}$ is positive. This solution is unique. In Example 2, $p_{HL}$ is increased from 0.45 to 0.60 and, as indicated in Table II, HL is binding and an optimal solution exists where $s_{GG} = s_{BG}$, so that the first task need not be measured. However, this solution is not unique. In fact, it is also optimal to increase $s_{GG}$ (and appropriately decrease $s_{BG}$). Finally, if $0.5 < p_{HL} < 0.6$, HL is binding and both $s_{GG}$ and $s_{BG}$ may be greater than zero, but an optimal solution cannot set $s_{GG} = s_{BG}$ without violating LL.

## References

Antle, R. and Demski, J. (1988), "The controllability principle in responsibility accounting", *The Accounting Review*, Vol. 63 No. 4, pp. 700-718.

Arya, A., Fellingham, J. and Young, R. (1996), "On the role of historical cost reporting", *Issues in Accounting Education*, Vol. 11 No. 1, pp. 15-22.

Arya, A., Glover, J. and Radhakrishnan, S. (2005), "The controllability principle in responsibility accounting: another look", in Antle, R., Gjesdal, F. and Liang, P. (Eds), *Essays in Accounting Theory in Honour of Joel S. Demski*, Springer, New York, NY, pp. 183-198.

Nikias, A., Schwartz, S. and Young, R. (2009), "A note on bundling budgets to achieve management control", *Journal of Accounting Education*, Vol. 27 No. 3, pp. 168-184.

Sangster, A. (2010), "Using accounting history and Luca Pacioli to put relevance back into the teaching of double entry", *Accounting, Business & Financial History*, Vol. 20 No. 1, pp. 23-39.

Schwartz, S., Wallin, D. and Young, R. (2007), "Managerial accounting experiments for the classroom", *Issues in Accounting Education*, Vol. 22 No. 3, pp. 515-534.

**Corresponding author**
Steven T. Schwartz can be contacted at: sschwart@binghamton.edu