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How an industry standard may enhance the mediating capacity of calculations: Cost of ownership in the semiconductor industry

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ABSTRACT

Drawing on a field study of the semiconductor industry, we look at a standard for interorganizational management accounting—more specifically, for cost of ownership (COO) in the semiconductor industry. These COO calculations are inscriptions that make the costs of manufacturing processes and products of integrated circuit manufacturers visible to other organizations in the industry. COO calculations mediate between these organizations by guiding their R & D and capital equipment investment decisions. We consider how the standard that defines the method for calculating COO enhanced the mediating capacity of COO calculations. Drawing on Robson's (1992) notions of mobility, stability, and combinability, we find that the standard provided a common understanding when COO calculations were exchanged and compared to targets. At the same time, the standard provided adaptability that was needed for COO calculations to be mediating instruments. Adaptability meant that companies could significantly modify calculations by inserting private data and adjusting the manufacturing setting and products. Further, companies could switch between default values of the standard and their own proprietary data, and they could use the standard to a greater or lesser extent by selectively applying different parts of the standard. The standard enabled different versions of COO calculations to coexist, which would be similar and commonly understood in exchanges but for internal use, different versions could be calculated and used.

1. Introduction

Sharing information on technology, operational processes, and costs with other companies is relevant in the context of research and development (R & D) cooperation and supply chain management (Agndal and Nilsson, 2009; Anderson et al., 2000; Caglio and Ditillo, 2008; Carr and Ng, 1995; Cooper and Slagmulder, 2004; Håkansson and Lind, 2004; Kulp, 2002; Munday, 1992). A particularly interesting setting for studying such cooperation and the role of interorganizational management accounting is the semiconductor industry. Prior research that focused on this industry has investigated various kinds of mediating instruments that help firms align their investment decisions with investments made by other firms and agencies in the same or related industries (Miller and O'Leary, 2007; Miller et al., 2012). These mediating instruments also comprise calculations of cost of ownership (COO), which include depreciation of the expensive capital equipment and various kinds of recurring costs, such as for tools, operators, and auxiliary materials.

Understanding the mediating capacity of COO calculations is important, because these calculations guide large investment decisions in R & D and capital equipment (Miller and O'Leary, 2007). Our intention is to provide more depth to those findings by examining the role of a costing standard in strengthening the mediating capacity of COO calculations. "Standard" in our research refers to a defined, official, but voluntary method for calculating COO of semiconductor manufacturing equipment, which is described in two publicly available documents published by the industry association Semiconductor Equipment and Materials International (SEMI) (SEMI 2012a,b). This standard incorporates definitions of input parameters and steps in the calculation method.[1] In particular, we want to further develop the ideas of Miller and O'Leary (2007) and Miller et al. (2012), because although they addressed how COO helps to mediate between different organizations, they did not investigate how the presence of the standard for the calculation method mattered for that mediating capacity. We investigate

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[1] "Standard" can be a confusing term. It is a defined *method* for calculating COO. In contrast, we use "calculation" to refer to a set of *numbers* showing a COO result, which may or may not have been conducted according to the method defined in the standard. "Standard" does not refer to quantitative benchmarks or norms, which actually do play an important role in this industry, but for those we use "targets."

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how the standard for the calculation of COO influences and reinforces the mediating capacity of COO calculations.

The context of the semiconductor industry is important for COO calculations acting as mediating instruments. Investments in R & D and manufacturing equipment are enormous, and lead times for developing future technologies are very long and the outcomes are difficult to predict. Moreover, many parties are involved in creating markets and shaping technological progress. COO calculations are used as an indicator of the attractiveness of a candidate technology and of a specific supplier offering. Looking only at the initial investments would not be enough, because operational costs are also considerable; moreover, interdependencies between investments, operational costs, throughput, yield, uptime, and other variables also affect the economics of the technology. These COO calculations represent a form of inter-organizational management accounting (Caglio and Ditillo, 2008, 2012; Fayard et al., 2012). While the integrated circuit manufacturer incurs the COO, equipment suppliers and other firms and agencies provide some of the data and use the results. Therefore,

> calculations of cost of ownership are utilized extensively throughout the semiconductor and related industries. They are intended to compare two or more systems or technologies by relating the capital costs and operating expenses associated with each one to measures of output and operational effectiveness (Miller and O'Leary, 2007, p. 727).

Why would we expect a *standard* to be important for the mediating capacity of COO calculations—an aspect Miller and O'Leary (2007) do not pay much attention to? Imagine two parties negotiating about particular capital equipment investments and thereby also exchanging COO calculations. They could probably define a calculation method to be used in that particular context. The role of an international, institutionalized standard would not be apparent. A standardized method for calculating COO could also be initiated by a large customer firm enforcing this on its suppliers (Dekker 2003; Schulze et al., 2012). However, Miller and O'Leary (2007) provide a deep understanding of how in the semiconductor industry many different organizations (such as semiconductor companies and suppliers for production equipment, subsystems, and materials) need to work together for creating new technology and markets. COO mediates when these organizations make decisions on investments in R & D and capital equipment. A standardized method for calculating COO becomes relevant in that highly networked and hybrid context. Standards are generally of greater importance when an industry is more networked and hybrid (Schilling and Steensma, 2001; Sahayn et al., 2007). We will also see, however, that the role of the COO standard is quite nuanced and not equally important in all exchanges.

Standards in the semiconductor industry are developed and revised through SEMI, which is focused solely on that activity. It provides a forum for collaboration and standard setting, mainly of technical standards (such as for production processes, testing, or wafer size) but also of some standards called "equipment metrics" that relate to topics such as COO. In fact, the semiconductor industry seems to be alone in having a cost accounting standard for the calculation of COO that is voluntary, publicly available, and widely used (Geißdörfer, 2008). Thus, in the networked semiconductor industry standards are likely to be important, and that industry provides an intriguing and rare example of a management accounting standard that is unexplored by Miller and O'Leary (2007).

This background leads to the research question for the present study: In what way does the existence of a standard for the calculation of COO enhance the capacity of these calculations to be a mediating instrument? This research does not address the accuracy or comprehensiveness of the standard, but focuses on how the standard helps to make these calculations "work," in the sense of influencing what is happening in organizations, or more specifically, in directing semiconductor companies' investment decisions.

The main contribution of the present study is to show that the standard supported the mediating capacity of COO calculations because it provided adaptability to those calculations. We analyze COO calculations as inscriptions of the manufacturing processes and products of integrated circuit manufacturers, through which these products and processes are made visible to other organizations in the industry. Drawing on Robson's (1992) notions of mobility, stability, and combinability of inscriptions, we find that the standard provided a common understanding adequate to make the numbers understandable to different users. This understanding increased the possibility to meaningfully aggregate, disaggregate, and recombine the calculations and compare these to norms. Moreover, information could more easily be exchanged when organizations were contributing to calculations and spreading the results. However, we find that the standard also enhanced the meditating capacity of COO calculations in a more intriguing and paradoxical way, namely by providing adaptability. By having a common *method*, users could make significant changes to the actual *calculations* and thereby adapt these to their own needs and situation. These changes concerned quite fundamental modifications to the calculations, such as inserting proprietary data or changing the manufacturing processes. Users could also switch between their own data and default values that are defined in one of the documents describing the standard. Furthermore, the standard could be used in different ways: from completely (including the encompassing COO metric), to only partially regarding particular performance metrics (such as uptime, utilization, or mean time between failures), or to even only for the definition of the basic data on machine states as input for performance metrics. The standard provided adaptability that allowed the calculations to be mediating instruments, because different users had different requirements. In other words, the standard codified the *method* for calculating COO and at the same time provided the groundwork that allowed users to flexibly adapt specific *calculations* to make them more relevant mediating instruments.

This study is based on various kinds of data. We consulted research papers and other publicly available documents, and we spoke with many COO experts in the semiconductor industry, several of whom have been involved in these developments for over 20 years. We also obtained documents and an example calculation based on software that incorporates the COO standard. Furthermore, we created a spreadsheet-based model of COO calculations to verify our detailed understanding of the standard for the calculation of cost of ownership.

The remainder of this paper is structured as follows. A literature review follows in Section 2. Details on the empirical research method appear in Section 3. The findings and analysis are in Section 4, which includes a description of the standard for the calculation of COO, examples of use of the standard, and analyses of how the standard contributed to the mediating capacity of the calculations. In Section 5 we discuss these findings and analyses, and Section 6 concludes the paper.

2. Literature review

We quite extensively summarize prior work analyzing COO calculations as a mediating instrument for coordinating investments across companies in the semiconductor industry (Miller and O'Leary, 2007). We also briefly mention other research in accounting that has investigated mediating instruments in other industries. Furthermore, we review the framework of Robson (1992), which we use to analyze the role of the standard for the COO calculation method. To get a first idea of how we will look at COO calculations that mediate between very diverse areas, consider the following example from Latour (1987). When Thomas Edison was looking for a way to create an affordable electrical lamp, he considered that the cost for consumers needed to be equal to that of gas lighting. He collected information about market prices for various materials for the filament, and he was bound by the laws of physics behind electrical resistance and the generation of electrical light. All these very diverse considerations were related to