MANAGEMENT ACCOUNTING INFORMATION PROPERTIES AND OPERATIONS MANAGEMENT[1]

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Abstract

This monograph introduces Management Accounting to Operations Management researchers and illustrates how unleashing this accounting information perspective into the world of Operations Management can improve our understanding of topics of interest to Operations Management researchers and practitioners. We start by offering a crash course in accounting terminology and then introduce the three important properties of accounting information (i.e. imperfect nature, endogenously determined, and multi-purpose). Next, we address four different areas in Operations Management: capacity acquisition and allocation, inventory management, production scheduling, and product design. For each of these areas, we describe the approaches used in Operations Management and Management Accounting and spend considerable attention on how using an accounting approach can spur progress in Operations Management.

Keywords: management accounting, operations management, capacity, inventory management, scheduling, product design, interface between management accounting and operations management

1. Introduction

1.1. Main Objective of this Monograph

This monograph is motivated by our observation of an unfortunate trend of pigeon holing and niche forming in business research. This trend is understandable, because researchers require specialist knowledge and a deep understanding of the literature in their field to execute research projects. However, the trend is also unfortunate, as it limits our academic understanding of business practice, which is much less fragmented. In an, albeit very modest, attempt to counter fragmented thinking in academia, we focus in this monograph on the interface between the fields of Management Accounting and Operations Management, which, in practice aim to work together to create value for the firm. Operations Management consultants incorporate a variety of Management Accounting tools in their work. For example, PWC's Global Operations Survey (2015) indicates that 61% of operations managers believe cross-functional collaboration has the greatest potential for helping the firm reach its strategic goals. Deloitte's Operations Transformation group offers services in "Revenue cycle transformation" by working with healthcare providers to help them identify ways to increase their net revenues, accelerate cash flow, and reduce costs and in "Strategic cost transformation" by focusing on structural, enterprise-wide changes that can produce sustainable cost savings and margin improvements.[2] As a final example, McKinsey's Operations group works with clients to produce rapid, significant, measurable improvements in productivity, cost, quality, sales and other metrics.[3]

In academia, there is some overlap in the topics that are studied in Management Accounting and Operations Management, but research findings in one discipline seldom find their way into

[2] See https://www2.deloitte.com/us/en/pages/operations/solutions/revenue-cycle-transformation-services.html and https://www2.deloitte.com/us/en/pages/operations/solutions/about-our-strategic-cost-reduction-services.html.

[3] See https://www.mckinsey.com/business-functions/operations/how-we-help-clients. Of course, in practice, conflicts between "finance and control", which is the label used in firms for Management Accounting, and "operations" exist. A well-known conflict between "finance and control" and "operations" is the conflict in which the finance manager may want to reduce inventories to increase working capital and free up cash, whereas the operations manager may want to keep customers happy by ensuring that products are always in stock and can be immediately delivered.

scholarly discussions in the other discipline leading to quite separated academic communities publishing in nearly disjoint sets of journals. For example, Shin et al. (2012) use Management Accounting tools such as Activity-Based Costing to study customer cost-based pricing and takes issue with the "whale curve" that depicts customers' cost to serve – a topic that Management Accounting professors standardly cover in their teachings as best practice. It was accepted to Management Science through the Marketing Department and has, at the time of this manuscript going to print, not been cited in any accounting journal. A similar story is true for Nagar et al. (2009). In this paper, the authors explain that excessive work-in-process inventory – a topic that is extensively discussed in the core Operations Management course when covering modern manufacturing practices – can be suboptimal from a job-scheduling perspective but can be optimal when agency relationships are taken into account. The paper was published in Journal of Accounting Research, which is one of the top journals in the accounting area, but has to date never been cited in any Operations Management journal. It appears Operations Management and Management Accounting academics insufficiently read each other's work, let alone build on each other's work to develop a stronger interface. As Management Accounting essentially deals with developing information and such information is needed to make operational decisions, Management Accounting and Operations Management *are* intimately related at a fundamental level, suggesting that combining insights from both disciplines provides interesting opportunities to contribute to research and practice.

Our aim is to introduce Management Accounting to Operations Management researchers and to illustrate how incorporating this accounting information perspective into the world of Operations Management can improve our understanding of topics of interest to Operations

Management researchers and practitioners.[4] While Accounting may not be the topic that researchers in Operations Management would ex ante judge to be the most exciting pathway to moving Operations Management forward, we hope that, after reading this piece, they will be convinced the opposite is true and be inspired to build bridges between both areas.

1.2. Accounting as "the Language of Business"

Considering accounting as "the language of business" identifies the following properties:

1. Imperfection
2. Endogenous determination by the object accounting describes
3. Serving multiple purposes
    a. Decision-making
    b. Measuring performance

Accounting focuses on providing information for improving, assessing, valuing, and predicting performance of objects such as firms, business units, individuals and business transactions, and is often labeled as "the language of business". This commonly used metaphor reflects three important properties of accounting information. The *first property* is the notion that accounting is an *imperfect language*. Although languages are helpful to describe a certain object, and thus have the potential to improve communication, languages often give an imperfect description of the objects they aim to describe. The imperfect nature of a language becomes salient when you do not find a word or expression in another language with the same meaning and connotation. Usually, accounting describes objects by quantifying them (see Kadous et al. 2005).

[4] Since this piece was prepared for the Foundations and Trends in Operations Management series, we focus on how Management Accounting can be useful to Operations Management. Of course, Management Accounting research and practice can also benefit considerably from considering the Operations Management perspective. While we hope Management Accounting researchers too may find some inspiration for doing interdisciplinary work in this manuscript, this alternate direction of cross-fertilization is outside the scope of this paper.

For instance, accounting assigns numbers to the current value of inventory, the total cost of a product or service, or the performance of a supplier. Despite the numerical nature of accounting, these accounting numbers are, in most cases, an imperfect description of the business transactions. For instance, to support various decisions such as product pricing, product line decisions, capacity planning, and product scheduling, management accountants want to understand how costs behave and how much resources are consumed to produce a product, serve a client, or work together with a supplier. To that end, management accountants develop cost functions, which are mathematical descriptions of how cost changes in volume or in the level of an activity or process that consumes resources (see Labro 2006a). Importantly, the calculated cost of producing a product, serving a client, or working together with a supplier is an approximation of the true cost. This approximation can be inaccurate, not in the least because accounting uses linear cost functions to describe non-linear resource consumption patterns. As another example, firms have to determine the monetary value of their inventory at the end of the fiscal year. The inventory value is typically calculated based on the sum of the previous year's ending inventory level and production during the year from which sales during the year are subtracted. The value of the inventory is then determined by multiplying the inventory level and the monetary value per unit. The imperfection in the inventory value reported on the balance sheet thus depends on the accuracy of the inventory system (as the inventory system contains information regarding the inventory level) and the accuracy of the costing system (as the costing system contains information regarding the monetary value per unit). Overall, a first important property of accounting information is that it is imperfect.

The *second property* of accounting information reflected in the metaphor that "accounting is the language of business" is that the properties of a language are *endogenously determined* by the objects the language aims to describe. For instance, ancient languages like Greek and Latin

cannot describe modern objects such as cell phones and personal computers because these objects did not exist in the ancient times. Applied to a business setting, the structure of the objects (i.e., the business transactions, business units, and firms) that accounting aims to describe, determines the properties of that accounting information. For instance, the accounting information that is reported to an operations manager differs depending on whether the production is organized as a push system or a pull system. In a push system, a metric such as inventory turnover rate will be reported to the operations manager but under a pull system, a metric such as the time between the customer order and delivery will be made available. Also, the accounting information that is collected to evaluate the performance of a business unit depends on the responsibility assigned to the business unit. Specifically, if the business unit has the full responsibility for the different tasks, including pricing of the products and services, more aggregated performance measures such as 'net profit' and 'economic value added' will be collected. However, if the business unit cannot set prices for the products and services delivered, more disaggregated performance measures such as total production costs, and quality-oriented measures such as the number of defect parts per million will be used (Bouwens and Van Lent 2007; Ittner and Larcker 2001).

The *third property* of accounting information reflected in the language-metaphor is that the properties of a language are determined by the *multiple purposes* for which the language is used. For instance, the plain version of a language and the dialectic version of a language have different properties because they are used for different purposes. Broadly speaking, accounting information has two broad purposes in modern firms. First, accounting information is expected to enable the operations manager to make decisions that increase firm value, which is often referred to as the decision-facilitating role of accounting information. For instance, an operations manager decides how often the inventory status should be determined, when a replenishment order should be placed,

and what the characteristics of the replenishment order should be. An operations manager also decides on product line design and has an important input during new product development processes. Developing production schedules is another example of a task of an operation manager with a big impact on overall firm value and firm performance. The second purpose of accounting information is to resolve agency conflicts between the owners of the firm (Principal) and the operations manager (Agent) or between the operations manager (Principal) and his subordinates (Agents), which is often referred to as the decision-influencing role of accounting information. Firms can use accounting information to measure performance, provide incentives, and hence influence effort decisions. Because the effort of the Agent, who is assumed to be self-interested, is typically unobservable, he has the opportunity to shirk rather than to put in high effort. However, the Agent can be induced to exert effort in a way that generates value for the firm by designing an appropriate pay structure. The pay structure typically consists of a wage which is a function of an observable outcome that is related to the unobservable effort of the operations manager. Such an observable outcome that proxies for unobservable effort is typically labelled a 'performance measure'. For instance, product costs can be used to evaluate the performance of the operations manager on the firm's objective to be cost efficient.

Importantly, the properties of the accounting information depend on whether the purpose of the accounting information is to improve managerial decision-making or to measure and evaluate managerial performance. For instance, when improving decision-making is the main purpose, more disaggregation of the product cost is desirable so that the operations managers can see where the biggest cost reductions can be realized. However, when headquarters wants to evaluate a manager's contribution to a collaborative effort among the firm's business units to introduce innovations to its internal supply chain that reduce overall costs, they are better served

by an aggregate cost measure at firm level than by a measure of business unit costs, which does not take the interdependence of the cost reduction effort across business units into account. Overall, the metaphor that "accounting is the language of business" nicely reflects the three important characteristics of accounting information: its imperfect nature, the endogenous determination of its properties, and its multi-purpose nature. In this piece, we will explore how incorporating the three important properties of accounting information can improve our understanding of topics studied in Operations Management.

1.3. Delineating the Monograph's Objective

As Accounting and Operations Management are broad areas, we have to make choices regarding the sub-areas we want to cover in this paper. The two main sub-areas of accounting are Financial Accounting and Management Accounting.[5] Financial Accounting is concerned with the role of accounting information to improve decisions of external decision-makers such as tax authorities, banks, governments, analysts, and investors or to help these external parties assess the firm's performance and value. Management Accounting is concerned with the provision of accounting information within the firm to improve decision-making and performance measurement. Overall, Management Accounting information serves to make improved decisions and to measure progress towards the firm's objectives. Since we believe that there is a more intuitive fit between Operations Management and Management Accounting and since our main expertise lies in the domain of Management Accounting, we have chosen to explore how well-established findings in the area of Management Accounting can enrich our understanding of Operations Management topics. As for the type of Operations Management topics we will study in this paper, we have chosen to focus on decision problems that stay within the boundaries of the

[5] Tax Accounting and Auditing are outside the scope of this manuscript.

firm.[6] Such decision problems include problems related to scheduling, inventory management, new product development, forecasting, work process design, etc. By no means do we aim to be exhaustive in the Operations Management topics covered. Instead, our aim is to provide illustrations that may inspire other researchers to think about further Operations Management applications where the imperfection, endogeneity, and multi-purpose character of information used may shed new light and generate new insights.

This paper is organized into several sections. Before we move to developing the three properties of accounting information previously introduced (imperfection, endogeneity, and multi-purpose character) and provide an overview of Management Accounting research on these properties in Section 3, we first provide a crash course in the Management Accounting terminology on costing systems in Section 2. We warn our readers that particularly Section 3 is fairly long, given the amount of introduction to the Management Accounting literature that is necessary to set you up to do a deep dive in its application to the Operations Management topics. We are grateful for your patience. In Section 4, we will give some excellent examples of studies on the interface between Operations Management and Management Accounting. In Section 5 to 8, we explore 4 areas in Operations Management (i.e. capacity planning and allocation, inventory management, production scheduling, and product design) and provide suggestions on how the use of a Management Accounting perspective can generate new insights that are important for research and practice. Section 9 gives some practical advice on how to set up research projects on the interface between Operations Management and Management Accounting. The last section concludes.

[6] We do not cover topics related to buyer-supplier relationships and the optimization of the supply chain that span beyond the single firm orientation as there already exists substantive work that examines the usefulness of accounting to study these topics (Anderson and Dekker 2014).

2. A Crash Course in Costing System Terminology

Every field comes with its terminology, and before we dig deeper in the role of the properties of accounting information in Operations Management, we want to ensure that all readers are comfortable with the language used in Management Accounting. In this section, we will introduce some frequently used Management Accounting terminology related to costing system design. One of the most important sources of accounting information in general and maybe the most important one in the specific context of Operations Management is cost information. Readers familiar with the terminology are free to skip this section. This section borrows extensively from Hemmer and Labro (2017).

In most firms, costing systems serve many different needs such as product pricing, product line decisions, capacity planning and allocation, performance measurement and control, project scheduling, project selection, and benchmarking. In order to improve decision-making and performance management, managers try to understand how costs behave and how cost objects consume resources by means of cost functions. A cost function is a mathematical description of how cost changes with changes in volume or in the level of an activity or process relating to that cost (Labro 2006a). Cost objects are the products, services, distribution channels, customers, or any other part of the business for which a manager may wish to understand how much of the firm's resources it consumes. Costing is therefore in essence an approximation exercise: within a relevant range, management accountants seek to derive a function that approximates the underlying true cost behavior. Various methods have been developed to make this approximation. These methods typically are considered "full costing" methods where the cost of all resources consumed by the cost objects, including fixed costs, are allocated to these cost objects.

2.1. Traditional Costing Methods

Traditional costing methods estimate cost as a linear function of the volume of products (even if the true behavior may be non-linear). Johnson and Kaplan (1987), Cooper and Kaplan (1987), and others have claimed that these traditional costing methods were systematically distorting product costs, leading to wrong decisions being taken on the basis of these costs. They critiqued the simplicity of only considering costs to be either variable with volume or fixed and disapproved of the exaggerated use of direct labor hours as an allocation base in the changed production environment of that time where fewer hours of direct labor were used. Also, with a move towards the service industry, a bigger share of the costs become indirect and therefore had to be allocated using some allocation base. Picking the wrong allocation base in this setting has disastrous consequences.

2.2. Activity-Based Costing

Activity-Based Costing (ABC) was then coined as a more accurate costing method whereby allocation bases are chosen to better reflect the cause and effect relationship in resource consumption patterns. ABC estimates change in cost as a function of changes in level of activity, where an activity is any discrete task that a firm undertakes to make or deliver a product or service. New cost drivers (factors that cause or "drive" an activity's cost; in essence, the same as the old term "allocation bases"), other than volume-based drivers such as direct labor hours and direct machine hours, were now used to allocate the cost of the resources aggregated in these activity cost pools. Examples include number of set-ups to allocate the cost of the set-up activity, number of purchasing orders to allocate the cost of the procurement activity, number of machine insertions to allocate the cost of the machining activity, number of inspections to allocate the cost of the inspection activity, and number of different components to allocate the cost of maintenance of the Bill of Materials.

Important is that these new cost drivers are introduced in the ABC hierarchy, creating an understanding that costs are driven by (and hence vary with respect to) activities that occur at different levels. The typical hierarchy considers 4 levels: unit, batch, product (or service)-sustaining, and facility-sustaining. The hierarchical level at which a particular cost is classified indicates when this cost becomes variable. Costs on the unit level are the costs that are traditionally called variable costs and are incurred per unit (e.g. price). Costs on the batch level are incurred each time a batch is delivered or brought to the production line (e.g. inspection and set-up costs). Product-sustaining costs are incurred to enable the production and sale of a particular product (e.g. product design and product advertising). Facility-sustaining costs are costs that are fixed in the short run. They only become variable when the facility is closed down or reduced in size. This ABC hierarchy helps management identify which costs are incremental for different types of decisions. For example, if the decision concerns whether or not to produce one extra unit of a product, only the unit level costs (such as the material to use in the unit) are relevant. However, for the introduction of a new service to the firm's service mix, all costs up to the service-sustaining costs (such as service development and service specific marketing) are to be considered. Furthermore, this distinction captures more of the non-linearity in true cost behavior, although at each hierarchical level costs are still assumed to be linear with the cost driver at that level.

2.3. Time-Driven Costing

A more recent cost method innovation is Time-driven costing (TDC) (Kaplan and Anderson 2004). TDC was introduced because of a perceived dissatisfaction with the complexity and low maintainability of ABC systems, which were argued to be particularly harmful in industries subject to rapid change. Two simplifications are proposed in this method. First, TDC systems only use time as a cost driver. The first TDC implementations were in the distribution and health care sector where time spent by the employees and human capital of the firm is an obviously

big percentage of resources. However, the idea of time as a cost driver can extend to time spent on machinery or in facilities or warehouses. Cost rates per unit of time of each resource can then be calculated. Second, TDC introduces the notion of time equations. A time equation collects information on the quantity (in units of time) of each resource that supports an activity that is required to produce a unit of the cost object. Next, the cost rates per unit of time are multiplied with the units of time needed to calculate the cost of the cost object. While no survey evidence is available yet on widespread adoption of this technique, case studies illustrating its use have been published.

Next to ease of maintenance, proponents of TDC argue it is a better method to identify the cost of unused capacity. In TDC, employees are asked for estimations of the time they spend on doing one activity in minutes (e.g. how many minutes does it take to type up an invoice) rather than allocate the percentage of their time they spend on different activities (e.g. how much percent of your time goes to typing up invoices versus placing orders) as is done in the ABC method. ABC hence is unlikely to identify unused capacity as employees will bias their time estimates upwards to conceal the fact that they have some idle time and ensure that all percentages add up to 100%. Hence, ABC cannot identify unused capacity well. In TDC, employees would need to have information on the number of times they do an activity in a working period readily available, multiply these quantities with the time estimates per activity, and compare those minutes to the number of minutes that they are contracted to work to conceal any idle time. It is unlikely that boundedly rational employees go through such process, so at the end of the contracted time period the Management Accounting system can easily make this calculation and in doing so identify idle capacity, both in time units as in monetary cost. For more detail on the mechanics of each of these techniques and numerical examples, we refer to Balakrishnan et al. (2012).

3. Properties of Management Accounting Information

With the appropriate dictionary under our belt, we are now ready to fully develop the three properties of accounting information as provided by the accounting department to other functional disciplines, such as the operations management group.[7] That is, accounting information is imperfect, endogenously determined, and serves multiple purposes.

3.1. Accounting Information is Imperfect

Imperfection of accounting information can arise from incompleteness (not all aspects of the business are described or are described with insufficient detail) and inaccuracy (aspects of the business are described with noise and/or bias).[8] Once it is decided which aspects of the business ought to be measured, accounting information aims to measure these underlying constructs of interest (such as the unit cost of a product or the effort level of an employee) as accurately as possible but there is often a difference between the measured value and the true value of the underlying construct, resulting in imperfect information. In its very basic form, the difference between the measured value and the true value can be described as follows (Bloomfield 2016): Measured value = True value + Noise + Bias. Noise refers to the random and unpredictable differences between the true value and the measured value and can arise because accounting information is incomplete (i.e., not all aspects of a particular business transaction are described)

[7] We will use the 'accounting department' and the 'finance and control department' interchangeably to refer to the department in a firm that supplies information for making decisions and developing performance measures. These terms are both used in practice.

[8] A third aspect of imperfection in accounting information is lack of timeliness: aspects of the business are described with delay. There can be substantial delay in producing management accounting information. For example, Kaplan and Anderson (2004) mention the example of a bank's brokerage operation where it takes 14 full-time management accountants to produce monthly ABC reports. However, the financial accounting literature has been dominant in focusing on the timeliness of accounting information, since a particular frequency of financial reporting is mandated (e.g. yearly, quarterly) (e.g. Gigler and Hemmer 1998; Fu et al. 2012) and since particular earnings news needs to be presented without delay (e.g. losses need to be recognized in a timely manner) (e.g. Bushman et al. 2011; Jayaraman 2012). Our development will hence focus mostly on the aspects of incompleteness and inaccuracy.

or inaccurate (i.e., not all aspects of a particular business transaction are described in sufficient detail).

Bias is the predictable sign in the difference between the true value and the measured value. As we will illustrate in later sections in more detail, bias can have several sources. For example, collecting information for performance measurement can introduce bias because people will behave differently when they know that particular (parts of a) business transaction they are involved in are measured. This idea originates in Campbell's Law, which is an important law in social psychology stating that "*the more any quantitative social indicator is used for social decision-making, the more subject it will be to corruption pressures and the apter it will be to distort and corrupt the social processes it is intended to monitor*". For instance, if you announce you will start measuring employee effort by checking each Wednesday whether employees arrive on time and do not leave the firm earlier than the contractually agreed time, employees will make sure they arrive and leave on time on Wednesdays, leading to a higher percentage of employees working the contractually agreed hours on Wednesdays compared to any other day of the work week, resulting in an upwards bias in the measure of employee effort.[9] Bias can also be consciously introduced in cost information used for decision making. For instance, to incentivize development teams to use common components when developing new products, managers can deliberately over-cost unique components, implying that managers increase the cost of the unique components as reported by the costing system with a certain amount or percentage (Merchant and Shields 1993).

[9] Note that this measure is a noisy measure for employee effort as well since the manager does not know whether the employee provides any effort between arriving and leaving nor has insights into the intensity with which the employee works.

There are several reasons why accounting information is imperfect. Below we give a non-exhaustive overview of these reasons. Broadly, these reasons fall into two classes. First, perfect information is a benchmark that is impossible to be achieved. Second, even if a firm can theoretically move closer to perfect information provision, the trade-off between the costs and the benefits of developing more complete and more accurate accounting information may cause it to not adopt the most complete and accurate Management Accounting system possible.

Why is accounting information imperfect?

1. Impossible to achieve perfect information
2. Cost-benefit trade-off may stop firms from moving closer to perfect information
    a. Financial constraints
    b. Decreasing marginal benefits
    c. Trade-off is affected by firms' environment

3.1.1. The Impossibility of Perfect Information

Completeness and full accuracy are usually unachievable. Indeed, the entire incomplete contracting literature (Alchian et al. 1978) starts from the premise that the contracting parties are unable to foresee or describe (in a contract) all potential future states of the world. The focus of this established and extensive economics literature is on the potential for post-contractual opportunistic behavior created by such incompleteness, and the resulting hold-up effect: the party expected to be held up will underinvest in the relationship. This literature has studied the allocation of control rights as a mechanism to resolve or alleviate the hold-up problem: whichever party owns the asset gets to make the decisions regarding the asset at the time the future state of the world materializes.[10]

[10] For papers on the role of incomplete contracting in accounting, we refer the reader to Christensen et al. (2016) on financial accounting and debt contracting and to Baiman and Rajan (2002) on managerial accounting and supply chain contracting.

But even if we venture to a complete contracting world where all future states of the world are foreseeable, the Management Accounting literature on costing has researched the impossibility of obtaining fully accurate information. Although accountants have become better at approximating the true cost by using more advanced costing systems such as ABC and TDC, these more advanced costing systems still produce unit costs with error. Datar and Gupta (1994) and Noreen (1991) are complementary papers that establish how errors in product costs can arise. Noreen (1991) derives necessary and sufficient conditions for (ABC) product costs to reflect incremental cost that capture the changes in cost as a result of a decision and discusses violation of non-jointness and linearity assumptions. The three conditions are:

1. Separability of cost pools: total cost can be partitioned into cost pools, each of which depends solely upon one activity
2. Linearity in activities: cost in each cost pool must be strictly proportional to the level of activity in that cost pool
3. Additivity / separability of drivers: activity drivers assigned to individual products can be simply summed to arrive at total activity

These conditions rule out a lot of situations. First, joint costs (where production costs are a non-separable function of the outputs of two or more products, and unavoidable jointness arises from the technology used to produce the joint outputs) can only be treated as incremental to all the cost objects which use the underlying resource, as they have a public good characteristic. Examples are capacity for peak and off-peak demands, spare capacity information technology, corporate advertising and corporate credit rankings. An oil refinery takes crude oil and refines it into car gasoline, motor oil, kerosene and heating oil in pre-specified proportions. A decision to increase the production of kerosene will affect not just the cost of kerosene, but will lead to increased

production of all the other products that crude oil transforms into as well. That is, the cost is incremental to the portfolio of these products, and not just to kerosene. Second, non-linear functions at cost pool level (e.g., quantity discounts) are also ruled out as are (third) linear functions with non-zero intercept at cost pool. Lastly, any interdependences between products in the production process result in a violation of the necessary and sufficient conditions.

Datar and Gupta (1994) discuss further costing errors assuming away jointness and linearity issues raised by Noreen (1991). They start from the premise of ABC advocates that multiple cost pools and multiple activity drivers better reflect the cause and effect relation between overhead resource consumption and products and that refinement in the cost system must hence lead to improved accuracy of product costs. However, they define different kinds of errors in costing systems (in general and ABC in particular) and document trade-offs between them. The first error is *specification error* where a wrong cost driver is chosen that does not exhibit a cause and effect relationship between resource use by products. For example, the traditional costing systems are high on specification error because of an overuse of volume-based allocations. The second error is *aggregation error* where similar cost drivers are added together, and cost and units of a resource are aggregated over heterogeneous activities to derive a single cost allocation rate. For example, marketing and insurance costs may be pooled together in a "general overhead" cost pool.

The demand for refined cost systems such as ABC arises from the desire to reduce specification and aggregation errors. *Measurement error* can, however, also occur. First, there is measurement error of cost pools where costs are wrongly identified costs with a particular cost pool. For example, financing costs are accidentally added to the marketing cost pool. Note that financial accountants and auditors focus on reducing this type of measurement error by ensuring

each invoice is booked in the correct general ledger account. Second, there exists measurement error of units of allocation bases, where the specific units of resources consumed by individual products are wrongly measured. For example, the reported usage of the set-up activity by product line A is higher than its true usage. In a series of examples, Datar and Gupta (1994) illustrate that one type of error may over-cost a product, while another may under-cost a product, but that overall the product may be fairly accurately costed because of the trade-offs between these errors. However, if the firm refines its costing system by removing or reducing one error, it may end up with a less accurate product cost! They conclude that partial refinement of costing systems (an approach advocated by ABC advocates for reasons of reducing resistance to change, limiting scope and cost of new systems implementations, etc.) may not always work!

Of course, while this is an important warning against common practice at that time, at this point in the literature we still do not know how prevalent the trade-off between errors is, and hence how widespread the problem with partial refinement may be. In a simulation study of a two-stage cost allocation system, Labro and Vanhoucke (2007) show that the trade-off typically only happens in very extreme cases, and that the only general, potentially problematic, trade-off occurs between measurement error on the resource cost drivers and aggregation error on the activity cost pools. They also show that measurement error on the activity drivers impacts inaccuracy the most, followed by aggregation error on the activity cost pools and that measurement error on the resource cost pools impacts accuracy the least. Labro and Vanhoucke (2008) proceed to look into the efficacy of textbook rules of thumb on focusing accuracy improvement on "high diversity" in resource consumption situations. Balakrishnan et al. (2011) look into the efficacy of the Willie Sutton rule that advises to focus on the largest resources and devises further rules of thumb on disaggregation and the selection of drivers at each cost pool. They focus on rules of thumb that

can be set up given limited information about resource consumption by products (e.g., resource consumption is only known at a level of aggregation or for particular "driver" resources). Cardinaels and Labro (2008) show in a laboratory experiment that also in a TDC setting, people introduce measurement error in the time estimates used for the cost calculations, even if they are incentivized to report as accurately as possible.

The Management Accounting literature has also documented unintended biases in costing information. Christensen and Demski (1997) stress the importance of looking at cost estimation errors from a portfolio objective, because biases may be upwards or downwards on different products in the portfolio. Labro and Vanhoucke (2007) find that the presence of aggregation and measurement errors usually results in relatively more products being under- than over-costed, with large amounts of over-costing for a few "big-ticket" (in dollar terms) products, and small amounts of under-costing for a larger number of less expensive products. Cardinaels and Labro (2008) find that when laboratory experiment participants are asked to estimate the time they spend on various activities in minutes (time spend is one of the most commonly used cost drivers in Activity-Based Costing and the sole cost driver in Time-Driven Costing), they overestimate the total time spent by an average of 37%.

In principle, cost objects can be any part of the business of which we wish to understand how much of the firm's resources it consumes. This moves beyond products and services to customers, suppliers, distribution channels, and business units. In the literature, though, often the term "product costing" remains used. This can be confusing to non-accountants, as the term does not make it explicit that the same costing procedures can be used to approximate the resource costs of any type of cost object. However, the fact that firms may be interested in approximating the cost of different types of cost objects can entail another source of incompleteness of cost

information, as typically costing systems are designed to report on one type of cost object. In some instances, reported costs can easily be aggregated up to a higher level cost object. For example, business unit costs can be aggregated from the costs reported for all products produced in that business unit. In other instances, aggregation may not solve the informational incompleteness of only looking at one "cut" of the costing data. For example, in the context of the use of common components in product architecture, Israelsen and Jørgensen (2011) show that the cost accounting system centered around components cannot accommodate the higher level portfolio view required for all products that may be candidates to use such a common component. Since many Operations Management decisions are at portfolio level, this particular informational incompleteness may hamper optimal decision making.

3.1.2. The Trade-Off between the Costs and Benefits of Developing More Accurate and Complete Information

The consideration of the trade-off between the costs and the benefits of developing more complete and accurate accounting information results in firms settling for Management Accounting systems that are less accurate and complete than what is theoretically achievable. The first aspect in this trade-off is the financial constraints firms experience in developing better accounting information. That is, producing accounting information is costly, and a manager can only choose an information production system that satisfies the financial constraints. For instance, smaller firms are less likely to have ABC- or TDC-systems because of the investment that is needed to set up such costing systems (Al-Omiri and Drury 2007). Not only will firms that rely on the traditional volume based costing systems have more noise in their Management Accounting information, but they will also have more biased information.

Bias in costing makes products look cheaper or more expensive than they are. When comparing ABC to traditional volume based costing, traditional costing favors low-volume, high-

specialty products. High-volume, low-specialty products attract a lot of overhead when that is allocated based on volume and hence are over-costed. Low-volume, high-specialty products attract very little volume-based overhead, and it is not recognized that they use a lot of specialty activities. Hence, these products are under-costed. When a firm moves from traditional costing to ABC, we can predict which types of products will look more expensive and cheaper than before. High-volume (low-complexity) products tend to drop slightly in costs as they now get less overhead allocated, whereas low-volume (high-complexity) products tend to increase dramatically in costs as it is now recognized that they consume a lot of specialty activities. The decrease in costs for the high-volume products is spread out over many products, whereas the increase in cost for the low-volume products has to be borne by few products. Hence, percentage cost reductions tend to be small, while percentage cost increases are likely to be large. This is reflected in many Harvard Business School case studies. For example, the changes in reported product costs in the Shrader Bellows case ranged between -10% and +1000%, while those in Rockwell International (now Meritor) ranged between -20% and +40%.

Second, even without financial constraints, it is very unlikely that trading off the costs and benefits of developing better accounting information results in firms opting for the highest level of quality in accounting information achievable. From some point onwards, the additional monetary costs to develop better accounting information outweigh the benefits that can be monetarily proven.[11] For instance, an operations manager optimizing a newsvendor problem claims that he can reduce the probability on a stock-out if the noise in the sales figures is reduced.

[11] As far as we know, there is no large-scale survey evidence available on the price of advanced costing systems in firms. Anecdotally, prices seem to vary from a few $1,000 to millions depending on the characteristics of the firm and the sophistication of the system. Balakrishnan et al. (2011)'s evidence suggests that the accuracy benefits of improved costing system sophistication taper off fairly quickly, so for firms with the least sophisticated systems it is possible that the benefits do not outweigh the cost.

However, the firm will only invest in better information about future sales if the reduction in the number of stock-outs leads to an increase in revenues that is higher than the cost of obtaining sales figures with less noise.

Third, the cost-benefit trade-off is also influenced by contingencies or contextual variables faced by the firm. That is, the benefit of the same reduction in the imperfection of Management Accounting information differs across firms because firms are operating in different environments. For instance, Al-Omiri and Drury (2007) document a positive relationship between the importance of cost accounting information and the sophistication of the cost system as well as a positive relationship between the intensity of the competitive environment and the sophistication of the cost system. These observed relationships can be explained by the fact that the benefits of better accounting information are larger when that information can be used for multiple strategic and operational decisions such as pricing, cost reduction, and innovation. Also, better accounting information is more useful when competition is strong as in such environment pricing mistakes can be detrimental to the firm's survival and firms in competitive areas or sectors hence require a better insight into their product costs.

Fourth, from some point onwards, the benefits of providing better accounting information do not increase anymore and may start to decrease because humans are boundedly rational. People face difficulties in processing increased amounts of more detailed accounting information. Impaired cost-based decision-making will result when the costing system uses 1000 drivers to allocate costs to the different products compared to a costing system that only uses 50 drivers. Accounting research has studied which characteristics of the decision maker and the information affect the processing capabilities of boundedly rational people.[12] Cardinaels (2008) documents that

[12] Machine learning techniques may provide a way to relax this processing constraint, and start to make their entry in research too (e.g., Glaeser et al. 2017).

the impact of more detailed accounting information on better decision-making quality depends on the match between the accounting knowledge of the decision-maker and the format in which the detailed accounting information is presented. Specifically, decision-makers with strong cost accounting knowledge perform better when the detailed accounting information is presented in tables, but decision-makers with weak cost accounting knowledge perform better when the detailed accounting information is presented in graphs. Furthermore, given such bounded rationality, firms will choose to only introduce cost drivers that are of focal interest (Merchant and Shields 1993).

3.1.3. Summary

Taken together, Management Accounting information is imperfect (that is, incomplete, inaccurate, and biased) because (1) it is impossible to perfectly describe complex business transactions, (2) the properties of accounting information are the outcome of a trade-off between the costs and benefits of better accounting information which is influenced by the financial constraints faced by the firm, the decreasing marginal benefits of improving the properties of accounting information, the environment in which the firm operates and bounded rationality of the people using the accounting information, and (3) both deliberate behavior and accidental choices increase the signed difference between the true value and the observed value.

3.2. Accounting Information is Endogenously Determined

A common misconception about accounting information is that accounting information properties are exogenously imposed. In particular, this misconception is prevalent when financial accounting information is considered. Indeed, to some extent, the properties of financial accounting information, such as the balance sheet, profit-and-loss statement, and cash flow statement, are determined by accounting regulators and are thus quite homogeneous across firms. For instance, all firms have to provide an estimate of the value of their property, plant and equipment on the balance sheet, and their sales on the income statement. The main goal of

accounting regulators is to impose a lower bound for the precision of the financial accounting information in order to ensure a sufficient information flow to various types of outsiders such as shareholders, future investors, government agencies, and other stakeholders.[13]

3.2.1. Endogenous Determination of Financial and Management Accounting Information

Despite the presence of financial reporting rules, firms still have the discretion to increase the precision of the financial accounting information. For instance, the line item on the income statement 'Selling, General, and Administrative (SG&A) Costs' typically includes the advertising expenses of the firm, next to labor expenses that are not included in the cost of goods sold and a wide range of other administrative costs. For outsiders, it can be interesting to have insight into the pattern of advertising expenses as this can be predictive of future sales. It is, however, not mandatory to separately disclose the advertising expenses. For instance, Apple only discloses the SG&A-costs as a whole and does not provide additional information on the advertising expenses in the notes. Johnson & Johnson, however, discloses the SG&A-costs in the income statement and provides information about the advertising expenses in the notes. Importantly, firms have additional ways to disclose information to outsiders (e.g., voluntary disclosures, news releases, earnings conference calls, etc.) leading to more heterogeneity in the properties of financial accounting information compared to what is commonly expected. The main reason why we see variation in what firms disclose to outsiders is that the trade off between the costs and benefits of disclosing particular information differs across firms. As a result, properties of financial accounting information are endogenously determined by trading off the costs and benefits of providing such information to outsiders.

[13] Note that regulatory financial reporting requirements may differ in stringency based on firm characteristics such as whether a firm is public or private and below or above certain size cut-offs.

As the properties of Management Accounting information are not determined by external regulators, the endogenous nature of the properties of Management Accounting information is even stronger than the endogenous nature of the properties of financial accounting information. The properties of Management Accounting information are endogenously determined through other organizational design choices. A large stream in the Management Accounting literature studies how the performance measures used to evaluate business unit managers depend on organizational decision choices such as the authority that is delegated to these business units and the interdependencies between the business units. Bouwens and Van Lent (2007), for instance, document that the weight on accounting return measures, such as return on investment or Economic Value Added (EVA), to evaluate business unit managers is positively related to the authority of the business unit manager and that the weight on disaggregated measures, such as revenues and expenses, and the weight on nonfinancial measures, such as customer satisfaction or the percentage of defect units, is positively related to the interdependencies between business units. Moers (2006) documents that the relationship between the delegation of authority to a business unit manager and the use of financial performance measures for evaluating the business unit manager depends on the properties of the financial performance measures (vis-a-vis nonfinancial performance measures) to reliably measure the extent to which the effort of the business unit manager contributed to firm value. Other papers in this area include (non-exhaustively) Abernethy et al. (2004), Bushman et al. (1995), and Hwang et al. (2009). Overall, the important message is that the properties of Management Accounting information as observed in firms cannot be considered in isolation but should be considered in relation to other organizational design choices. As a result, a potential reason why firms may not invest in better Management Accounting

information is the lack of fit with other organizational design choices and/or the difficulty to adapt the organizational design to create such fit.

3.2.2. Operations Management Endogenously Determines Accounting Information Properties

The endogenous determination of the properties of Management Accounting information is important for Operations Management researchers because a lot of the organizational design choices are linked to the operations of the firm and are thus choices that are studied in Operations Management. Ittner and Larcker (1995), for instance, argue that total quality management (TQM), which they define as an firm-wide philosophy and problem-solving methodology that focuses on systematically and continuously improving the quality of products, processes, and services, requires new approaches to Management Accounting information. Specifically, they argue that TQM requires a more extensive distribution of information across the organizational hierarchy, the development of new types of accounting information, and the use of reward systems that place a greater weight on quality and team-based performance. Their empirical results not only reveal that the implementation of TQM is indeed related to the properties of the accounting information that is collected, but that this relationship differs between firms that implement some basic TQM-practices and firms that implement advanced TQM-practices. Firms that implement basic TQM-practices place greater emphasis on team and nonfinancial performance have more frequent provision of quality information to all levels and are more likely to use bottom-up data-gathering techniques such as statistical process control. Firms that implement advanced TQM-practices, on the other hand, have more frequent external benchmarking of products, processes, and services, communicate strategic information more broadly throughout the firm and have more frequent reviews of the quality plans and reports by the board of directors. Focusing on the choice of performance measures in CEO annual bonus contracts, Ittner et al. (1997a) document a positive

relationship between the adoption of strategic quality initiatives and the inclusion of nonfinancial performance measures such as product quality and customer satisfaction in CEO annual bonus contracts. Other studies have focused on other Operations Management philosophies, such as just-in-time, and the results also reveal a relationship between the extent to which a particular Operations Management philosophy is implemented and the properties of the accounting information collected in the firm (Fullerton and McWatters 2001).[14]

3.2.3. Summary

Management Accounting information is endogenously determined:

1. Direct: Firms have discretion in choosing properties of Management Accounting information
2. Indirect: Organizational design choices affect properties of Management Accounting information
3. Bi-directional:
    a. Changing operations lead to changes Management Accounting information
    b. Management Accounting Information supports decisions on how to organize operations

Taken together, the properties of Management Accounting information are not exogenously imposed on firms but endogenously determined by various organizational choices, among which choices studied by Operations Management researchers are an important category. The endogenous relationship between Operations Management choices and properties of Management Accounting information seems to be quite intuitive. That is, as the main role of Management Accounting information is to reflect the operational reality of the firm, it is straightforward that the variation in the operational reality of the firm will induce variation in the properties of the accounting information. On the other hand, switching from one way of organizing your operations to another is only possible if Management Accounting information with particular properties is available or can be made available. For example, lean strategies are likely only

[14] Hoozée and Bruggeman (2010) illustrate how the process of implementing a new time-driven costing system in their case firm helped employees and leaders identify operational improvements.

successful if inventory accounting records are accurate enough so that inventory can be kept low without running into an unanticipated stock-out problem. We will develop examples on Operations Management topics in subsequent sections that show that additional insights are gained when this bi-directional role between Operations Management practices and properties of Management Accounting information is considered.

3.3. Accounting Information serves Multiple Purposes

3.3.1. Multiple Purposes

Management Accounting information can be used for two purposes. First, Management Accounting information can be used to make organizationally desirable decisions, thereby enhancing employees' ability to contribute to the realization of the firm's objectives. In other words, employees need Management Accounting information to make decisions related to pricing, planning, capacity utilization, cost reduction, etc. For instance, to make good pricing decisions, employees need appropriate Management Accounting information about the costs of a product. This purpose of Management Accounting information is often referred to as the 'decision-facilitating role' or Management Accounting information for 'planning and decision-making'. Second, Management Accounting information can help to align the interests of the employees with those of the owners of the firm by directing effort and attention to activities that contribute to the realization of the firm's objectives. In other words, Management Accounting information is used to address agency conflicts that arise in firms. For instance, to motivate operations managers to pay attention to continued cost reductions of the manufactured products, the bonus of the manager can be based on an accounting measure of the percentage change in cost compared to last year for the products the manager is responsible for. This purpose of Management Accounting information is often referred to as the 'decision-influencing role' or Management Accounting information for 'control and performance measurement' (Sprinkle 2003).

The ideal characteristics of information to support decision-making are different from those that are best suited to support performance measurement. For decision-making, information that improves the predictability of the future state of nature and hence allows the decision maker to better adapt his decisions to that state is better (Blackwell theorem). On the other hand, information is valuable for performance measurement if it improves the Principal's knowledge of the Agent's action choice, helping the Principal to better discern whether the Agent put in high or low effort (Hölmstrom 1979). As a consequence, they will bring down the cost of contracting with the risk averse Agent whose incentive compensation can be made less risky, in that high effort becomes more likely to be reflected as such in the observable performance measure. [15]

3.3.2. Trade Off between Multiple Purposes

Under ideal circumstances, the accounting department tailors the Management Accounting information to the intended usage of that information for planning or control. For instance, if capacity information is used in a firm to make capacity decisions and to evaluate performance of managers, then the accounting department ideally would design two separate information sets with each information set having its own properties. Specifically, capacity information that is used to make short-term capacity decisions should be timely as a speedy reaction to capacity shortages is necessary. Timeliness is, however, less important when the capacity information is used for the evaluation of managers as the firm wants to know the average capacity utilization over the entire

[15] The planning role and control role of Management Accounting information are not necessarily leading to conflict on what are desirable characteristics of Management Accounting information but ought to be at least considered jointly in their impact on which information ought to be provided. For example, ABC-information on non-volume drivers of costs can be useful to realize cost reductions and process improvement as opportunities at the batch-level, product-level, and facility-level are made visible. Inspired by the idea that realizing such cost reductions requires the cooperation between employees and/or departments, Drake et al. (1999) document that the benefits of providing ABC-information to realize cost reductions are dependent on the incentive system that the employees are subject to. Specifically, combining ABC-information with an incentive system that stimulates cooperation among employees leads to the highest amount of cooperative innovations that reduce costs and also the highest overall profits. When employees have ABC-information and are subject to an incentive system that stimulates competition between employees, employees focus on individual innovations that reduce costs, but this leads to a higher cost per unit and lower overall profits. Thus, the benefits that firms derive from providing better decision-making information depend on the incentive system that is in place.

period for which it pays bonuses and to what extent the capacity utilization is influenced by factors that cannot be controlled by the manager.

Financial constraints, however, impose restrictions on the (number of) information sets firms can produce. Because of these financial constraints, the properties of accounting information also reflect the trade off the firm makes between the importance of a particular information set for planning versus control purposes. In our capacity information example, if the planning role is more important, then the firm will invest more in timely information, but if the decision-influencing role is more important, then the firm will invest more in correcting the observed capacity utilization for uncontrollable factors. Financial constraints are not the only source of conflict between the purposes for which accounting information is collected. For example, if detailed accounting information is collected for supporting decision making, it is automatically also available to develop a better, more disaggregate performance measure on the unobservable effort of the operations manager. In the agency setting, however, there may be some reasons why that detailed information is actually undesirable. For example, if the provision of detailed information means that the Agent can more easily shirk as they can better match their effort level to the information they observe, and pretend to be working rather than shirking, the Principal may actually not like that such detailed information is provided for performance measurement reasons, and may hence choose to withhold it too for decision-making purposes.

3.3.3. Summary

Management Accounting information is used in firms to facilitate decisions that improve firm value as well as to address agency problems. Because of the presence of financial constraints and other strategic reasons, the observed properties of Management Accounting information in a particular firm reflect the trade off between the use of Management Accounting information for

facilitating decisions and addressing agency problems. In the next section, we will describe how properties of Management Accounting information can be empirically measured.

3.4. Measuring Properties of Management Accounting Information

Empirical Operations Management research and empirical Management Accounting research share a common hurdle: data availability. The properties of Management Accounting information are by definition private to the firm. Firms are not mandated to disclose which Management Accounting information they collect. Most firms also do not disclose much information about the decisions for which Management Accounting information is used (including the many Operations Management decisions that this information supports). Furthermore, properties of information like noise and accuracy are hard to observe even with full access to firms' data because the true noiseless benchmark against which researchers would like to assess the accuracy of the reported information is unobservable. That is, in the earlier presented equation, Measured value = True value + Noise + Bias, Noise and Bias cannot be observed because True value cannot be discerned. Management Accounting researchers have been creative in overcoming these hurdles, and Operations Management researchers who wish to incorporate informational properties in their empirical research can hence rely on a substantial body of work that offers a wide variety of potential solutions to this problem of unobservability of the quality of the information.

Management Accounting researchers have used surveys to collect data on *perceived* quality of Management Accounting information. Ittner et al. (2002) reports on one of the largest surveys in Management Accounting research, but sample sizes for tests still range between 452 and 2,241. Maiga and Jacobs (2008) has 691 respondents. These sample sizes are bleak compared to what our financial accounting colleagues use when accessing Compustat to observe their variables of interest. Furthermore, there may be a non-response bias in that firms with low-quality Management

Accounting information may be less likely to respond. Simulations offer another methodological opportunity because they can make the "true value" observable by simulating it (e.g., Labro and Vanhoucke 2007, 2008; Balakrishnan et al. 2011).[16] While their additional advantage is in very large sample size, they may suffer from external validity issues if not enough practice-based information is available to make realistic choices for parameters and distributions used in the simulation models.

Experiments also allow to model the "true value" benchmark or to observe such benchmark. For example, Cardinaels and Labro (2008) models a perfect information benchmark and subsequently presents their participants with a high or low-quality approximation. In a TDC setting, Cardinaels and Labro (2008) observe the actual time participants spend on various activities, which allows them to compare the participants' noisy estimates of that time with that true benchmark under the manipulated conditions. Of course, sample size issues also arise here, and complaints about the external validity related to the use of students as participants and the simplification of the tasks presented are common place. Another way to collect information that is needed to address research questions centered on Management Accounting information is to develop proxies based on publicly observable data. Both mandatory and voluntary disclosure by firms has increased over time and, as this data is collected in databases such as Compustat and Audit Analytics, it becomes easier to develop such proxies.[17] Advantages of larger sample sizes

[16] For a framework and guidance on how to set up and execute numerical experiments or simulations for researching costing (in)accuracy, see (Anand et al. 2018, forthcoming).

[17] Some researchers manually collect data because not all publicly available data are organized in databases. An example here is Costello (2013) who collects data about major suppliers for a sample of firms from Forms 10-K that US-listed firms have to submit. Another example is Ak and Patatoukas (2016). This paper documents that manufacturers with a more concentrated customer base hold fewer inventories for less time and are less likely to end up with excess inventories. Additional analyses reveals a valuation premium for manufacturers with a concentrated customer base, revealing that investors trade off the costs and benefits of a concentrated customer base and consider a concentrated customer base as a net positive for firm valuation.

and high external validity come at the expense of construct validity – researchers indeed use public data to measure a private construct.

Gallemore and Labro (2015) use the following four publicly available proxies of internal information quality. First, high earnings announcement speed (the time elapsed between the end of the fiscal year and the announcement of earnings) indicates high-quality internal information. Improved coordination allows for books to be closed more quickly (Jennings et al. 2012). Increased accuracy caused by eliminating manual intervention, reducing redundancy and rework and streamlined reporting should also reduce such time lag. Second, management forecast accuracy can only be high if managers have access to accurate internal information. Dorantes et al. (2013) and Cassar and Gibson (2008) have shown that firms with better internal information make more accurate forecasts. Third, the absence of financial accounting restatements caused by unintentional error is indicative of a reasonable level of internal information quality. This category of restatements is mostly the result of basic accounting or data errors (Hennes et al. (2008), Plumlee and Yohn (2010)). Such unintentional errors also affect the information on which management relies for decision making and performance measurement because they reflect a lack of accurate records and poorly designed and managed information systems (Hayes 2013).

Fourth, at the very low end of the Management Accounting information quality spectrum sit firms that report a Sarbanes-Oxley Section 404 material weakness in internal controls. The Sarbanes-Oxley Act (SOX) was implemented in 2004, in the aftermath of major accounting scandals such as Enron and WorldCom and contains a set of expanded reporting requirements for US-listed firms on the quality of internal controls. The presence and frequency of material weaknesses have been documented to relate to higher cost of equity, higher cost of debt and inefficient investments (e.g. Ashbaugh-Skaife et al. 2009; Costello and Wittenberg-Moerman

2011; Cheng et al. 2013). Material weaknesses are likely to result in erroneous internal management reports, untimely and stale information (Feng et al. 2009). Masli et al. (2010) and Morris (2011) show that after installing information technology and Enterprise Resource Planning systems respectively, the likelihood of a material weakness decreases.

In this Section, we developed the different characteristics of Management Accounting information: its imperfection (including incompleteness, noise, and bias), its endogenous nature, and its multi-purpose character. We have also provided some guidance on how the quality of managerial accounting information may be measured in empirical research. In the next section, we outline our approach to Sections 5 through 8 where we apply the Management Accounting information perspective to a select set of Operations Management topics to illustrate its use and the opportunities for further research on these topic that this perspective sheds light on.

4. Approach to our Application of the Management Accounting Perspective to Operations Management Topics

We selected 4 exemplar Operations Management topics to develop and illustrate how an application of the Management Accounting information perspective we outlined in previous section can provide new insights and advance research in Operations Management on these topics. We stress that the selection of the Operations Management topics is based on our taste and the extent to which we are familiar with particular topics, and by no means a value judgment on interfacing research in other areas of the Operations Management literature, nor an assessment that other topics would not be amenable to such perspective. In fact, we hope that this monograph will stimulate further applications.

In Section 5, we develop the capacity planning and allocation problem. Section 6 covers inventory management. Section 7 discusses production scheduling, while Section 8 examines product development. We will start each of these sections by discussing the approach in Operations

Management regarding the particular topic. Next, we discuss the approach in Management Accounting. The last part of each of the Sections 5 through 8 delves deeper into how a Management Accounting lens can advance research in Operations Management on the particular topic. In the Appendix, we describe a selection of these examples in more detail and differentiate between markedly different approaches with respect to the way in which Operations Management and Management Accounting are interfaced.

In order to make sure that we capture the important insights in the four selected areas in Operations Management, we first screened the studies published in top journals in Operations Management since the year 2000 (i.e. Journal of Operations Management, Management Science, Manufacturing & Service Operations Management, Operations Research, and Production and Operations Management). We analyzed the studies linked to the four selected Operations Management topics. Core studies published before 2000 and recent working papers in each of the four areas were also analyzed. This analysis phase was a creative endeavor in which we tried to distill how data, concepts, and insights from Management Accounting could advance research and practice in each of the four Operations Management areas. During this analysis phase, we also screened accounting journals to make sure that we cover existing research in Management Accounting on the particular interface we are studying.[18] Section 5 to 8 are the structured output of this creative process and should thus not be considered as a comprehensive overview of available research in each of these areas. Given the audience of this monograph, we have mainly focused on developing suggestions that use a Management Accounting lens to provide insights on an Operations Management topic.

[18] The accounting journals we screened are as follows: Accounting, Organizations, and Society, Contemporary Accounting Research, Journal of Accounting and Economics, Journal of Accounting Research, Journal of Management Accounting Research, Management Accounting Research, Review of Accounting Studies, and The Accounting Review.

5. Capacity Acquisition and Allocation

5.1. Operations Management Approach / Interest

At its core, both the Management Accounting literature and the Operations Management literature approach the capacity acquisition and allocation problem in the same way. The firm determines its resource capacities and list prices in the first stage when demand for its products is still uncertain. In the second stage, when demand uncertainty is resolved, the firm determines where to allocate its capacity and sets tactical prices.[19] However, the features of this problem that both literatures have focused on are different.

The Operations Management literature has focused extensively on the capacity input side. Topics of interest here are the effect of competition on initial capacity investment (e.g. Anupindi and Jiang 2008), sharing of capacity among firms[20] (e.g. Yu et al. 2015) and the flexibility of the capacity investment (e.g. Anupindi and Jiang 2008; Goyal and Netessine 2007; Biller et al. 2006; Van Mieghem 2007; Goyal and Netessine 2011). This flexibility is typically modeled as whether or not production decisions can be postponed until demand is observed. On the output side, both pricing (e.g. Allon and Zeevi 2011) and demand for products (e.g. Anupindi and Jiang 2008; Bish et al. 2012) have been studied. Price postponement and flexible capacity both can hedge against demand uncertainty, and it is of interest to determine under which conditions one hedging strategy is preferred to the other (Biller et al. 2006). Other areas of interest are capacity rationing (Huang and Liu 2015), cost sharing (Harks and Miller 2011) and lead times for purchasing and salvaging capacity (Ye 2007). (Van Mieghem 2003) provides a nice and much more detailed overview of the literature.

[19] The term "list price" is typically used for the long run price, while "tactical price" is used for the adjusted price after observation of demand.
[20] The accounting literature focuses on sharing of capacity among products instead.

5.2. Accounting Approach / Interest

The accounting literature has mostly been interested in understanding the role of full product cost allocations in solving this capacity acquisition and allocation problem and hence has focused on features that provide a role for product costs. This literature developed in an attempt to reconcile the economic theory prescription of using marginal cost in decision making with the accounting practice observed in surveys (e.g. Shim and Sudit 1995; Drury and Tayles 2005; Al-Omiri and Drury 2007) of full costing, where (part of) fixed costs (usually sunk) are allocated. The accounting literature has hence studied when full product costs are a good approximation of the opportunity costs that need to be managed in the capacity planning and allocation problem. [21]

5.2.1. Opportunity Cost and the "Grand Program"

At the time of acquisition, opportunity cost is the cash spent to acquire the resource. Once acquired, opportunity cost is a function of the resource's alternative uses, which vary over time. Because product demand is uncertain at time of capacity purchase, firms may experience idle capacity in some periods and shortages in others. The opportunity cost of idle capacity is zero. The opportunity cost under shortage of capacity is contribution lost by not being able to manufacture the products to sell. The optimal solution to the capacity planning problem trades off opportunity costs of acquisition with expected opportunity cost of installed capacity given demand uncertainty.

Balakrishnan and Sivaramakrishnan (2002) formalize this in what they call the "grand program":

$$Max_{P_{it},L_j,R_{jt}} E[\sum_t [\sum_i (P_{it} - v_i)(A_i + \in_{it} - B_i P_{it}) - \sum_j \theta_j c_j R_{jt}]] - T \sum_j c_j L_j$$

s.t.

[21] Full-cost allocations have also been rationalized in a pricing context without a capacity acquisition decision (Ray and Gramlich 2016).

$$\sum_i m_{ij}(A + \in_{it} - B_i P_{it}) - L_j - R_{jt} \leq 0 \qquad \forall_{j,t}$$

$$A_i + \in_{it} - B_i P_{it} \geq 0 \qquad \forall_{i,t}$$

$$P_{it} \geq 0 \qquad \forall_{i,t}$$

whereby

- N products (indexed i), M resources (indexed j)
- v_i: variable costs per unit of product i
- m_{ij}: units of capacity resource j consumed by one unit of product i
- D_i: demand for product i
- Q_i: amount produced and sold of product i
- P_i: price of product i
- L_j: units of resource j installed in the first stage, lasting T periods
- Demand function $D = A_i - B_i P_i$
- $\in_{it}$: demand shock
- R_j: emergency capacity acquisition for resource j
- c_j: unit cost of resource j when bought at the time of capacity planning
- $\Theta_j > 1$: premium price to pay for emergency capacity acquisition

Note that the accounting literature has almost exclusively worked with Leontief production functions because of how they resemble the linear approximations by costing systems, as discussed in Section 2. In such production technology, the production factors (i.e., resources) are used in

fixed proportions, and there is no substitutability between factors. In contrast, the Operations Management literature has also studied the flexibility of technology (e.g. Anupindi and Jiang 2008; Goyal and Netessine 2007, 2011). Furthermore, the Management Accounting literature typically assumes that Q_i is both the amount produced and sold of product i. Hence, there is no inventory. The presence of an inventory of products would complicate the costing problem substantially, and assumptions would need to be made about its longevity. Again, this stands in stark contrast to the vast literature in operations on inventory management, a topic we cover in the next Section. Note too that the only connection across products in the "grand program" (Balakrishnan and Sivaramakrishnan 2002) is through capacity constraints where products share capacity resources, but their demand is independent. Even with these simplifications, this problem is informationally demanding as the firm needs to anticipate each possible demand state for entire product portfolio at the time of capacity planning.

5.2.2. Are Full Product Costs Accurate Approximations of Opportunity Costs in Capacity Acquisition and Allocation Decisions?

The accounting literature identifies important features that determine whether or not the full product costs are an accurate approximation of the opportunity cost that needs to be used in this capacity acquisition and allocation problem (see Balakrishnan and Sivaramakrishnan (2002) for a full development on this topic). First, the desirability of emergency capacity purchases depends on whether or not the resource constraints are hard or soft. With soft capacity constraints, emergency capacity can still be procured in the second stage, but typically at a premium Θ_j. When Θ_j is low, it is economically viable to augment capacity to meet demand. The opportunity cost of understocking capacity equals the penalty cost of augmenting capacity, and the product's opportunity cost is a linear aggregation of the opportunity costs of the resources that it consumes. Because this penalty cost is exogenously given and the product's full cost provides such linear

aggregation, full costing works to approximate the opportunity cost. With hard capacity constraints, the first stage is the only point at which capacity can be procured. Technically, the premium $\Theta_j=\infty$ for the hard constraints case, and so it is never worthwhile to augment capacity. Hence, it could be the case that insufficient capacity is procured to fulfill all product demand. Here, the opportunity cost of understocking capacity equals the lost contribution of unfilled demand, which is endogenous. Hence, full costing does not work to approximate that opportunity cost.[22]

Second, whether or not tactical prices in the second stage can be set that are different from the list prices set in the first stage also affects the role for full costing. If prices are set in the first stage and cannot be revisited in the second stage (that is, tactical prices equal list prices), the price can be considered exogenous in the second stage, and the full costing calculation will equal the opportunity cost. However, if tactical prices can be adjusted, the product pricing problem needs to be solved at the product portfolio level rather than at the individual product level. This makes the opportunity costs endogenous as the pricing determines both the lost sales and the contribution margin for sold products. This entails that full costing, which considers each product independently, will not usually work to approximate the opportunity costs.[23]

Banker and Hughes (1994) model a firm that is a list price setter facing soft capacity constraints. They show that the grand program can be decomposed in 2 decision problems. The first is to choose prices to maximize expected gross margin:

$$Max_{P_i}\boldsymbol{E}[\sum_t \sum_i (P_i - V_i - \sum_i m_{ij}c_j)Q_{it}]$$

[22] This opportunity cost formulation of the problem presents a distinction between endogenous and exogenously formulated demand. Note that the source of this distinction is different from the one identified in Van Mieghem (2003).
[23] For some exceptions and a nuanced discussion, we refer to Banker et al. (2002) and Banker and Hansen (2002). Note that the bulk of the accounting literature on this topic uses analytical modeling methods. Hsu (2011) is a notable exception. Hsu uses hospital data to study the effect of cost allocations on pricing.

The second is to choose L to minimize expected capacity cost:

$$Min_{L_j} \quad \boldsymbol{E}[\sum_t \sum_i (\sum_j \max(m_{ij}Q_{it} - L_j, 0)\theta_j c_j)] + T\sum_j c_j L_j$$

Both problems can be solved at product level i.s.o. portfolio level and there is no economic loss in basing decisions on the aggregation process that full costing entails because capacity can be planned on a resource-by-resource basis. Furthermore, the paper provides a context where, if information is costly to communicate, full product cost becomes a sufficient statistic for such communication. For example, one can envisage the pricing decision being made in the marketing department while capacity is acquired by the production department. To coordinate these two decisions at no loss (compared to a centralized decision made by headquarters), the accounting department only has to communicate full product cost, rather than all the underlying information that goes into its calculation. This result establishes decentralized decision making as a possibility, a topic on which Van Mieghem (2003) called for more research.

Banker and Hughes (1994) established an economic environment where using full cost in decision making can be justified theoretically. Subsequently, the accounting literature goes onto establishing the robustness of this result. As mentioned before, the sufficiency result disappears when capacity constraints are soft and when tactical pricing is possible (e.g. Göx 2002). The literature also proceeds to quantify the magnitude of the economic loss when decomposing of full costing is used in situations where it should not be (e.g. Balachandran et al. 1997). If the loss is not too high, firms may benefit from employing a heuristic that is less informationally and cognitively demanding. As expected, the loss associated with full cost based capacity acquisition and pricing will be smaller if a firm's flexibility in emergency capacity acquisition increases and its ability to set tactical prices decreases. Balachandran et al. (1997) study the efficiency of cost-

based decision rules for capacity planning. They model a setting in which product cost data are used to infer the expected cost of under-and over-stocking and to determine installed capacity. Comparing to a benchmark where there is perfect information on product demand over the entire planning horizon, they consider the performance of various product- and resource-based planning rules, and, using simulations, determine the conditions under which each of these cost-based planning rules comes closest to the benchmark solution.

5.3. Advancing Operations Management Research on Capacity Acquisition and Allocation

We see three particularly fruitful ways to enhance Operations Management research on capacity acquisition and allocation by using a Management Accounting lens. First, we propose to further research that incorporates noise in the information used to make capacity planning and allocation decisions. Initial steps have been made on this front, but a lot more remains to study. Second, bias in the information used to support this specific decision has not yet been considered. A third fruitful area would be to incorporate a multi-divisional setting with incentives issues in the capacity planning problem and study the endogenous biases in the information provided in this setting.

5.3.1. Noise

In all of the above, and indeed also in a big part of the accounting literature on this topic, the resource consumption by the different products m_{ij} and hence the product costs have been assumed to be accurately known without measurement error or *noise*. All the above costing literature on measurement error and noise described in Section 2 has been developed in decision making free contexts. However, if no decisions are supported by the reported product costs, it is not clear why a firm would invest resources in developing an allocation system in the first place. That is, there is no endogenous need for a costing system (Demski 1981).

This is where the capacity acquisition, allocation, and pricing problem comes in, as the costing literature has (from various potential cost-based decision-making settings) chosen to focus

on this very important problem to take the next step in the development of the literature and combine this decision making context with the costing system design literature. Even in a world devoid of uncertainty and under the stark assumption that capacity is acquired as needed without a premium price, making these product planning decisions under limited information results in a dynamic problem with a feedback loop (Anand et al. 2017).[24] The outputs of a costing system, cost estimates, contain error because of the limitations in the information on which they rely. When a product mix decision is made based on these estimated reported costs, real capacity acquisition occurs to produce the product mix. Resource expenditures are triggered and recorded by the financial accounting system. These financial accounting system data on resource expenditures are an input to the costing system, which allocates these costs to the products. Hence, these actual expenditures will trigger a revision in the product costs. Rational decision-makers at the firm in a deterministic world without uncertainty will, upon viewing these updated costs, review the past decision. The decision should be self-confirming: the firm should not wish to change its decision after updating costs, i.e., the system should be informationally consistent. Hence, the decision-makers will choose to revise their product mix decision if it is inconsistent with the current reported product costs. That is, even in the absence of uncertainty, a variance between reported cost in period t=0 and period t=1 will obtain, and a dynamic process will ensue. Anand et al. (2017) show that this problem can be modeled as a discrete nonlinear and non-analytic dynamical system and define an informationally consistent equilibrium. They show that the first-best solution with full (unlimited and accurate) information is hardly ever an equilibrium solution. They devise a heuristic solution that converges to an informationally consistent equilibrium solution quickly and efficiently (when it exists) in the limited information case. This heuristic will allow researchers to

[24] Hwang et al. (1993) is an early paper that considers a decision context for a costing problem, but ignores this feedback loop.

conduct further work that relaxes some assumptions on the capacity acquisition and allocation problem (such as in the more realistic modeling done of this problem in the Operations Management literature) under imperfect information on cost while being able to generate informationally consistent equilibria.[25]

5.3.2. Bias

To the best of our knowledge, accounting research has not yet studied the role of costing biases in capacity planning and allocation. However, costing biases as described earlier could impact the capacity acquisition and allocation problem via the quantity demand side. For example, if low volume specialty products are undercosted, and high volume regular products are overcosted in a firm with a traditional costing system and these products are mispriced accordingly, this firm will see a demand increase for the specialty products and may use more capacity on production of those products as they seemingly have a higher contribution margin. Regular products will look less profitable than they really are, and may be dropped from the product mix. Such firm will drop more and more truly profitable products and run into a death spiral whereby the remaining resource cost will be allocated to the remaining products which in turn look unprofitable and will be dropped from the portfolio. Eventually, no products are left, and the firm has gone bankrupt in a death spiral.[26]

Another promising avenue with respect to the bias of reported cost in capacity planning presents itself because all costing methods other than TDC tend to overcost products (by including

[25] Operations Management research has considered imperfect demand forecasts / information in capacity planning problems (e.g. Biller et al. 2006).

[26] The cost-based death spiral differs from the revenue-based death spiral analyzed in, for instance, Cooper et al. (2006). A revenue-based death spiral arises when a firm has two classes of prices for similar products (such as high-fare and low-fare tickets in the airline industry) and the firm determines the supply of the high-priced product based on past sales for the high-priced product but neglects to account for the fact that an increased supply of the low-priced product will further decrease demand for the high-priced product. If more low-priced products are made available, sales of the low-priced products increases and sales of the high-priced products further decreases. The latter further decreases the supply of high-priced products.

some idle capacity cost in the reported product costs) and underestimate unused capacity cost.[27] It would be interesting to research how the inability to separate out used and unused capacity cost affects the OM models on this topic and impacts on decision variables such as tactical prices and emergency capacity acquisition. Furthermore, imperfect information about future demand may lead to increased unused capacity if the penalty cost of procuring emergency capacity is high. Note that the Management Accounting terminology uses the term "idle" capacity if there is an identifiable reason for carrying the unused capacity, such as fulfilling of demand in high demand periods in seasonal production or capacity only being available for procurement in bulk. In this case, the Management Accounting prescription is to allocate the idle capacity cost to the reason for having such idle capacity. In the examples, idle capacity costs should be allocated to peak production and to the entire volume of products that require such lumpy capacity purchases, respectively.[28] "Excess" capacity is used if no such reason can be identified. In this case, excess capacity costs should be allocated to the profit and loss account of those managers that can make the divestment of capacity decision so as to incentivize them to either divest or find alternative uses for the excess capacity.

5.3.3 Multiple Purposes and Endogenous Bias

Once the capacity allocation setting is extended to a multidivisional firm in which divisions forecast their resource needs and headquarters acquires the required capacity, the Management

[27] As explained in Section 2, this difference between TDC and other costing methods in identifying unused capacity is caused by the minutes response mode in TDC, combined with the bounded rationality of the employee filling out the time use survey. Hasija et al. (2010) develop a method to estimate the capacity of contact center employees using aggregated historical data that have been distorted both by constraints on work availability and by incentives for the employees to slow down when true capacity exceeds demand. That is, their method undoes the endogenous bias (see later) in the aggregate information provided. The method is used to plan daily capacity required. Chen and Zhao (2015) document a behavioral bias in estimating underage and overage costs in the context of the capacity planning problem.

[28] In an OM paper, Biller et al. (2006) apply this management accounting prescription to the capacity planning problem when advising that the cost of idle capacity should be assigned to peak demand to optimize capacity decisions. Indeed, fixed capacity may be idle during some low demand periods, but is in place to fulfill demand during high demand periods and hence idle capacity cost should be identified and allocated to the peak demand production volume.

Accounting perspective has implications for *endogenous bias* in cost measurement. Divisions have incentives to overestimate demand and resource needs to ensure they can produce.[29] This creates excess capacity: resources are not being put to use. If there is excess capacity, it is optimal for the headquarters to only charge variable costs to ensure utilization by a division as the opportunity cost of that capacity equals its variable costs. This will lead to an undercosting bias since no fixed costs are allocated to the division.

However, additional complexity arises in the more realistic case where firms exist over multiple periods. In the first period, headquarters needs to decide how much capacity to acquire and will use demand and resource need forecast by divisions as inputs in this decision. Subsequently, the firm needs to ensure proper utilization of that capacity after it has committed to a capacity level. For incentivizing optimal utilization, indeed no fixed costs should be allocated if there is excess capacity. Yet, when only variable cost is charged for capacity in the second period, managers of divisions have an incentive to over-forecast their future need for capacity to create excess capacity in the first period to ensure that they will only be charged variable costs in the second period. Headquarters hence allocate (part of) fixed costs in the first period to discipline managers from seeking excess capacity. In sum, there is a tradeoff between efficient investment and utilization of capacity: depreciation (or the allocation of fixed costs) controls overinvestment in the first period but creates capacity under-utilization in the second period. The optimal bias in costing, then, depends on the importance of the over-investment versus the under-utilization problem. Allocating fixed costs make sense if over-investment is the bigger problem, while only using variable costs is optimal when excess capacity exists and under-utilization is most important.

[29] Karabuk and Wu (2005) is an Operations Management reference that shares the viewpoint that managers manipulate demand information to increase their resource allocation.

Because over-investment is likely the bigger problem for most firms, we observe fixed cost allocation in most cases.[30]

6. Inventory Management

6.1. Operations Management Approach / Interest

Inventory management is one of the core areas in which Operations Management researchers have made considerable progress over the last decades. Researchers typically try to provide an answer to three related but different questions (Silver 1981). A first question deals with the frequency of determining the inventory status (Rudi et al. 2009). A second question deals with the timing and the size of the replenishment order (Feng et al. 2015a). A third question deals with the way in which the replenishment order should be fulfilled. An important determinant of the answer on each of these questions is the objective(s) that the inventory management of a firm needs to realize. These objectives can vary a lot and frequently observed objectives are value maximization, cost minimization, maximization of the rate of return on stock investment, maximization of the chance of survival, and ensuring flexibility of the operations. Researchers in inventory management have mainly focused on developing analytical models to answer the different central questions (Williams and Tokar 2008). One important critique on the modeling approach in the inventory management literature is that there is a considerable gap between the common assumptions used in the analytical models and actual practice, leading to an impediment of the theoretical models and the propositions derived from these theoretical models on how to improve inventory management (Cattani et al. 2011).

[30] While the above describes the basic results on the endogenous bias in reported costs in firms facing capacity planning problems, this accounting literature has been developed in much more detail (e.g. Baldenius et al. 2007; Rajan and Reichelstein 2009; Dutta and Reichelstein 2010). Other incentive frictions can also explain the role for allocation of fixed costs to support the capacity acquisition decision (e.g. labor market frictions in Balakrishnan and DeJong (1993)).

6.2. Accounting Approach / Interest

Inventory is an important item on the balance sheet of a firm and has received a quite extensive investigation in the accounting area. That said, the interest of accounting researchers in inventory management diverges substantially from that of Operations Management researchers.

6.3.1. Two Classical Topics: Valuation of Inventory and Managing Earnings through Inventory

A big part of the accounting literature related to inventory management has focused on the valuation of inventory and its implications for earnings and tax benefits (e.g. Dopuch and Pincus 1988; Barth et al. 2001). A second stream deals with real earnings management, which refers to managers manipulating real activities during the year to meet certain earnings targets. For example, Roychowdhury (2006) documents that managers engage in overproduction as this lowers the cost of goods sold per unit because the fixed overhead costs are spread over a larger number of units. Specifically, as long as the reduction in fixed costs per unit is not offset by an increase in the marginal cost per unit, the total cost per unit declines and the reported cost of goods sold is lower. However, although overproduction typically increases operating margin and accounting profit, it reduces the cash flow from operations because the firm incurs production and holding costs on the overproduced items. Overproduction also increases the risk for the firm as the excess inventories have to be sold in the future. Research in this area clearly shows how accounting and financial reporting incentives influence managerial behavior linked to inventory management. Roychowdhury (2006) also develops a methodology that researchers in operations management can use to proxy for overproduction based on publicly available datasets.

6.3.2. A Modern Topic: Inventory Management and Management Accounting Practices

A third relevant stream in accounting investigates how design choices in inventory management influence the design, use, and usefulness of accounting information. Nagar et al. (2009) start from the idea that modern manufacturing settings shift the information balance from

the managers to the employees, implying that important information needed to continuously improve arises on the factory floor, and that management needs to develop mechanisms to motivate employees to use that information in the best interest of the firm. They develop a model with a principal, an upstream Agent and a downstream Agent. The downstream Agent receives noisy, short-term information that he reports to the principal via the usual worker-management communication channels. Importantly, the downstream Agent is not restricted to be truthful in his communication. Next, the principal offers a menu of production schedules and the upstream Agent picks an allowed production quantity and starts producing work-in-progress. When the downstream Agent starts to convert work-in-progress, he receives a piece of ultra-short information that determines the optimal conversion rate of the work-in-progress. Potentially, it is efficient to not convert all work-in-process, but build up work-in-process to motivate the downstream Agent to work. Thus, the costs of building up work-in-process are balanced against the efficiency gains work-in-process provides to motivate the downstream Agent. As long as the costs are not too high, an excessive level of work-in-process can be optimal. An important implication of the paper is that excessive work-in-process inventory can exist in equilibrium when a production process is considered both from a scheduling perspective and an agency perspective.

Baiman et al. (2010) model a manufacturing setting in which an Agent exerts effort to process intermediate units. As intermediate units arrive, they are stored in an inventory buffer until the Agent can process them. The compensation scheme of the Agent consists of a fixed wage plus an incentive wage based on realized throughput, which is the number of intermediate units processed per unit of time. The performance metric 'throughput' is an imperfect proxy for the effort of the Agent as throughput depends on two sources of uncertainty: the stochastic arrival rate of the intermediate units and the Agent's stochastic processing rate. When the mean processing

rate of the Agent is higher than the mean arrival rate of intermediate units, throughput is relatively uninformative about Agent effort when the inventory buffer of intermediate units is small. The intuition behind this result is that the probability of starving, which is the probability that the inventory buffer is empty when the workstation is free, is large, which makes it more difficult for the Agent to deliver higher throughput. The principal can improve the informativeness of throughput as a proxy for Agent effort by increasing the buffer size as throughput will be less sensitive to the stochastic arrival of intermediate units. However, when the buffer size increases up to levels that there is no blocking, which is the probability that the workstation is full when an intermediate unit arrives, the informativeness of throughput decreases again. The takeaway of this result is that minimizing inventory buffers creates unnecessary agency costs if the Agent is not being asked to work relatively hard. When the mean processing rate of the Agent is lower than the mean arrival rate of intermediate units, the informativeness of throughput increases when the inventory buffer increases as this lowers the probability of blocking, which in turn increases the opportunity for the Agent to influence the probability of blocking and, thus, throughput. The take-away here is that minimizing inventory buffers as advocated by the JIT literature increases the incentive problem and agency costs.[31]

While the prior accounting papers take an analytical approach, some empirical work has also been done on how inventory management practices correlate with management accounting practices. For example, Fullerton et al. (2013) examine how the implementation of a lean manufacturing strategy influences the management accounting practices that are used in general and inventory tracking in particular. Relying on the idea that tracking accumulated inventory costs will encourage firms to overproduce, create excess inventories, and reduce the flow of production,

[31] Balakrishnan et al. (1998) analytically show how audit information quality affects whether team-based production or individual production is optimal in achieving inventory reduction.

they find a negative relationship between the extent to which lean manufacturing is implemented and inventory tracking, but only in the presence of strong support of the top management team for the implementation of lean manufacturing. A last area in accounting research that touches on inventory management is research we previously discussed in Section 3.4 that investigates the determinants and consequences of inventory-related internal control weaknesses (e.g. Feng et al. 2015b).

6.3. Advancing Operations Management Research on Inventory Management

In this part, we will focus on three topics which we believe can be advanced by incorporating insights from Management Accounting research. The first topic adds to the discussion in the prior section and deals with the relationship between inventory management and Management Accounting practices. The second topic is inventory record inaccuracy. Because inventory record inaccuracy is defined as the discrepancy between the inventory records and the actual inventory, it is essentially a problem of imperfect information. In line with the two sources of imperfect information (i.e. noise and bias) that are explained in earlier sections, we will discuss how our understanding of inventory record inaccuracy can be further improved by considering it from a noise perspective (see sections 6.3.2.1 and 6.3.2.2) and a bias perspective (see section 6.3.2.3.). The third topic is the newsvendor problem. We will discuss how moving from a centralized to a decentralized decision-making structure and how introducing noisy cost information in the setting of the newsvendor problem, as applied to an inventory management setting, can enrich our understanding of this classical problem in Operations Management.

6.3.1. Endogenous Effect of Inventory Management Choices on Management Accounting Practices

In section 3.2., we explained that the properties of management accounting information are endogenously determined by operations management choices. Choices related to inventory management are a first-order candidate to create such endogenous link, of which Ittner et al.

(1997b) provide an excellent example. They show that the use of Economic Order Quantity models for inventory management affects whether or not the ABC hierarchy is descriptive and hence whether or not ABC reported costs will be accurate. As explained in the crash course in Section 2, the ABC hierarchy assumes that the levels of the hierarchy are independent of each other and that each activity only varies on one level. Using EOQ models to manage inventory brings dependency or correlation between batch and unit levels because batch level costs and holding costs (which are unit level costs) are linked through the EOQ formula. As a result, the holding and order cost used in the EOQ model are inaccurate, creating a viscous cycle whereby potentially non-optimal EOQ decisions are made. Anderson and Sedatole (2013) further investigate the link between inventory management practices and management accounting information. Inspired by the ABC hierarchy, they start from the observation that although modern cost accounting posits that overhead costs vary with volume, batches of production, and the variety of products many studies fail to find these associations. One explanation could be that flexible manufacturing methods, which have had an important impact on inventory management practices, reduce the usefulness of the ABC hierarchy and again increase the importance of production volume as a determinant of overhead. Using data from a float glass manufacturing plant, they find evidence for the relevance of the ABC hierarchy to describe the cost patterns. Furthermore, they suggest that the failure to find a validation for the ABC hierarchy can be caused by (1) crude measures of the batch- and product-related activities which obscure the complex resource consumption patterns and (2) aggregation of granular data to the month or quarter which is a convenient practice to record accounting information. Thus, to develop tests of the ABC hierarchy, it is important that one (1) has accurate measures of the activities and (2) aggregates the data in such a way that the periodicity of variation in production activities coincides with the recording period.

In order to better understand the properties of management accounting information, it can be interesting to consider other choices related to inventory management. For instance, modern information technology combined with innovations in inventory management, such as radio frequency identification (RFID), makes it easier to collect an enormous amount of data. The use of RFID opens up several interesting research opportunities on the interface between Operations Management and Management Accounting. First, this allows for more inventory-related costs to be traced directly to products, which will decrease the indirect overhead that needs to be allocated. Future research needs to validate this assumption as the direct tracing of inventory-related costs to products can decrease the imperfection in the calculated product costs and thus potentially lead to better managerial decision-making. Second, important research questions relate to the way in which data need to be aggregated to be meaningful for decision-making. Researchers in operations management and/or management accounting can investigate (1) whether the properties of management accounting information have changed since the availability of data has increased, (2) how data are aggregated and (3) whether the aggregation of data coincides with the periodicity of variation in production activities. Third, it would be interesting to investigate how the use of RFID impacts agency costs and performance measurement in firms of employees involved with inventory management. That is, RFID allows to develop a better insight into the effort of an Agent and traditional economic theory would suggest that this decreases the agency costs as one does not need to resort to noisy performance measures of the output of the Agent. However, the use of RFID to address incentive problems can be considered as "controlling" by the Agent and previous research documented that controlling actions initiated by the Principal can increase agency costs (Falk and Kosfeld, 2006). Researchers can thus investigate whether and when RFID data are used to address incentive problems in firms.

6.3.2. Inventory Record Inaccuracy

6.3.2.1. Noise

Inventory record inaccuracy is problematic as key aspects of inventory management such as forecasting and ordering are based on the assumption that inventory records are accurate (DeHoratius and Raman 2008; Heese 2007). The study of DeHoratius and Raman (2008) among retail firms revealed that retailers only have an accurate inventory record for about 35% of their products and that inventory records are larger than physical inventory nearly as often as they were smaller. Most of the current literature in Operations Management seems to assume that the discrepancy between the recorded inventory level and the true inventory level is driven by factors that increase *noise* such as environmental complexity, annual selling quantity of an item, and the dollar value of an item (DeHoratius and Raman 2008). Mersereau (2013), for instance, argues that "*record inaccuracies are assumed to arise via an error process that periodically perturbs physical inventory and that cannot be directly observed by the inventory manager, implying that the true physical inventory level is a random variable from the perspective of the inventory manager*". Consistent with the idea that inventory record inaccuracy is a form of noise, analytical models on the topic typically assume a symmetric distribution around zero (see Kök and Shang (2007) for an example; we will discuss notable exceptions later).

Accounting provides interesting insights that can further advance how such noise, or a reduction thereof, determines inventory record accuracy and the resulting improvement in inventory management decisions. SOX Section 404 mandates listed US-firms to report material weaknesses in internal control and specify their nature. One category of specific interest here are inventory-related material weaknesses in internal control, which can be used as a proxy for the adequateness of the information collection processes developed by the firm to control inventory

purchase, tracking, and valuation. [32] For example, the absence of a clear policy with respect to the access to the warehouse or problems with the methodology of order-picking could lead to an inventory-related material weakness. Feng et al. (2015b) show that firms with inventory-related material weaknesses have lower inventory turnover ratios and are more likely to report inventory impairments. They also find that firms that remediate these inventory-related material weaknesses report increases in sales, gross profit and operating cash flows. Using inventory-related material weaknesses allows operations researchers to examine other outcomes and determinants of inventory record inaccuracy on large samples of firms (DeHoratius and Raman 2008; DeHoratius et al. 2008). That said, an important step towards using inventory-related material weaknesses as a proxy for inventory record inaccuracy is further reinforcing the validity of the proxy by means of additional empirical tests. For instance, researchers in Operations Management can examine whether investments in technology that should reduce inventory record inaccuracy, such as radio frequency identification (RFID), explain cross-sectional and temporal variation in inventory-related material weaknesses.

The quality of a firm's internal control over inventory-related internal control processes is not solely determined by the firm itself. That is, accounting regulation imposed on the firm determines the quality of the internal control processes in general and the inventory-related internal control processes, specifically. Interestingly, new accounting regulation may bring research designs with exogenous sources of variation into the realm of possibilities. Furthermore, the quality of the external auditing services that are provided, even though they are less frequent, also determine the accuracy of the inventory processes. The accounting literature links the industry specialization of auditors with the quality of the work. Auditor industry specialization measures

[32] Note that these are different from the year-end inventory control procedures implemented by the external auditor.

can be developed based on publicly available data and can be used by researchers in Operations Management to proxy for the extent to which firms have accurate inventory recording processes inaccuracy. We refer to Minutti-Meza (2013) for a critical view on measuring auditor industry specialization.

6.3.2.2. Multiple Purposes and Noise

The performance measures used in the employment contract of the business unit manager can also have an impact on the inventory record inaccuracy. Take, for example, the practice of using sales observations to provide a signal to the manager about the inventory level (DeHoratius et al. 2008). That is, a period with no sales may indicate a stocked-out situation while a period with positive sales implies that the previous inventory level could not be zero. Mersereau (2013) develops an optimal forward-looking replenishment rule that incorporates the sales signal. Considering this updating process from a management control perspective, we can analyze whether the performance of such updating process as proposed by Mersereau (2013) depends on the performance measures of the manager and the way decision rights are allocated among managers. For instance, assuming that sales provide additional information about the true inventory level, a forward-looking manager may want to experiment with sales to make the sales signal more informative (i.e., by stimulating sales the manager runs the risk of a stock-out but will obtain additional information about the inventory level). The extent to which the manager will experiment with sales depends on the allocation of decision rights (is the manager responsible for sales and can hence drive such experimentation or is he solely in charge of inventory cost reduction) as well as on the weight and properties of the performance measures he is evaluated on.

6.3.2.3. Multiple Purposes and (Endogenous) Bias

Some analytical models on inventory record inaccuracy also allow the random variable that describes inventory record inaccuracy to have a nonzero mean. Kang and Gershwin (2005), for

instance, describe inventory record inaccuracy as a random variable that is symmetric around a positive mean and Mersereau (2013) allows for a symmetric distribution around a value that can be positive or negative. The nonzero value around which the distribution emerges can be considered as the bias-component of inventory record inaccuracy, which is the predictable sign of the difference between the true inventory and the reported inventory. However, the way in which bias in inventory record inaccuracy arises is, with the exception of some notable references mentioned below, mostly still a black box for researchers in Operations Management. Management Accounting puts forward two potential sources of such bias: actions that determine the actual inventory and actions that determine the inventory records.

First, bias in inventory record inaccuracy can emerge through actions that determine actual inventory but are not reflected in the inventory records. We label such a bias a "real action bias". For instance, the inventory records indicate an inventory level of 100 units but the true inventory is only 80 because of, for instance, stealing by employees or customers. Performance measurement as well as organizational design choices affect such actions. DeHoratius and Raman (2007) document that decreasing the weight on inventory shrinkage in the compensation plan of store managers leads to an increase in inventory shrinkage. [33] Organizational design choices may affect stealing by employees, a topic that concerns Operations Management researchers. Chen and Sandino (2012) document that stealing among employees is quite prevalent and can be partially explained by variation in wage levels among employees, in that employees who feel unfairly paid

[33] As the extent to which a store manager can intervene in the calculation of the inventory shrinkage of his own store is not entirely clear from the paper, it could be that the lower degree of inventory shrinkage before the change in the incentive plan is caused by reporting behavior of the store manager rather than by the store manager's effort to prevent inventory shrinkage in itself. Reporting behavior of a store manager can change after reducing the weight on inventory shrinkage in the compensation plan because of the reduced marginal benefits of untruthful reporting after the change.

will resort to stealing. Hence inventory levels are endogenously determined by other organizational design choices such as compensation practices.

Second, bias in inventory record accuracy can also arise through conscious manipulation of the reported inventory numbers, or "reporting bias". For instance, the manager knows that true inventory level is 80 units but reports that the inventory level is 100 units. Such reporting bias can also be affected by performance measurement and organizational design choices. Indeed, a common theme that runs through the management accounting literature on reporting bias is that such bias is more likely when the reported numbers are explicitly or implicitly used in the performance evaluation. In other words, the multi-purpose nature of accounting information induces bias in the reported information. Obviously, a reporting bias is more likely to emerge in firms that allow for human intervention in the inventory recording process. The use of technology in the inventory recording process, such as RFID, and the segregation of duties with respect to inventory recording and inventory reporting is expected to reduce this reporting bias and can thus be used as proxies for the (lack of) existence of a reporting bias in inventory record inaccuracy.

Interestingly, a "real action bias" and a "reporting bias" can arise at the same time. For instance, continuing the above example, the predictable effect of wage levels on in stealing will drive down *true* inventory as a first order effect. As a second order effect, such stealing will create a predictable *upwards* bias in inventory records as compared to the true level as employees committing acts of theft may deliberately bias their inventory recording upwards to conceal their unsavory activities. A good start to develop ideas regarding other potentially interesting determinants of the real action bias and the reporting bias in the inventory recording process is the well-established literature on honesty in capital budgeting (see Brown et al. (2009) for an overview).

6.3.3. The Newsvendor Problem

The newsvendor problem describes the core issue in inventory management. The basic version of this problem features a newsvendor who must decide about his inventory before demand realizes. Demand can be modeled by means of a stochastic function. If the newsvendor orders too little, he loses sales. If the newsvendor orders too much, he must dispose of the excess stock at a cost. The features of the newsvendor problem can be easily implemented in an experimental design resulting in a considerable stream of papers examining the newsvendor problem from a behavioral point of view. Previous studies have examined whether the newsvendor problem differs for high-profit versus low-profit products (Schweitzer and Cachon 2000), the role of experience and feedback (Bolton and Katok 2008), whether mean demand anchoring, demand chasing, and inventory error minimization explain the behavior of the newsvendor (Kremer et al. 2010), the sensitivity of students versus professionals to training and feedback (Bolton et al. 2012), and the role of cognitive reflection in newsvendor decision-making (Moritz et al. 2013).

6.3.3.1. Multiple Purposes

Although the newsvendor problem has also been analyzed in accounting to study capacity planning (e.g. Balakrishnan and Sivaramakrishnan 2001) the approaches in Operations Management and Management Accounting are completely different. The Operations Management literature typically considers this problem from a central planning perspective in which a central planner formulates an optimal inventory policy given a certain information structure (a function of demand, structure of stock-out and inventory costs and many other parameters that can be changed). Most accounting research does not assume a centralized planning system but starts from the idea that inventory-related decisions are delegated to managers as they have better information that is difficult to get truthfully communicated to the centralized planner. Thus, an accounting

researcher would typically assume an agency problem in the broader newsvendor problem.[34] Next, the delegation of decision-making implies that the manager is evaluated by means of performance measures. Such performance measures are often based on accounting data because these outperform cash-flow data when it comes to intertemporal matching of costs and revenues. In search of a performance metric that yields an inventory cost charge equal to the relevant costs, Baldenius and Reichelstein (2005) analytically show that use of a particular residual income performance metric results in efficient delegation. Their residual income measure deducts from income an interest charge for the value of all operating assets including inventory based on compounded historical cost, which ensures that the manager is charged the real production cost when inventory is sold, and based on the LIFO inventory flow rule, which first expenses the most recently produced inventory units.

Operations Management researchers can increase their understanding of how operations managers take their inventory management decisions by further advancing in the spirit of Baldenius and Reichelstein (2005), considering inventory management decisions from an incentive and control perspective. This implies that (1) the inventory management decision is delegated to an operations manager who has superior information and (2) the operations manager is evaluated by means of particular performance measures. Particularly, in a multi-tasking setting where the Agent not only needs to provide effort, but also allocates his effort to the different tasks in the manner desired by the Principal (Hölmstrom and Milgrom 1991), the question becomes which performance measures (if any) are best to ensure a high degree of congruence between the Agent's actual and the Principal's desired allocation of effort to tasks. For example, inventory management decisions have both an aspect of keeping cost down by sourcing from low cost

[34] The Operations Management literature does not always make this distinction nor includes the agency issue, often presuming a manager making decisions while perfectly aligned with the objective of the overall firm.

suppliers and increasing revenue by ensuring that inventory is replenished in a timely way so as to not interrupt production and/or sales.

The accounting literature has established that the choice to delegate decision rights on specific tasks to an Agent and the performance measures used to assess the performance of that Agent are endogenously determined. Explicitly considering this endogenous relationship can provide insights in the role of performance measures for inventory management. Tokar et al. (2016) run an experiment in which managers have to take replenishment decisions. They vary the performance measure of the manager from cost-focused, which they argue brings in a negative frame, to profit-focused, which brings in a positive frame. Profit is determined by sales minus costs, and the manager's replenishment decisions can affect cost and lost sales. However, changes in the performance measure used should go hand-in-hand with parallel changes in he assigned responsibilities. For example, a manager is unlikely to be evaluated on a cost-focused performance measure if he has responsibility for activities that influence the firm's revenues. Relatedly, the research design of Tokar et al. (2016) changes the performance measure while keeping constant the responsibilities of the manager. In doing so, they change the noise-versus-congruence relationship. Specifically, when the manager can only influence costs and assuming the goal of the firm is to maximize firm profit, a cost-focused performance measure is less noisy (i.e., the cost-focused measure reflects the effort of the manager well because the manager is responsible for cost) but not very congruent (i.e., the cost-focused performance measure does not induce the manager to take actions that increase revenues, the second lever of firm profit). A profit-focused measure would be more congruent but also noisier because firm profit can be influenced by a lot of factors that cannot be influenced by the manager, such as seasonality in demand. Thus, further

work can incorporate the endogenous relationship between the performance measures and assigned responsibilities.

6.3.3.2. Noise

Another way to move forward in understanding the dynamics of the newsvendor problem is by including cost information in the decision problem. In a lot of the existing analytical models, the accuracy of cost information is moot as they focus on analyzing and predicting replenishment decisions for one-product firms (see, for instance, Arslan et al. (2007)). In such firms, the reported product costs cannot be misspecified as all costs can be traced to the same product. Some analytical models include overhead costs, implying that they have a firm with at least two products, but they focus on the replenishment of one product. These models do not really differ from the one-product firms as the overhead costs are in most cases assumed to be accurately allocated. Introducing cost information, thus, also implies that one has to move to situations with at least two products, where misallocations of overhead have consequences on the reported product cost of each product. This means that the results derived for one-product firms are not readily generalizable to firms with multiple products where costing inaccuracies add additional complexity. Furthermore, predictable costing biases are created. First, since costing is a zero-sum game, if one product is under-costed, another will be over-costed. Previous research in accounting has documented that decision-makers are not very good in correcting for costing errors and this is especially true when volume-based costing methods produce accounting losses (Cardinaels et al. 2004). Second, under traditional costing systems, high volume products are over-costed, and the low volume and specialty products are under-costed, affecting directly the parameters that are incorporated in EOQ models, and endogenously resulting in changes in quantity ordered of the different products.

7. Production Scheduling

7.1. Operations Management Approach / Interest

7.1.1. The Scheduling Process

Production scheduling is the activity of allocating a firm's resources, such as the workforce, machines, vehicles, and material, to the tasks or activities to be executed within a certain period (De Snoo et al. 2011; Leung 2004; Pinedo 2012).[35] The Operations Management literature has studied optimal scheduling in the context of, among others, manufacturing, services, projects, nursing, operating rooms, outpatient clinics and school bus routing. The scheduling process typically encompasses several steps. The first step is gathering information about the available resources, the demands that need to be satisfied and the goals and constraints that the schedule should obey. The second step is the interpretation of the gathered information. The third step is communication and negotiation with different departments, which often set different goals and have different constraints regarding production time, workload, and service costs. The scheduler should trade off the interests of the different departments when designing the schedule. Fourth, different schedules are developed through techniques drawn from operations research, mathematical programming, and artificial intelligence and evaluated based on a number of criteria. The next step is the choice of a particular schedule.

The last step, which is typically not considered in the traditional conceptualization of the scheduling process, is the implementation of the developed schedule. This step also involves the reaction of employees towards the schedule. As we do not assume employees are behaving as perfectly rational individuals, the reaction of employees towards the schedule can lead to an outcome that differs from what is expected (Gino and Pisano 2008). Another aspect of the last step

[35] In this part, we focus on the scheduling of tasks given a certain production structure. We do not cover issues related to production planning such as the design of an assembly line and the choice of a production technology. For good examples in accounting that cover these issues, we refer to Hemmer (1995) and Bai et al. (2016).

is that the implementation of a schedule also generates information about how the scheduled process unfolds over time. Such incoming information can reveal that there is a lack of resources (material, machines, and workforce), that there are deviations from the proposed schedule, or that the quality of the output is lower than certain predetermined standards. Scheduling is thus also a dynamic activity, and the scheduler needs to reevaluate the developed schedule on a continuous basis based on incoming information. Such rescheduling typically involves one or more of the steps that are undertaken to develop the initial schedule but often takes place under increased time pressure.

7.1.2. Mathematical Scheduling Models and the Behavioral Scheduling Approach

An influential area of research considers scheduling as an optimization problem and typically assumes that employees will execute the schedule chosen by the central planner. As a result, the main focus of the current literature on scheduling in Operations Management is on the development of new techniques to optimize the scheduling problem. The major benefit of the current approach in this literature is that we have a well-developed understanding of the features of different classes of scheduling problems. For instance, Mak et al. (2014) develop heuristics for a class of scheduling problems that involves both a job sequencing decision (i.e., determining the order in which a list of jobs should be performed) and an appointment scheduling problem (i.e., determining the starting times for the different jobs). As another example, Chen and Solak (2015) develop optimal sequencing and spacing policies for the optimized profile descent procedure, which is an operational procedure that is increasingly used by airports to schedule the arrival of airplanes with the aim of reducing the environmental impact of airplane arrivals. As a last example, Freeman et al. (2016) develop a novel scheduling formulation for operation rooms that explicitly considers uncertainty in elective operations and allows for randomly arriving additional urgent demand.

While mathematical scheduling models are key in further improving scheduling performance, they underestimate the importance of human intervention in the different steps of the scheduling process and thus the influence of such human intervention on scheduling performance. Importantly, almost every step of the scheduling process involves human intervention. Humans intervene in the scheduling process when information has to be gathered regarding the available resources, the demands that need to be satisfied and the goals and constraints that the schedule should obey. Human intervention is also present when the gathered information is interpreted, when the developed schedule is communicated and negotiated with the different departments, and when a particular schedule needs to be chosen. Humans also intervene when the developed schedules are implemented. For instance, analyzing data on doctors reading radiological images at a firm where images are randomly assigned to qualified doctors, Ibanez et al. (2018, forthcoming) document that doctors deviate from the assigned first-in first-out scheduling policy, which follows a computer-based algorithm, 42% of the time.

Given the different points in the scheduling process where humans can intervene, it can be argued that the behavioral complexity is much larger than what the developed techniques, which mainly focus on aspects of the planning problem that increase the computational complexity, typically assume. During the last two decades, an interesting wave of studies has focused on how humans react to particular features of the way in which the work is planned, scheduled, or organized. For instance, a common assumption in the mathematical scheduling models is that the rate at which employees work is exogenously determined. This simplifying assumption stems from the core consideration in most scheduling models that employees are fixed entities who execute the schedule as developed by the central scheduler. The seminal paper of Kc and Terwiesch (2009) uses operational data from patient transport services and cardiothoracic surgery to validate this

assumption empirically. Their results show that the service rate is endogenous to workload and increases as the load increases. Specifically, a 10% increase in load reduces length of stay by two days for cardiothoracic surgery patients, and a 20% increase in the load for patient transporters reduces the transport time by 30 seconds. However, sustained periods of overwork decrease the service rate and the quality of care. Subsequent studies extend the findings of Kc and Terwiesch (2009) by investigating how employees use their discretion and whether deviations from predefined schedules have performance consequences. Ibanez et al. (2018, forthcoming) use data from 2.4 million radiological diagnoses and show that doctors deviate from the developed schedule to group similar tasks and to prioritize shorter tasks. Deviating from the developed schedule also erodes productivity. Experience increases the probability of deviation from the developed schedule and weakens the erosion of productivity. Additional tests also reveal that batching of similar tasks is associated with better performance but not when batching results from a deviation from the schedule, suggesting that the additional costs to batch, such as search costs, do not outweigh the benefits of processing similar cases after each other. Kc et al. (2017) also examine how employees select tasks in a hospital emergency department and document that employees choose to complete easier tasks when the workload increases. They label such behavior as a 'task completion bias' and find that it improves short-term productivity but hurts long-run performance. In an experiment, they replicate the 'task completion bias' and show that this bias occurs because employees derive utility from task completion.

7.2. Accounting Approach / Interest

The work in Management Accounting that focuses on scheduling is fairly limited. A notable exception is O'Brien and Sivaramakrishnan (1996) who examine the economic performance of a traditional accounting information system and a cycle time accounting information system for coordinating order processing and production scheduling in an order-

initiated production environment. Their starting point is that the efficacy of an accounting system in coordinating order processing and production scheduling is a function of how accurately the accounting system measures the marginal cost of production, which consists of an out-of-pocket cost (cost of labor and material, inventory holding costs, quality costs) and an opportunity cost. By scheduling a particular order now, an opportunity cost arises because it may result in a future order being rejected if capacity is scarce. O'Brien and Sivaramakrishnan (1996) compare the marginal cost of production of a traditional cost accounting system, which calculates direct and indirect product costs, and a cycle time accounting system. In their cycle time accounting system, all incoming orders which increase the waiting time in the system beyond a cutoff are rejected. Their simulation results reveal that the cycle accounting system performs better because it better incorporates the opportunity cost component compared to a traditional cost accounting system. Other work in management accounting that is related to scheduling mainly investigates how management accounting systems are adapted when firms switch to production philosophies such as Just-In-Time (Mia 2000).

7.3. Advancing Operations Management Research on Production Scheduling

While the Management Accounting literature has not extensively covered production scheduling, in this section, we will rely on insights from more general contemporaneous research in management accounting. First, in Section 7.3.1., we will open the black box of how information that is needed to develop a schedule is gathered by introducing information asymmetry between the scheduler and the employees that will be executing the tasks that are being scheduled. We will first discuss how the presence of such information asymmetry can introduce bias in the information that is gathered for scheduling purposes. Next, we will provide suggestions on how the bias in the information gathered for scheduling purposes can be mitigated. Second, in Section 7.3.2, we will focus on the fact that employees frequently deviate from the developed schedule and engage in

discretionary task selection. We will develop ways in which noisy and multi-purpose accounting information can be used to address discretionary task selection. In both sections, we will focus on the role of human intervention as we believe that there are foundations in management accounting research that provide a jump start to illuminate the role of human intervention in the different steps of the scheduling process.

7.3.1. Gathering Scheduling Information

7.3.1.1. Information Asymmetry Introduces Bias

A first step in the scheduling sequence is gathering information about the available resources, the demands that need to be satisfied and the goals and constraints that the schedule should obey. In the scheduling literature, a common assumption is that the scheduler has all the information available that is needed to optimize the schedule at no cost. An implicit assumption is also that the employees involved in the tasks that need to be scheduled do not play any role in the process of gathering the information that is needed to optimize the schedule. As the generation of information is a core task of an accountant, accounting researchers will typically relax both assumptions. To structure the way in which information becomes available to the scheduler, accounting researchers would assume that there is an information asymmetry between the employees involved in the tasks that need to be scheduled and the scheduler with respect to the information that is needed to optimize the schedule. That is, employees involved in the tasks that need to be scheduled typically have more and better information regarding these tasks compared to the scheduler. Such information can, for instance, be about the duration of the different tasks, the sequence of the tasks, and the amount of units that need to be processed to satisfy customer demand. Furthermore, the scheduler has some information regarding the tasks that need to be scheduled but to improve his scheduling performance he wants to obtain the information that the

employees have. Finally, the scheduler also has his own incentives in what he wishes to achieve with the schedule.

To summarize, gathering of information to optimize a work schedule can be characterized as a double moral hazard problem. Employees are asked to report this information to the scheduler, but they have an incentive to report untruthfully. That is, if an employee is asked to report the duration of several tasks to a scheduler and assuming that (1) the employee prefers less work pressure and (2) the scheduler cannot detect untruthful reporting, employees will report a longer task duration than the truthful task duration. In the remainder of this section, we will show that considering the process of gathering information from an accounting perspective can explain the existence of bias in the gathered scheduling information. Before doing this, we will introduce some insights about problems with a similar structure that has been (unlike scheduling) extensively studied in management accounting research.

The most closely related problem on information gathering in accounting is budgeting. A typical budgeting problem consists of two parties: a Principal and an Agent. The Principal has to allocate resources, which are often monetary resources, to the Agent. These monetary resources can then be used by the Agent to set up activities that can advance firm value. A crucial feature of the budgeting setting is that the Agent has private information that is useful for improving the allocation decision of the Principal. Such private information can, for instance, relate to customer demand, employee productivity, the cost to produce a unit, etc. The argument is that the Agent has private information as he is closer to the operational processes. In a next step, the Agent is asked to report his private information. The important aspect here is that Agent can lie as it is impossible for the Principal to verify without additional costs whether the Agent truthfully reveals his private information. If the Agent lies about his private information, he creates budget slack by, for

example, building in extra time or monetary resources to complete a project. This benefits the Agent but reduces firm value. Based on the reported information, the Principal then allocates resources to the Agent.

A simplified version of the budgeting process that is often used in experimental accounting research is structured as a modified version of a dictator or ultimatum game (Evans III et al. 2001). The structure is as follows: the Agent observes a value, X, from a uniform distribution, which for instance reflects the unit cost of a product, that goes from 1 to N with increments of T; the Agent has to produce W units of the product for the Principal that are sold by the Principal at price Y; the Principal only knows that the distribution is uniform and can never detect that the Agent observes X; the Principal asks the Agent to report the unit cost of the product, which is represented by R. In case of the dictator game version of the budgeting process, the Principal always allocates the budget based on the reported unit cost, which is equal to the reported unit cost R multiplied by W (i.e. the number of units the agent has to produce) to the Agent. In case of the ultimatum game version of the budgeting process, the Principal has the power to allocate a budget to the agent that is lower than the requested budget. The payoff function of the Principal is W*(Y-R), and the payoff of the Agent is W*(R-X), which is the budget slack. From these payoff functions, it is clear that the Principal wants a reported unit cost that is truthful but that the Agent has an incentive to overestimate the unit cost. That is, the higher the reported unit cost R, the higher the Agent's payoff but, the lower the Principal's payoff.[36]

Since the seminal paper by Antle and Eppen (1985), the literature in Management Accounting on the determinants of budget slack has grown substantially (for an overview, see Brown et al. (2009)). For instance, accounting researchers have investigated how features of the

[36] For simplicity, the literature typically assumes that the agent cannot underestimate the unit cost, which would reduce his wealth, although there are situations in which the agent is willing to underestimate his unit cost (Cardinaels 2016).

budgeting setting (Church et al. 2012; Hannan et al. 2010), features of the private information the Agent has available Dierynck (2012), and features of the environment in which the firm operates (Arnold 2015; Cardinaels 2016) influence the creation of budget slack. The important takeaway from this stream of research for better understanding the information gathering process in the context of scheduling is that the information gathering process in the context of a scheduling problem shares two important features of the budgeting processes that are studied in management accounting: (1) there is an information asymmetry between the party who needs the information to make decisions (i.e. the principal in the budgeting context and the scheduler in the scheduling context) and the party who observes the information (i.e. the Agent in the budgeting context and the employee in the scheduling context) and 2) there is an incentive for the party who has the best information to lie about this information.

7.3.1.2. Endogenous Bias in Gathered Scheduling Information

A first implication of looking at the information gathering process from an accounting perspective is that the distributional properties of the gathered information are likely to be different compared to what is commonly assumed in mathematical scheduling models. That is, although scheduling models use different types of distributions to show the robustness of the derived solutions, the common assumption is that the imperfectness of information is random noise. The prior discussion suggests that consciously induced bias is another aspect of imperfect information. That is, employees will deliberately over-estimate the time and monetary resources needed to complete an activity. Management accounting research has examined which organizational design choices influences such bias and how to structure the information collection process in such way to minimize such slack creation, and hence suggest the bias is endogenous.

A powerful mechanism to address bias in the gathered scheduling information is the span of control of the principal, which refers to the number of Agents that report to the same principal.

In the budgeting context, Hannan et al. (2010) and Dierynck (2012) experimentally examine whether the truthful revelation of private information depends on the number of Agents that report to the same principal while keeping constant the size of the monetary resources that the principal needs to allocate. In one condition, there is one Agent that has to report to the principal, while in another condition three Agents have to report to the same principal. Both studies document that the reporting of private information is more truthful in the condition in which three Agents have to report to the same principal compared to the condition in which only one Agent has to report to the principal. There are two mechanisms that can explain such results. First, economically, an increase in the number of Agents allows the principal to compare the reports if their private information is correlated. If Agents anticipate on such comparison, they will mute their slack creation in the reporting.[37] Behaviorally, even in a case where the distributions from which the private information of the three Agents is drawn are independent, implying that the principal cannot learn anything about the private information from one Agent based on the reported numbers of the other Agents, Dierynck (2012) documents that principals engage in such comparison behavior. Second, Hannan et al. (2010) argue that a higher number of Agents reporting to the same principal makes it easier for the principal to enforce a norm of honesty. If Agents anticipate such norm enforcement, slack creation will be lower when more Agents report to the same principal.

Another mechanism to combat bias in the gathered scheduling information is the way in which employees rotate across tasks. In some firms, employees rotate frequently from one task to another while, in other firms, employees execute the same task for a long period of time. Economic models suggest that rotation is a powerful information revelation mechanism because it reduces the time that Agents spend at one single unit and thus the value of the private information (Arya

[37] Balakrishnan (1995) shows analytically that when multiple divisions compete for a limited amount of centrally procured resources, divisions will earn fewer expected information rents.

and Mittendorf 2004; Prescott and Townsend 2006; Arya and Mittendorf 2006). The impact of job rotation on the truthful revelation of private information has also been empirically investigated in several contexts. Hertzberg et al. (2010) document that loan officer reports about the corporate borrowers they are assigned to are more accurate and contain more bad news about the borrowers' repayment prospects when loan officers rotate compared to when they do not rotate. In the context of suggesting improvements to the performance measures they are evaluated on, Cardinaels et al. (2017) document that business unit managers are more likely to suggest such improvements, which are in their own disadvantage and based on their private information, when business unit managers rotate frequently across business units.

These insights from the management accounting literature on budgeting provide interesting opportunities to better understand the bias in the gathered scheduling information, particularly with experimental methods. One can first validate the effect of the previously mentioned aspects of the information structure (i.e., number of Agents reporting to the scheduler, rotation of employees across tasks) on truthful revelation in the context of scheduling. Although research in the context of budgeting is insightful, it would be interesting to see whether similar patterns of results are observed in the scheduling context. Experiments are an appropriate method to examine the determinants of the truthful revelation of private information in the scheduling context as they allow to observe both the private information and the reported information. In such an experiment, participants can be asked to execute particular tasks and be provided with the time it took them to complete the tasks. The task durations serve as the private information. In the next step, participants are asked to report the task durations to another person who plays the role of a scheduler. In a second step, experimental researchers in operations management can examine other aspects that characterize the structure within which information for scheduling purposes is

gathered. To make an appropriate choice here, it could be valuable to first set up some descriptive studies in order to better understand how the information gathering process in the context of scheduling works.

7.3.2. Addressing Task Selection through Noisy and Multi-Purpose Accounting Information

Recent research in operations management documented that employees frequently deviate from the developed schedule and engage in discretionary task selection with negative performance outcomes. For instance, Ibanez et al. (2018, forthcoming) document that radiologists deviate from the prescribed task order 42% of the time and Kc et al. (2017) document that people have a task selection bias, implying that they select easier tasks when the workload increases. Importantly, both papers document that discretionary task selection hurts performance, albeit that the task selection bias as documented in Kc et al. (2017) improves short-term productivity. When it comes to addressing the problem of discretionary task selection, both papers include quite drastic solutions, such as fully centralizing the ordering of tasks, or soft solutions, such as educating workers about the task completion bias. Although fully centralizing the task ordering looks like an appealing solution, it opens up the question why task ordering has been delegated to employees in the first place. Centralizing the task ordering also is likely a costly solution as (1) the firm has to set up information gathering mechanisms to develop an appropriate task ordering and (2) it reduces the flexibility to adapt the task ordering based on information that comes in during the task execution.

The problem of discretionary task selection can be addressed from a Principal-Agent perspective. The Principal (in this case a manager or headquarters) delegates the task ordering to the Agent as the employee has better information to optimize the task ordering and because constant monitoring of the task ordering is too costly for the firm. Ibanez et al. (2018, forthcoming)

suggest that employees can be encouraged to order their tasks optimally to generate value by developing appropriate nudges. Management accounting information can serve as the basis to develop such nudges. A good way to nudge employees is through providing relative performance feedback on productivity combined with sharing of best practices. Song et al. (2017, forthcoming) document that implementing relative performance feedback in combination with sharing best practices is associated with a 10.9% increase in physician productivity.

While relative performance information is one source of such informational nudge, management accounting information can serve as a basis to develop other efficient nudges towards appropriate task selection. For instance, the ABC hierarchy focuses on the distinction between costs that are unit-driven versus batch-driven. Since deviating from the predetermined order induces a batch-level cost (the cost of setting up to start doing a different task), presenting such ABC hierarchy tailored to the particular setting will give a better insight into the trade-off between costs at different levels in the hierarchy, and hence into the opportunity costs of such deviation. Since Ibanez et al. (2018, forthcoming) argue that the performance-decreasing effects of discretionary task ordering mainly emerge because employees do not correctly trade off the costs of switching against the benefits of repetition, presenting such management accounting information may provide the right nudge. When it comes to addressing the task selection bias as documented in Kc et al. (2017), a TDC system with complex time equations that include the benefits of repetition can show the decrease in duration when more units of the same batch are processed, and provide another example of a good management accounting nudge. Although the suggestions above seem to be intuitive from a practical standpoint, prior accounting research has documented that it is difficult to convince people to include the opportunity costs of their actions when deciding on how to behave (Hoskin 1983; Northcraft and Neale 1986; Vera-Munoz 1998).

Researchers could study in both field and lab experiments where employee behavior and its consequences can be observed whether management accounting nudges are effective, and which nudges (e.g., ABC hierarchy versus time equations) are most effective under which circumstances. Management accounting information used to develop the nudges is noisy and often developed for other purposes. This implies that, next to various behavioral explanations, these informational characteristics of the nudges could explain why nudges may not be working as expected. Properties of the information that are used to develop the nudges should be considered when evaluating the effectiveness of the nudges.

8. Product Design

8.1. Operations Management Approach / Interest

The Operations Management literature has a deep and wide interest in the area of product design and development. A substantial body of work (for an overview, see Ramdas (2003)) considers the role of product variety. A recurring theme is the identification of ways in which to offer such product variety to clients while keeping operational efficiency and costs under control through both process and product design activities. Modular designs such as vanilla boxes (Swaminathan and Tayur 1998) and product architecture choices (Ulrich 1995) such as the use of common rather than unique components across multiple products (Heese and Swaminathan 2006; Ramdas and Randall 2008) are advocated because of their efficiency gains and their risk and cost reducing effects.[38] Kumar and Telang (2011) document that product customization does not necessarily come at higher costs, since after sales service costs are found to be reduced in their setting. Next to cost and operational efficiency, another big theme in the literature is the optimal

[38] Labro (2004) studies existing evidence for the claim that component commonality reduces cost from an Activity-Based Costing perspective and finds that for some levels in the costing hierarchy such evidence is inconclusive.

choice in timing of the new product introduction and the factors that impact this such as decay speed (Caro et al. 2014) and inventory cost (Ke et al. 2013).

Another branch in the literature is mostly empirical and considers new product development (NPD) performance. Gopal et al. (2013) find that new product launches lead to a productivity loss, while Jacobs and Singhal (2014) document that announcements of the restructuring of the product development process generate significant shareholder value. Xia et al. (2016) show a link between the winning of design awards and firm value. Gokpinar et al. (2010) dig into the alignment of the organizational structure with product architecture and show how misalignment negatively affects quality in complex product development. Interestingly, given the theme of this piece, Bendoly et al. (2012) document an important impact of information system quality on NPD performance.

A third branch in the literature focuses on the incentives for in product development and innovation. For example, Hutchison-Krupat and Chao (2014) experimentally investigate how tolerance for failure interacts with incentives in achieving collaborative innovation. Chao et al. (2014) model the incentives and the role of private information in decentralized decision making on which products should be further developed and which projects should be dropped.[39] As an exemplary paper on the focus of this piece, Schlapp et al. (2015) develop a similar setting but focus on the imperfect and costly character of information. This last area of research is possibly the area where Management Accounting and Operations Management research are most closely connected since some accounting research has also modeled this project selection and continuation problem under asymmetric information (e.g. Baiman and Baldenius 2009; Brüggen and Luft 2016; Baldenius et al. 2007).[40]

[39] Zhang and Zenios (2008) write a more general model that also can be applied to the go / no go setting.
[40] The vast majority of work on internal capital markets, however, is done within the corporate finance field.

8.2. Management Accounting Approach / Interest

8.2.1. Management Control Systems and Creativity

Other than on this last topic, the Management Accounting literature has developed quite disjointed from the Operations Management literature on product development. The by far largest focus in the Management Accounting literature has been on the role of management control systems in fostering innovation and creativity, with a large number of papers explicitly focusing on such innovation in new product design.[41] Chenhall and Moers (2015) provide a comprehensive overview of this literature, and we refer to this paper for the plentitude of references therein. They define management control systems as a set of many formal and informal input, process and output controls that are used by management to achieve organizational goals. The overarching conclusion of the literature is that a strong focus on financial performance measures and controls is insufficient when innovative tasks are considered. Broader controls that include nonfinancial performance measures and subjective performance measures (e.g. Grabner 2014) are needed to both encourage and evaluate innovative efforts, particularly since the level of noise in short-run performance measures is high when innovation is concerned.[42] While a lot of this literature is developed with a focus on mature firms, an important sub-branch has been focused specifically on the role of management control systems in entrepreneurial firms / start-ups (see Davila et al. (2009b) for an overview, other references include Davila et al. (2009a)).[43]

8.2.2. Cost Management during Product Development

A smaller literature also developed on cost management methods used during product development. By far the most popular method is target costing (Wouters and Morales 2014), which

[41] For a notable exception of an Operations Management paper that focuses on control systems, see Goodale et al. (2011).
[42] Some experimental studies have spoken to the difficulty of encouraging creativity, even when using performance measures constructed to measure such creativity (e.g. Kachelmeier et al. 2008).
[43] Drake et al. (1999) research how the decision supporting ABC information interacts with the incentives provided in generating innovative outputs.

is a Management Accounting costing method that specifies the allowed cost for a new to be developed product with specific functionality and quality while ensuring the desired profit margin. Unlike cost-based pricing which starts from the newly developed product cost and adds the required margin to determine sales price, target costing is market-driven and starts with market research to understand the functionalities and specifications the customers desire and the price they are willing to pay for these. If, at first, the target cost seems unachievable, product designers, engineers, and management accountants go through repeated value engineering processes, functional cost analysis and other cost reduction strategies to eventually, if successful, reach the cost goal and have the opportunity to launch the new product. Achieving this cost goal depends critically on the collaborative effort of all parties mentioned.

Both Management Accounting and product development publications have suggested that the largest proportion of costs are committed or set in stone during the product design phase, while the actual cash outflows of course only happen much later when buying materials, equipment, and labor. Conventional wisdom suggests an 80/20 rule with 80% of costs committed during the first 20% of a product's lifecycle, roughly coinciding with the design and development phase.[44] Given the importance of cost control in product design, it is not surprising that tools such as target costing and life cycle costing have been developed to support such endeavors. Life cycle costing goes a step further in an attempt to estimate costs over the entire life cycle of the product, including the final salvaging phase, bringing the temporal dimension of cost management into play. The target costing literature, however, has (pardon the sweeping generalization) been much more normative than what is common place in most of the accounting literature. Various case studies describe

[44] Labro (2006b) suggests that there is actually no empirical evidence to back up this claim, while the only empirical evidence suggests a much more muted importance of the design phase in cost commitment of 50% (Ulrich and Pearson 1998).

target costing applications. Navissi and Sridharan (2017) provide a very recent overview of the target costing literature, while Wouters and Morales (2014) and Wouters et al. (2016) provide extensive overviews of the broader literature on all cost management methods used during product development.

8.3. Advancing Operations Management Research on Product Design and Development

We see three particularly fruitful routes for furthering research on product design and development using a Management Accounting lens. The first considers how product architecture endogenously determines accounting measurement noise and bias for decision making. The second develops on how performance measurement and incentives can deliberately or accidentally bias product design decisions. The third considers how product architecture also endogenously determines the availability of performance measures and their properties.

8.3.1. Endogenous Noise and Bias

A first fruitful route considers the endogenous effect of product architecture on accounting measurement noise and bias. A large Operations Management literature studies the role of cost management at product portfolio level, rather than individual product level. For example, the use of common components across different products in the firm's product portfolio is put forward as a way to control costs while offering product line variety (Labro 2004). However, given such portfolio approach, the use of common components will make accurate costing harder than the use of unique components, while typically also increasing the component-level costs in the ABC hierarchy that the firm would like to allocate to the different products they produce. Component-level costs include costs like design costs to design common components that can be fitted into multiple end-products (Gupta and Krishnan 1999; Perera et al. 1999) argue that these design costs can be extensive) and the sourcing cost to identify the vendor that can supply this common component in the required (typically big) volume. For unique components, such cost can simply

be traced directly to the product in which the unique component is used. For common components, however, these costs are indirect and need to be allocated using an appropriate cost driver to understand individual product costs. Any allocation necessarily is somewhat arbitrary and involves some inaccuracy or *noise*. There is a potential for *bias*ed measurement as well. If the common component-level costs are allocated based on the volume of the products in which the component is used, high volume products are likely overcosted. If it is allocated based on the number of different products in which the designed component is used with each of n products bearing 1/n of the component level costs, low volume products may be overcosted. The component commonality problem illustrates clearly that the management accounting practice of product (in this case component) costing may also provide only incomplete information for the optimal commonality decision. While decisions about unique components can be made at the component level, optimization of the portfolio of components require an understanding of costs at the portfolio level, which is usually not the focus of costing systems. Israelsen and Jørgensen (2011) formally show how such portfolio level cost insights are necessary to make the optimal commonality decisions, and how accounting procedures may prove to be impediments when focused on the component level.[45]

8.3.2. Multiple Purposes and Bias

A second fruitful route can focus how incentives and performance management affect the specific features of product development that the Operations Management literature cares about. As outlined in the prior section, the Management Accounting literature on incentives, performance measurement, and control systems to drive innovation and creativity is extensive. Innovation and creativity tend to be quite generally defined, though, and even experimental work that uses a

[45] For a development on this aggregate versus disaggregate (or global versus local) theme in new product development applications more general, refer to Jorgensen and Messner (2009).

specific task (such as the generating of rebus puzzles in Kachelmeier et al. (2008)) is aiming to provide very generalizable insights. With the exception of some experimental studies that have focused on the incentives for collaboration in achieving cost reductions (e.g. Drake et al. 1999; Gopalakrishnan et al. 2015), such specific applications to features of product development are much more limited. In this vein, Israelsen and Jørgensen (2011) show the tension between the information that is necessary to support the optimal decision on the level of component commonality and the performance measurement information that is necessary to incentivize product managers to implement that level of component commonality. Indeed, a common component can be optimal for the firm as a whole, but costly at the level of a product manager who is rewarded solely on the profitability of his own product line.

It would be interesting to study how an increased use of common components in product architecture can be incentivized, if that is optimal from a decision making perspective, and may potentially require deliberate distortion of the cost information used in the commonality decision. Merchant and Shields (1993) and Cooper and Kaplan (1987) offer the example of a Tektronix division only using one cost driver, the number of unique parts, to allocate about 50% of manufacturing overhead costs. Such cost system introduces a deliberate *bias* in the costing information and over-costs unique components to incentivize the use of common components. The division chose to do so because simple product designs were crucial for products with very short life cycles and a strategy of trying to be the first to the market with any new product. As another example, finding ways to encourage information sharing patterns to coincide with product architecture would be a step forward, given the benefits Gokpinar et al. (2010) document of having such alignment. While the accounting literature has done extensive modeling on contracts that

elicit private information truthfully (e.g. Christensen 1982; Dye 1985; Gigler and Hemmer 1998), doing so in a network setting with multiple parties adds substantial complexity.

8.3.3. Endogeneity of Performance Measures

Third, product architecture also has an endogenous effect on the performance measures that can be used to provide incentives. Baiman and Rajan (2002) discuss function sharing (whether each function of the final product is produced by a single component) and coupling / decoupling (whether a change in one component requires a change in other components in order to maintain the performance of the final product). The extent to which components are designed to share functions and the extent to which they are coupled will affect the extent to which product failures can be traced to a particular component and hence to the firm's division, team or worker responsible for the production of the components. Increased function sharing and coupling makes it more difficult to measure the workings of the components separately and hence the performance of the employees in charge of producing the components. The optimal solution for performance measurement purposes will be to assign production of coupled and function sharing components to the same employee.[46] The same argument can be made about modular product architecture.[47]

9. Tips for working on the Management Accounting – Operations Management Interface

To close this monograph, we would like to share some tips that have helped us to do research at the interface of Management Accounting and Operations Management. These practices work well for us and are the result of a trial-and-error process but they are by no means exhaustive or the only way in which interesting research on this interface can be done.

[46] Note that Baiman and Rajan (2002) make this argument in a supply chain management / sourcing setting, but the same reasoning applies to internally sourced components.

[47] The design of the production process, too, can endogenously impact performance measure availability and incentives. While this section focuses on product design rather than process design, we refer to Hemmer and Labro (2017) and Hemmer (1998) for a discussion on how push versus pull production affects performance measurement and incentives.

9.1. Tip 1: Exploit Numerical and Non-Numerical Accounting Data

We believe that breakthroughs at the interface of Operations Management and Management Accounting can be realized by exploiting the quantity and diversity of data that are used in accounting research. Accounting research is typically connected to the analysis of numerical data from, for instance, balance sheets and profit and loss statements. Indeed, a large majority of accounting research still uses such numerical data, which can typically be easily collected from databases such as Compustat. That said, a growing group of accounting researchers also used other types of data to develop proxies for their theoretical constructs of interest.

Textual data is a first type of data that is increasingly used in accounting research. For instance, Costello (2013) collects data about firms' major suppliers from Forms 10-K that US-listed firms have to disclose. Techniques to analyze the large amount of textual data in annual reports, sustainability reports, websites, and tweets have been borrowed from linguistics. For example, Li (2008) measure the readability of the annual report and finds that annual reports of firms with lower earnings are harder to read and that firms with annual reports that are easier to read have more persistent positive earnings. Li et al. (2013) develop a new measure of competition by counting the number of references to competition in a firm's 10-K filing and scaling it by the total number of words in the 10-K filing.[48] Importantly, the textual data that firms make available also contain information that can be useful to proxy for important theoretical constructs in Operations Management. The annual report, for instance, often contains information regarding the approach towards quality management of a firm and can thus be used to proxy for theoretical constructs related to quality management.

Speech data is a second group of data that is increasingly used by accounting researchers to proxy for theoretical constructs that are insufficiently captured by databases. Conference calls

[48] Li (2010) provides an overview of the textual analysis literature in accounting.

are a very popular example. Most publicly-traded firms host conference calls during each quarter during which managers describe the strategy and performance of the firm and answer questions from interested parties, including institutional investors, individual investors, and buy-side and sell-side analysts. These questions deal with a very broad range of topics, including topics related to Operations Management. Importantly, conference calls are considered as an event during which significant information is communicated and conference calls can have costly consequences when managers communicate poorly. Li et al. (2014) use the delegation of answering a particular question by the CEO to a functional manager as a proxy for the relative location of knowledge in the management team. Hassan et al. (2017) use the share of the quarterly conference call devoted to political risk to construct a measure for firm-specific political risk. Overall, we believe that exploiting the potential of non-numerical data can be helpful to do research at the interface between Operations Management and Management Accounting.

9.2. Tip 2: Question Conventional Wisdom and Common Assumptions

A good starting point to do research at the interface of Operations Management and Management Accounting are the beliefs that are commonly held or assumptions that are commonly made in one of both disciplines. For instance, Labro (2004) questions the, at that time, commonly held belief that the use of common components, while likely costlier in purchase price than unique components, keep all other costs down when firms attempt to offer high variety in the product assortment. Relying on the ABC hierarchy, which is a core concept in Management Accounting, she argues that the effect of component commonality on total costs is subtler. Relaxing commonly held assumptions, in particular those on information properties, provides another source of research ideas. A good example here comes from the scheduling literature which typically assumes that the information about the duration of the tasks is available for the scheduler, implying that duration of tasks contains at best random error. Relaxing this assumption implies that the process

via which the information becomes available for the scheduler, and the incentives that may affect this, is incorporated in the analysis.

9.3. Tip 3: Meet with the Accountants

We have benefitted a lot from talking with researchers in Operations Management, and we believe that Operations Management researchers could also benefit from talking more intensively with their colleagues in the accounting department. Visiting the workshops of the accounting department are often a low-cost way to better understand the background of accounting research and provides also access to researchers of the accounting department. Cooperating with researchers from the accounting department is not necessary and does not guarantees success but can be helpful when researchers' knowledge and skills within a research team are strong complements.[49] We hope that this monograph can, at least, help the reader to set up for interesting conversations with colleagues from their accounting department.

10. Conclusion

In this piece, we introduce Management Accounting to Operations Management researchers, unleashing this accounting information perspective into the world of Operations Management to improve our understanding of topics of interest to Operations Management researchers and practitioners. The recurring themes that provide opportunities for application to Operations Management are the noise and bias in Management Accounting information and the fact that Operations Management choices endogenously determine what aspects of performance can be measured, and which noise levels and biases are introduced in performance measurement. We illustrated some of these avenues on the topics of capacity planning and allocation, inventory management, scheduling and product design. Obviously, Management Accounting information

[49] For example, combining an understanding of accounting accrual models with knowledge of dynamic processes in Operations Management may be a great avenue for future research, once the dynamic nature of decision making and the way in which accounting reports on decision making outcomes is considered.

can be useful to better understand other areas in Operations Management such as pricing and revenue management, profitability analysis, customer choice, forecasting, quality management, and work design. While we by no means aimed to be exhaustive in our coverage, and apologize to those readers whose relevant work was left uncited, we hope to have inspired readers to think more about the important interface between Management Accounting and Operations Management and generate novel and thought-provoking research that spans these areas.

11. Appendix: Good Examples of Studies on the Interface between Management Accounting and Operations Management

Although the central claim of this monograph is that incorporating a Management Accounting perspective into Operations Management research can improve our understanding of topics of interest to Operations Management researchers and practitioners and our objective is to stimulate more research on this interface, many good examples of research at the interface between Operations Management and Management Accounting are already available. Surveying the literature in Operations Management reveals markedly different approaches with respect to the way in which Operations Management and Management Accounting are interfaced. Some research uses accounting data to examine research questions in Operations Management. Other research focuses on Management Accounting topics using an Operations Management lens, while a last set of papers focuses on Operations Management topics using a Management Accounting lens. In this appendix, we will provide some selected (with apologies for self-citing) examples of papers on this interface for researchers who would like to have a more concrete idea of what such papers may look like.

11.1. Using Management Accounting Data

A vast line of research in Operations Management investigates the performance consequences of decisions in Operations Management such as decisions related to inventories,

pricing, and the implementation of new Operations Management techniques. Accounting – as a system developed to track firm performance – offers rich ground to develop reliable proxies for firm performance. Hendricks and Singhal (2008) is a good example of a study that uses accounting data to measure firm performance. The main finding of this study is that product introduction delays have a significantly negative effect on firm performance. The authors use Return On Assets (ROA) as a proxy for firm performance and further decompose ROA in Sales Over Assets (SOA) and Return On Sales (ROS), which they define as one minus total costs over sales, to show that the negative effect of product introduction delays on firm performance materializes through reduced revenues, which is evidenced by a decrease in SOA, and increased costs, which is evidenced by a decrease in ROS. Overall, by using publicly available accounting data a broad range of firms can be analyzed. Also, the disaggregated data about revenues and costs allow to provide more direct empirical evidence regarding the mechanisms through which product introduction delays influence firm performance.[50]

11.2. Incorporating Accounting Concepts

A second group of studies on the interface between Operations Management and Management Accounting studies accounting concepts through an Operations Management lens. For instance, Gaur et al. (2005) use publicly available accounting data to develop a model of inventory turnover performance in retail services. They find that a model including gross margin,

[50] To mitigate the concern that the observed effect is caused by other factors, the authors construct a measure for abnormal firm performance as the difference between the firm's actual performance (i.e. with product introduction delay) and the firm's expected performance (i.e. without product introduction delay). To proxy for the firm's expected performance, the authors calculate the performance of several benchmark groups based on performance, size, and industry and argue that the average performance of the benchmark group reflects the expected performance without product introduction delay. Although the approach to construct abnormal firm performance tries to control for well-known determinants of performance such as prior performance, size, and industry, it could still be the case that variation in abnormal performance is driven by other factors than product introduction delay. Not surprisingly, accounting researchers have struggled with such issues before. The mainstream approach in accounting is to first regress all known predictors of firm performance on firm performance. Next, one can use the residuals of this regression as a proxy for abnormal firm performance.

capital intensity, and sales surprise explains a significant part of the within-firm variability and total variability of inventory turnover. Next, they use their model to construct the adjusted inventory turnover, which is a metric that enables comparison across years and firms after controlling for the negative relationship between inventory turnover and gross margin, and the positive relationship between inventory turnover and capital intensity, and inventory turnover and sales surprise. Another example of a study that focuses on accounting concepts from an Operations Management perspective is Kesavan et al. (2010). The authors use publicly available accounting data to develop a simultaneous equations model that provides joint forecasts of cost of goods sold, inventory, and gross margin for retailers. The results show that historical inventory and gross margin contain useful information to forecast sales and that analysts do not fully exploit this information when making sales forecasts.

11.3. Incorporating Accounting Insights

A third group studies Operations Management topics by leveraging on contemporaneous accounting knowledge and insights. A first example is the study of Labro (2004), which considers the commonly held belief that component commonality allows to offer high variety in the product assortment while having lower costs compared to a situation in which different components are used across different products. Using the Activity Based Costing (ABC) framework and relying on the ABC hierarchy, which classifies cost in different levels (i.e. supplier, component, order, batch, and unit) depending on when the cost becomes variable, the author argues that the effect of component commonality is subtler and that existing empirical research at that time did not paint the intuitive picture. The study of Shin et al. (2012) exploits an important idea in Management Accounting to advance insights on pricing. Specifically, Shin, Sudhir, and Yoon (2008) integrate the use of ABC for determining the cost-to-serve of different customers (or customer segments), which typically leads to heterogeneity, in an analytical model with strategic customer behavior. In

the past, researchers in Operations Management and Marketing have not really considered heterogeneity in cost-to-serve because they assumed that profit margins far exceeded any differences in cost-to-serve. On the other hand, consultants often advocate the use of customer cost-based pricing irrespective the particular customer mix of the firm. Shin, Sudhir, and Yoon (2008) show that the profit improvement of customer cost-based pricing depends on the tradeoff between the valuation effect, which will increase profits because of the differential pricing for high and low cost-to-serve customers, and the ratchet effect, which will decrease profits because strategic forward-looking customers may delay purchases to the future because the information revealed through purchasing in a particular period can increase future prices. The model further shows that customer cost-based pricing can be profitable when cost-to-serve heterogeneity is large but suggests that firms should refrain from using variation in cost-to-serve when cost-to-serve heterogeneity is lower. A third example is the study of Cherchye et al. (2013). This study starts from the observation that existing methods of Data Envelopment Analysis (DEA), which is a nonparametric production frontier technique for efficiency assessment, essentially provide a black box treatment of efficient production behavior. That is, existing DEA methods only use information on inputs and outputs but the way in which inputs and outputs are linked to each other does not enter the analysis. The authors first show analytically that including information about the way in which inputs and outputs are linked to each other improves the discriminatory power of the DEA analysis and also allows to calculate output-specific efficiencies. Next, the authors introduce the core insight from the cost accounting literature that the goal of a costing system is to allocate different cost categories, which are labeled as inputs in the DEA literature, to products, which are labeled as outputs in the DEA literature. The authors demonstrate the usefulness of integrating costing data with DEA by means of ABC data from a large service company.

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