

Essays on Vertical Integration, Inventory Efficiency and Firm Performance

DISSERTATION



zur Erlangung des Doktorgrades des Fachbereichs Wirtschaftswissenschaften
an der Wirtschaftswissenschaftlichen Fakultät der Universität Passau

vorgelegt von
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August 2018

Acknowledgements

The process of writing this dissertation has been a period of intense learning for me. This project would never have been possible without the support and guidance of various people who have supported and helped me so much throughout this period.

First and foremost, I thank my supervisor, Prof. Dr. Robert Obermaier, for all the advice, ideas, moral support and patience in guiding me through this project. He substantially contributed to my research experience by giving me intellectual freedom in my work, supporting my attendance at various conferences, engaging me in thinking outside the box, and demanding a high quality of work in all my endeavors. His wealth of knowledge in the field of business administration, and especially in management accounting, has always been inspiring. I count myself incredibly lucky to have him as a mentor. I would also like to thank Prof. Dr. Andreas König as my second examiner and for his interest in my work.

I am grateful to all of those with whom I have had the pleasure to work during the last years. I am especially grateful to Dr. Markus Dirmhirn, Dr. Christian Meier, Philipp Mosch, Dr. Josef Schosser, Angelika Schmid, Stefan Schweikl, Felix Weißmüller and Bettina Wilke for our valuable exchanges of knowledge and insightful debates. Additionally, all the student assistants who supported me throughout my work deserve my thankfulness. Very special thanks go to Ulrike Haberl whose humor, administrative and moral support substantially contributed to an enjoyable atmosphere at the chair. I would also like to extend my thanks to Dr. Graham Neil Jackson who spent many hours of proofreading this dissertation.

I would also like to thank my friends and family. I am particularly grateful to my parents, Max and Ursula, my grandmother Elfriede and my friends, Daniel and Martin, who supported me in so many ways during my time in Passau.

Finally, my special thanks go to Julia, for all her love and support during the last years even when I spent long days with my dissertation. This project would never have been possible without her support.

August 2018

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Preface

Motivation

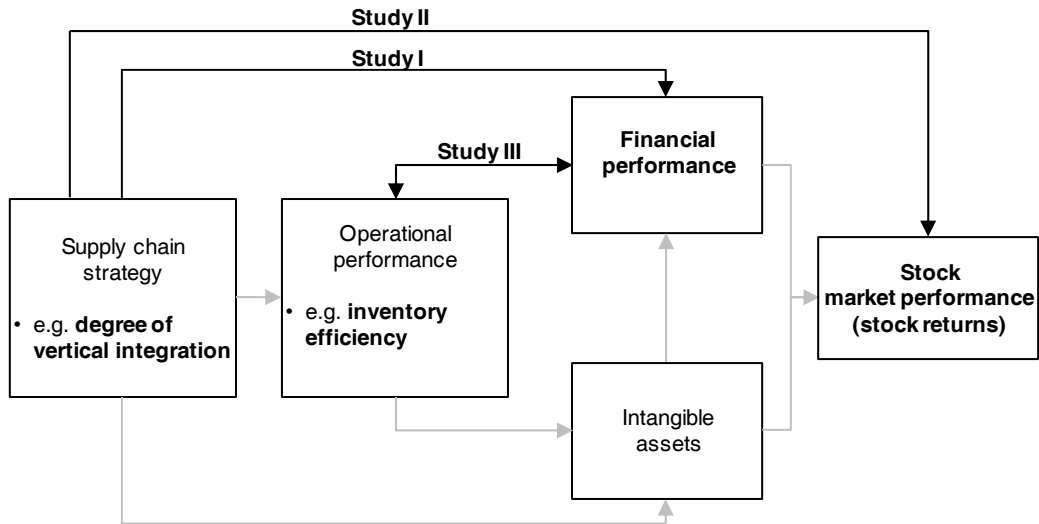
Many researchers argue that firms which build up effective supply chains by striking a balance between responsiveness and efficiency create for themselves an important source of sustainable competitive advantage (e.g. Morash et al. 1996; Chopra and Meindl 2001; Hendricks and Singhal 2005). In addition, firms which are not able to manage their supply chains effectively are more likely to be hit by supply chain disruptions (e.g. Hendricks and Singhal 2003; Hendricks et al. 2009), which have the potential to cause significant, negative economic impacts. For instance, such disruptions adversely affect operating performance (Hendricks and Singhal 2005) and shareholder wealth (i.e. stock returns and stock risk). Thus, supply chain disruptions are a major threat to a business. It is not surprising, then, that managers and investors alike are usually interested both in ensuring that supply chains are managed effectively and in monitoring how this relates to their firm's financial and stock market performance.

Thus, the link between, on the one hand, how a firm's supply chain is organized and, on the other, how good its financial and stock market performance is, has been a key issue in supply chain management over the past decades and has drawn interest from researchers and practitioners alike (Chopra and Meindl 2001; Hoberg and Alicke 2013). Among other things, the degree of vertical integration¹ and inventory efficiency, are two important determinants of a firm's supply chain structure which have been identified as key drivers of firm performance (Chopra and Meindl 2001; Shi and Yu 2013). The degree of vertical integration, inventory efficiency, financial and stock market performance are linked through a framework that has been proposed

¹ Vertical integration is defined as “the combination, under a single ownership, of two or more stages of production or distribution (or both) that are usually separate” (Buzzell 1983, p. 93). Vertical disintegration, as the counterpart to integration is defined as “the emergence of new intermediate markets that divide a previously integrated production process between two sets of specialized firms in the same industry” (Jacobides 2005, p. 465). The concepts of outsourcing and insourcing are closely linked to vertical disintegration and integration, although they may differ slightly in meaning. Throughout this thesis, I follow previous research and apply the terms “vertical disintegration” and “outsourcing” interchangeably. The degree of vertical integration is then defined as the proportion of a firm's total output that is accounted for by in-house production.

in previous literature and that is shown in Figure 1 (e.g. Chopra and Meindl 2001; Hendricks and Singhal 2003).

Figure 1: Research framework (Source: our own illustration based on Chopra and Meindl (2001) and Hendricks and Singhal (2003))



Note: The relationships which are investigated in this thesis are illustrated with black arrows. The variables of interest are highlighted in bold.

This classic framework illustrates the link between a firm’s supply chain strategy (e.g. the degree of vertical integration), operational performance (e.g. inventory efficiency), intangible assets, financial performance and stock returns. The present thesis addresses three relationships within the framework. Study I examines the relationship between the degree of vertical integration and financial performance. Study II links the degree of vertical integration, both theoretically and empirically, to long-term stock returns. Study III concentrates on the relationship between inventory efficiency and financial performance.

The relevance of the degree of vertical integration and inventory efficiency is now widely acknowledged, and there are constantly growing literature streams which investigate both the relationship between the degree of vertical integration and performance (financial and stock market performance) (e.g. Buzzell 1983; D’Aveni and Ravenscraft 1994; Jiang et al. 2006) and that between inventory efficiency and firms’ financial performance (e.g. Chen et al. 2005; Capkun et al. 2009; Eroglu and Hofer 2011a; Eroglu and Hofer 2011b; Obermaier and Donhauser 2012; Mishra et al.

2013). What these literature streams have in common is that their results have so far been inconclusive, i.e. some studies find a positive relationship, while others find a negative relationship or no relationship at all. A few studies conclude that the relationship between vertical integration or inventory efficiency and financial performance is curvilinear. In the light of these inconclusive results, this dissertation aims to gain deeper insights into the relationship between how a firm's supply chain is organized (in particular, the degree of vertical integration and inventory efficiency displayed) and how good its financial and stock market performance is with a view to closing several research gaps.

Research Gaps

Previous research on the relationship between vertical integration and financial performance has usually concentrated either on the advantages of vertical integration or on its disadvantages (i.e. on the advantages of disintegration or outsourcing). It is not sufficient, however, to take into account only one of these two perspectives, as transaction cost economics (Coase 1937; Williamson 1975) and the resource-based view of the firm (Prahalad and Hamel 1990; Barney 1991) both suggest that vertical integration can be associated with advantages and disadvantages, and these need to be considered simultaneously when the supply chain structure is defined on the basis of the degree of vertical integration it displays. Furthermore, the few exceptions that postulate and investigate a curvilinear relationship (i.e. inverted U-shaped; e.g. Rothaermel et al. 2006; Kotabe and Mol 2009) between the degree of vertical integration and financial performance do not test the robustness of the functional form. However, recent research (Lind and Mehlum 2010; Haans et al. 2016) has shown that it is essential to test the robustness of the functional form if misleading results are to be avoided. In particular, Haans et al. (2016) point out that the regression results gained from a huge number of empirical studies which investigate the link between a variable of interest and financial performance do indeed report an inverted U-shaped relationship. These results are not, however, robust with respect to their functional form.

Besides this theoretical and methodological issue, a further limitation of previous research arises from the concentration on US data when investigating the

relationship between the degree of vertical integration and financial performance. The relationship between the degree of vertical integration and financial performance for German manufacturing firms is scarce. However, it is important to better understand manufacturing firms in Germany as a major economy with a strong manufacturing sector and highly competitive firms.

Research shortcoming 1: Previous empirical research has not sufficiently considered and investigated a curvilinear (inverted U-shaped) relationship between the degree of vertical integration and financial performance, and knowledge on this relationship for German manufacturing firms is scarce.

There is even less knowledge on the relationship between the degree of vertical integration and stock returns. Previous studies mainly concentrate on accounting-based performance metrics such as return on assets or return on sales, when analyzing the relationship between the degree of vertical integration and firm performance, and have thus neglected the importance of stock returns for major firm stakeholders (Rappaport 1986; Hillman and Keim 2001). Moreover, the few studies which use stock returns instead of accounting-based measures as a dependent variable concentrate on short-term stock market reactions when they apply event study methodology. However, recent research has shown that investors are not able to incorporate qualitative information or intangibles fully into stock prices in the short-run, resulting in significantly abnormal long-term returns (Daniel and Titman 2006). As the degree of vertical integration is also qualitative in nature, the question remains as to how the stock market values such information in the long-run. Furthermore, previous empirical studies have rarely considered environmental uncertainty when they analyze the link between vertical integration and firm performance, although theory provides arguments that suggest this has a moderating effect. Despite the latest strategic shift seen during the recent financial crisis for firms to move towards an increasing degree of vertical integration (Drauz 2014), there is no study which investigates the effect of the recent financial crisis on the relationship between vertical integration and firm performance. However, the recent financial crisis was a trigger event that increased environmental uncertainty and affected supply chain

structures (Hoberg and Alicke 2013). Hence, the second research shortcoming is formulated as:

Research shortcoming 2: Knowledge on the relationship between the degree of vertical integration, the recent financial crisis and long-term stock returns is limited.

Inventory efficiency, representing another element of a firm's supply chain, has been subject to a literature stream that empirically investigates its relationship to financial performance (see Isaksson and Seifert (2014) for an overview of studies). Although previous research has extended knowledge in this field, the question of causality between inventory efficiency and financial performance has rarely been addressed.² Previous research concentrates on the impact exerted by inventory efficiency on financial performance and neglects the converse causal logic, i.e. the idea that financial performance may affect inventory efficiency as well. A positive relationship exerted by inventory efficiency on financial performance is usually explained by citing the cost savings generated by greater inventory efficiency (i.e. lower inventory levels), while a negative relationship is explained with reference to the need for higher inventory levels to act as a buffer with a view to ensuring that operations proceed smoothly, processes run well and higher levels of service are provided to customers (Obermaier and Donhauser 2012). However, inventory holding decisions may be based on a firm's financial performance as well. For instance, firms that are performing well can afford to hold higher inventories or invest in new technologies that allow them to operate with lower inventory levels. Thus, the relationship between inventory efficiency and financial performance is an interdependent (i.e. bidirectional) relationship, rather than a one-way relationship. Besides causality issues, previous studies have only investigated the relationship between inventory efficiency and financial performance in the short-run without considering long-term

² The terms "causality" or "causal" in this dissertation are based on Granger's definition (1969). Causality, in this sense, does not mean true causality in a deep sense of the word. Instead, causality refers to the time series nature of the data and measures intertemporal interactions among variables, i.e. Granger causality measures precedence and information content, but does not in itself indicate causality in the more common use of the term.

effects. Furthermore, although recent research has shown that the relationship between the individual inventory components (i.e. raw materials, work-in-process and finished goods) and financial performance differs substantially, knowledge on this issue is still scarce.

Research shortcoming 3: Knowledge on the interdependent and longevity relationship between, on the one hand, the efficiency with which raw materials, work-in-process and finished goods inventories are managed and, on the other, a firm's financial performance, is scarce.

Derivation of research questions

In order substantially to close the aforementioned research gaps, this dissertation answers the overarching research question: what is the relationship between the way in which a firm's supply chain is organized, and its financial and stock market performance? (see Figure 2 for an overview of focal research questions throughout this thesis).

Figure 2: Overview of the dissertation

| Overarching research question | Study | Focal research question |
|---|--|---|
| What is the relationship between the way in which a firm's supply chain is organized, and its financial and stock market performance? | (I) Vertical (Dis-)Integration and Firm Performance: A Management Paradigm Revisited | What is the overall relationship between the degree of vertical integration and a firm's financial performance? |
| | (II) The Myth of Vertical Disintegration: A Management Paradigm Revisited and Scrutinized from a Capital Market's Perspective in the Wake of the Recent Financial Crisis | (1) What is the relationship between the degree of vertical integration and long-term stock returns? (2) How did the recent financial crisis affect the relationship between the degree of vertical integration and long-term stock returns? |
| | (III) Inventory and Firm Performance: A Material and Financial View of an Interdependent Relationship | Is there an interdependent relationship between, on the one hand, the efficiency with which raw materials, work-in-process and finished goods inventories are managed and, on the other, a firm's financial performance? |

In view of the limited amount of attention paid to whether there is an inverted U-shaped relationship between the degree of vertical integration and financial performance, the first research question addresses research shortcoming 1 by scrutinizing the overall relationship between the degree of vertical integration and

financial performance (see also Figure 1). To address this issue, the first paper³ (co-authored by Prof. Dr. Robert Obermaier) hypothesizes that there is an inverted U-shaped relationship between the degree of vertical integration and financial performance, a hypothesis that is based on transaction cost economics (Coase 1937; Williamson 1975), on the resource-based view of the firm (Barney 1991; Prahalad and Hamel 1990) and on a whole series of advantages and disadvantages associated with vertical integration. Based on a sample of 413 German manufacturing firms in the period from 1993 to 2013, the regression results first indicate that there is indeed an inverted U-shaped relationship. However, in the light of recent research, further robustness checks were applied to verify the functional form of the relationship (Lind and Mehlum 2010; Haans et al. 2016). After these robustness checks were conducted, the results suggest more that there is a positive, but diminishing relationship between the degree of vertical integration and financial performance, i.e. we do not find the proposed inverted U-shaped relationship between the degree of vertical integration and financial performance.

The second paper⁴ (co-authored by Prof. Dr. Robert Obermaier) results from research shortcoming 2, which refers to the relationship between the degree of vertical integration and long-term stock returns, and to the moderating effect of the recent financial crisis on this relationship. Hence, the first research question builds on the relationship between the degree of vertical integration and long-term stock returns, while the second research question addresses the moderating effect exerted by the recent financial crisis. This paper examines the aforementioned relationships by analyzing a sample of 2,787 European manufacturing firms between 1992 and 2015, with 19,580 firm year observations. This paper's theoretical foundations are grounded in transaction cost economics and the resource-based view of the firm. A conceptual framework is developed and described to derive the hypotheses. The relationship between vertical integration and long-term stock returns is investigated by comparing the abnormal returns generated by stock portfolios that have been

³ This paper was presented at the 27th annual POMS conference and the 79th annual VHB conference. Furthermore, this paper has been submitted to *Schmalenbach Business Review* (SBR) and is now in the second round of review.

⁴ This paper has already been presented at the 24th EurOMA conference and has been accepted at the 78th annual *meeting* of the *Academy of Management* and the 80th annual *VHB conference*.

sorted by their degree of vertical integration. The results show that the capital market's attitude to the degree of vertical integration changed during the recent financial crisis. In particular, portfolios consisting of firms with the lowest degree of vertical integration generated abnormal long-term stock returns before the crisis (1992-2007), while portfolios with the most highly integrated firms generated the highest stock returns after the onset of the crisis (2007-2015).

The research question posed in the third paper⁵ (single-authored) addresses research shortcoming 3, i.e. the lack of knowledge on the interdependent relationship between inventory efficiency and firms' financial performance, and proposes a complex and dynamic view of the inventory-performance link. Thus, this paper sheds light on an interdependent relationship that has often been neglected until now. There are only a few studies that partially address reverse causality issues between inventory efficiency and firm performance (e.g. Swamidass 2007; Obermaier and Donhauser 2012; Isaksson and Seifert 2014; Sridhar et al. 2014; Kroes et al. 2018). Analyzing a sample of 332 German manufacturing firms with 3,028 firm-year observations from 1990 to 2016, results show that there are complex feedback loops among inventory efficiency of raw materials, work-in-process, finished goods and financial performance. Furthermore, the magnitude and longevity of the relationships among our variables substantially differs.

Contributions

Overall, this thesis sheds light on the link between how a firm's supply chain is organized and the financial performance it achieves by looking at the degree of vertical integration and inventory efficiency - two of the most important determinants of a firm's supply chain structure (Chopra and Meindl 2001; Shi and Yu 2013). In particular, the three studies make a number of contributions to the state of research. First, this thesis shows that the degree of vertical integration is positively related to financial performance in a sample of German manufacturing firms. This is especially interesting because the degree of vertical integration displayed by those firms decreased from the 1990s onwards until the onset of the recent financial crisis. These, at first glance, conflicting results are discussed in detail in the first study.

⁵ This paper was presented at the 19th International Symposium on Inventories in 2016.

Second, this thesis illustrates that the degree of vertical integration is related to long-term stock returns. On the basis of the presence of abnormal long-term stock returns, the results indicate that there is market inefficiency (Fama 1970), i.e. investors may not be able to incorporate information about the degree of vertical integration fully into stock prices. Instead, they correct their initial assessment when they get additional information, which becomes available as time goes by (Edmans 2011). Besides this, this thesis shows that the capital market changed its attitude to the degree of vertical integration during the recent financial crisis, i.e. the least vertically integrated firms generated the highest stock returns before the financial crisis, while the most highly integrated firms have generated the highest returns since the crisis. Thus, this result suggests that investors' perceptions about the degree of vertical integration changed in the course of the financial crisis, mainly because highly integrated firms overcame the financial crisis pretty well thanks to their being less dependent on external suppliers.

Third, this thesis adds to the literature about the inventory-performance relationship by showing that the relationship is much more complex than is typically assumed. There are complex feedback loops not just between the efficiency with which raw materials and work-in-process inventories are managed, and financial performance, but also among inventory components themselves. Furthermore, this thesis provides the first study that investigates the longevity of the impact exerted by inventory efficiency on financial performance, and vice versa, and it shows that the longevity of the impact varies substantially.

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Vertical (Dis-)Integration and Firm Performance: A Management Paradigm Revisited

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Abstract

An increasing trend towards vertical disintegration in the manufacturing sector has been detectable in many countries beginning in the 1990s. According to the concentration on core competencies as a management paradigm during the last decades, firms should have outsourced (i.e. vertically disintegrated) non-core competencies to achieve cost savings, enhance competitiveness and improve firm performance. Following this management paradigm, most empirical studies hypothesized a negative linear relationship between the degree of vertical integration and firm performance. However, findings of prior empirical research are mixed, i.e. the relationship between the degree of vertical integration and a firm's financial performance has found to be negative, positive, curvilinear or not significant. Based on transaction cost economics and the resource based view, and by considering advantages and disadvantages of vertical integration, we assume an inverted U-shaped relationship with an optimal level of vertical integration, where the highest financial performance can be found. On the one hand, we find descriptive analyses indicating an increasing trend towards vertical disintegration. On the other hand, after applying multiple regression analysis on a sample of 434 German manufacturing firms in the period 1993 to 2013, our data structure suggest a positive, but diminishing relationship between the degree of vertical integration and financial performance rather than an inverted U-shaped relationship. Our results indicate that managers might have gone too far in their vertical disintegration strategy.

Keywords: vertical integration, outsourcing, financial performance, transaction costs, resource-based view

1. Introduction

Vertical integration, defined as “the combination, under a single ownership, of two or more stages of production or distribution (or both) that are usually separate” (Buzzell 1983, p. 93) and vertical disintegration, defined as “the emergence of new intermediate markets that divide a previously integrated production process between two sets of specialized firms in the same industry” (Jacobides 2005, p. 465) are classic issues for researchers and practitioners.¹

Vertical disintegration has been a key business trend in the whole manufacturing sector during the last decades and has interpreted supply chain management as a key driver for financial performance not only in the supply chain literature (Shi and Yu 2013). This is in contrast to a former view where “owning the value chain” and a high degree of vertical integration has been a predominant strategy (Harrigan 1984). A classic example is Henry Ford’s River Rouge complex by the 1920s, with coal and iron ore mines, timberlands, rubber plantations, railroads and more resulting in total control over the entire supply chain. However, his widely successful strategy of high vertical integration pushed a bit out of fashion in the 1950s and 1960s when firms recognized that vertical disintegration has advantages as well which became then a widely used management tool in practice (Welch and Nayak 1992). Rigby and Bilodeau (2015) analyze the usage-satisfaction relationship among different management tools and show that outsourcing is on the one hand widely used and on the other hand dissatisfies managers most when asked about the outcomes of the outsourcing decisions.

There is also a rich body of empirical literature that investigates the performance implications of integration strategies (see Lahiri (2016) for an overview). However, the results so far are inconclusive, i.e. some studies found a negative, others detect a positive or an insignificant relationship. A few studies find a curvilinear relationship between the degree of vertical integration and firm performance.

¹ As in prior studies, we use the concepts of vertical disintegration and outsourcing synonymously although they may slightly differ (e.g. Broedner et al. 2009; Desyllas 2009). Further, the terms “vertical integration” and “degree of vertical integration” are used interchangeable throughout this study.

Despite a growing body of empirical research, there are still some major research gaps that we address in our study. First, prior research often hypothesize and investigate only a linear relationship between vertical integration (or disintegration) and firm performance although “many intuitively appealing arguments have been offered both for and against outsourcing as a means of achieving sustainable competitive advantage” (Gilley and Rasheed 2000, p. 763). Second, the few studies that investigate a curvilinear relationship do not check the robustness of the functional form. Third, knowledge about the relationship between vertical integration and firm performance for German manufacturing firms is scarce but essential, as most of the existing studies focus on US samples. It is especially important to better understand manufacturing firms in a major economy with a strong manufacturing sector and highly competitive firms. Fourth, prior studies that find a linear and positive relationship between vertical integration and financial performance do not discuss the decreasing degree of vertical integration during the last decades.

Accordingly, the objective of this study is to investigate the relationship between vertical integration and financial performance using data of German manufacturing firms between 1993 and 2013 and to close the aforementioned research gaps. Therefore, we are analyzing the following fundamental research question:

What is the overall relationship between the degree of vertical integration and a firm's financial performance?

Our results indicate that the degree of vertical integration is positively related to financial performance. Considering the decreasing degree of vertical integration since the beginning of the 1990s, our findings suggest that German manufacturing firms have outsourced too much of their activities or have not been able to realize the benefits they desired.

This study makes several contributions to extant research. First, we shed light on the hitherto often neglected inverted U-shaped relationship between the degree of vertical integration and financial performance. Second, we show that in particular financially low performing firms drive the decreasing trend of vertical integration.

Third, we empirically explore the relationship between the degree of vertical integration and financial performance based on a sample of German manufacturing firms. Thus, we contribute to the empirical vertical integration literature. We not only provide results for a major European economy but also discuss reasons why firms have vertically disintegrated since the 1990s although this strategy has been detrimental for firm performance.

The remainder of this paper is organized as follows: Section 2 gives an overview about the theory and develops the hypothesis. In Section 3 the research methodology is described. The results of the analysis are presented in Section 4 whereas Section 5 discusses its implications. The study concludes with a summary of the key findings and further research opportunities.

2. Theory and Hypothesis

Transaction costs economics (TCE) (pioneered by Coase (1937) and further developed principally by Williamson 1971; 1975; 1991b) and the resource-based view (RBV) of the firm (Penrose 1959; Wernerfelt 1984; Barney 1991) have made key contributions to our understanding of make-or-buy decisions. Within TCE, the core issue is, whether the transaction costs of utilizing the market or engaging in vertical integration (i.e. internalization of transactions across value chain) are greater or lower. Transactions should take place within the institutional framework (market or hierarchy) which causes the lowest costs. According to the RBV, vertical integration is mainly influenced by the competitive advantage a firm has in a particular stage of the value chain relative to the market (Jacobides and Hitt 2005; Jacobides and Winter 2005). This competitive advantage is a result of a firm's predominant resources and capabilities which arise from a unique, path-dependent learning process (Levinthal 1997; Jacobides and Winter 2005). According to Barney (1991), resources and capabilities lead to competitive advantage if they are valuable, rare, difficult to imitate and non-substitutable. Theory on TCE and RBV provide complementary explanations for the decision whether a firm should change its degree of vertical integration or not. The complementarity of these determinants has been subject to a rich body of literature (see McIvor (2009) for an overview). It has to be

emphasized that each of these determinants are both important when deciding to vertically integrate or utilize the market because neither TCE nor the RBV alone sufficiently explain a firm's degree of vertical integration.

Hypothesis

The literature reviewed so far summarizes the determinants of the degree of vertical integration. The degree of vertical integration then results in a bundle of advantages and disadvantages (respectively the benefits and risks) which are usually related to operational performance (e.g. inventory scheduling), intangibles (e.g. product quality) and to financial performance (revenues and costs), (e.g. Buzzell 1983; Harrigan 1984; Stuckey and White 1993; D'Aveni and Ravenscraft 1994). As operational performance and intangibles affect financial performance again, the degree of vertical integration is not only directly related to financial performance but also indirectly. It has to be emphasized, that the advantages of vertical integration are disadvantages of vertical disintegration (respectively outsourcing) while disadvantages of vertical integration are advantages of vertical disintegration (respectively outsourcing). Table 1 summarizes the advantages and disadvantages of vertical integration, which are described below.

Table 1: Advantages and disadvantages of vertical integration

| <i>Advantages</i> of vertical integration | <i>Disadvantages</i> of vertical integration |
|--|--|
| <ul style="list-style-type: none"> • higher quality standards • supply assurance of critical materials • better coordination between different stages of production • lower lead times; higher delivery performance • higher customer satisfaction • create credibility for new products • protection of proprietary products or process technology • create and exploit market power • lower transaction costs | <ul style="list-style-type: none"> • higher production, agency and coordination costs • higher capital requirements • higher fixed costs • risk of concentrating on additional non-core operations • reduced flexibility and market exit barriers |

A range of arguments try to explain a positive relationship between vertical integration and firm performance. Operational performance is improved through providing higher quality standards and having more control over input quality (D'Aveni and Ravenscraft 1994). Furthermore, vertical integration is often viewed as

a strategy to increase supply assurance of critical materials and improve coordination between different stages of production (Buzzell 1983; Harrigan 1984), i.e. coordination between production, inventory and logistics scheduling is improved. Consequently, vertical integration affects operational efficiency as it improves throughput of materials and information along the supply chain resulting in lower lead times and higher delivery performance.

A higher degree of vertical integration can also help to build intangible assets which, in turn, affect financial performance as they are traditionally perceived to be the basis of competitive advantage (Dierickx and Cool 1989; Barney 1991). Based on higher operational performance, improved delivery performance and lower lead time should result in higher customer satisfaction. Further, among other things, vertical integration creates credibility for new products (Harrigan 1984) and provides protection of proprietary products or process technology (Mahoney 1992) and is thus consistent with the resource-based view. Further arguments concern a firm's market power which is increased by building market entry barriers and price discrimination (Perry 1978; Stuckey and White 1993). Higher market entry barriers and price discrimination should increase firms' revenues and profits.

The positive impact of a higher degree of vertical integration on financial performance is usually explained with cost savings. These cost savings are mainly related to lower transaction costs associated with less dependency on external suppliers. A higher degree of vertical integration could reduce the cost of searching, negotiating, drawing up a contract, monitoring and enforcement costs with external suppliers (Mahoney 1992). Besides transaction costs, vertical integration leads to cost savings achieved by improved coordination of production or by eliminating steps, reducing duplicate overhead costs (Buzzell 1983; Harrigan 1984).

However, prior research argues that vertical integration is only beneficial to financial performance up to a certain point. Beyond that point, a higher degree of vertical integration would have detrimental effects on financial performance. A first group of arguments concerns the costs that are associated with an excessively high degree of vertical integration. These costs consist of production, agency and coordination costs (Bettis et al. 1992; D'Aveni and Ravenscraft 1994; Desyllas 2009). The simultaneous coordination of a large number of activities and the underutilization of capacities in

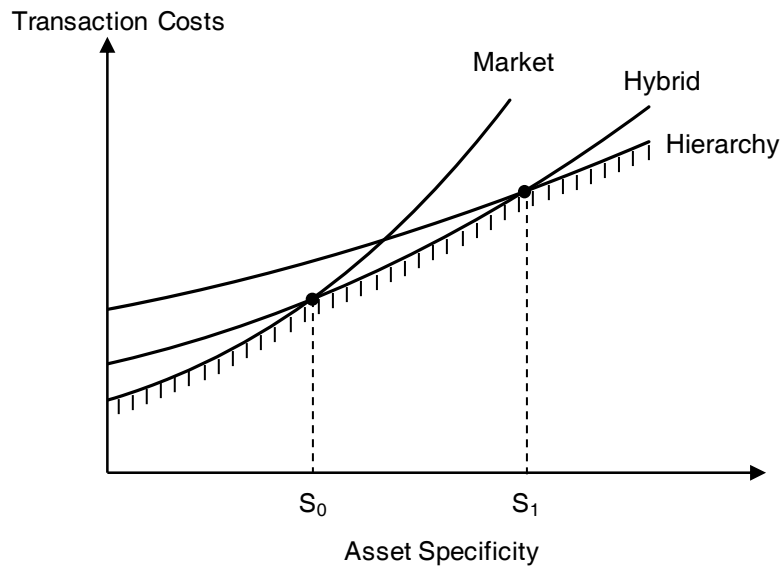
some stages of production (D'Aveni and Ravenscraft 1994; Harrigan 1985) could increase production costs. A higher degree of vertical integration leads to less efficient utilization of different stages of production which increases unit cost (Mahoney 1992). Further sources of production cost disadvantages are higher capital requirements and capital lockups (Mahoney 1992), higher fixed costs that lead to higher operating leverage and to a higher break-even point (Gilley and Rasheed 2000). Highly integrated firms bear the risk that they focus on additional non-core operations. This may result in information deficits among corporate-level managers due to information asymmetries about the non-core activities (D'Aveni and Ilinitich 1992). Moreover, changing technology or market conditions which make products obsolete in one stage of a vertically integrated firm are key drivers of reduced flexibility and exit barriers (Buzzell 1983). A higher degree of vertical integration then reduces strategic flexibility with respect to environmental changes by switching to suppliers with new and best technologies (Balakrishnan and Wernerfelt 1986; Gilley and Rasheed 2000; Mahoney 1992).

It has to be emphasized that most empirical studies only hypothesize and investigate a linear relationship between the degree of vertical integration and firm performance assuming either improvements of firm performance through integration or disintegration. This might be one reason why existing empirical research shows a mixed picture. In summarizing the literature on vertical integration and firm performance, Lahiri (2016) conclude that empirical findings are inconclusive. Some studies find a negative linear relationship (e.g. Rumelt 1982; D'Aveni and Ilinitich 1992; Desyllas 2009) others find the relationship to be positive linear (e.g. Buzzell 1983; Harrigan 1986; D'Aveni and Ravenscraft 1994; Novak and Stern 2008; Broedner et al. 2009). Only a few studies hypothesize and investigate a curvilinear relationship between vertical integration and firm performance (e.g. Rothaermel et al. 2006; Kotabe and Mol 2009). This issue is quite interesting because these studies rely on TCE and the RBV which should result in hypothesizing an inverted U-shaped relationship as we show below. Therefore, the advantages as well as the disadvantages of vertical integration should be considered simultaneously.

Based on TCE, there should be a superior structural form (market, hybrid or hierarchy). Within the framework of transaction cost theory, transactions should be

internalized (i.e. vertically integrated) when they are characterized by a high degree of asset specificity and uncertainty accompanied by a high degree of frequency (Picot and Franck 1993). Otherwise, a firm should use the market or a hybrid form. Thus, transaction costs would be as low as possible (Williamson 1991a). The relationship between asset specificity and transaction costs is shown in Figure 1.

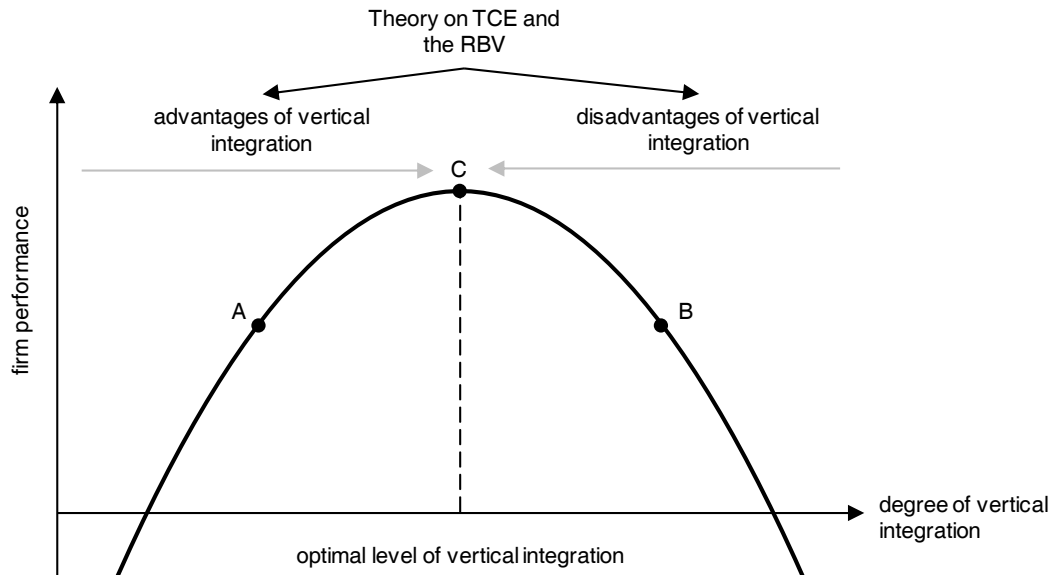
Figure 1: Asset specificity, transaction costs and structural form. Source: (Williamson 1991a)



It is obvious that a firm has to decide which activities should be integrated or outsourced as the structural form always causes different transaction costs. Most of a firm's activities are characterized by a different degree of assets specificity. If a firm decides to integrate (or outsource) all of these activities, then the level of transaction costs would not be as low as possible, as some activities should be outsourced (those characterized by low asset specificity) while others should be internalized (those characterized by high asset specificity). Figure 1 could be similarly interpreted for uncertainty or the frequency of transactions as they have similarly been identified as a determinant of the decision to vertically integrate (Williamson 1981). Within highly uncertain environments, contracts will be incomplete and transaction costs will rise. If uncertainty is lower, vertical disintegration is more favorable. This in in line with the resource based view of the firm: a firm should outsource its non-core activities and concentrate on core competencies. The results are a competitive advantage and a higher financial performance. A missing focus on activities as well as vertical

disintegration of all activities would lower performance. Based on these arguments, an optimal degree of vertical integration exists and is a firm specific decision. Figure 2 illustrates this relationship.

Figure 2: Hypothesized relationship between the degree of vertical integration and firm performance



The optimal degree of vertical integration depends on the starting position whether a higher or a lower degree of vertical scope would be profitable. If a firm starts in A, then the degree of vertical integration is below the optimum. In this case, a firm is “doing too less”, i.e. the degree of vertical integration is too low respectively a firm uses the market although vertical integration would be beneficial. The advantages of higher vertical integration predominate in that situation and an increase would improve performance. The opposite is true if a firm’s integration-performance starting point is B. The initial level of vertical scope is too high and the firm conducts core and non-core activities simultaneously or uses integration instead of using the market. Thus, the concentration on core competencies or using the market increases firm performance. Once, the optimum is reached (C) deviations from that optimal level would lower performance. Based on the arguments above, our hypothesis is proposed:

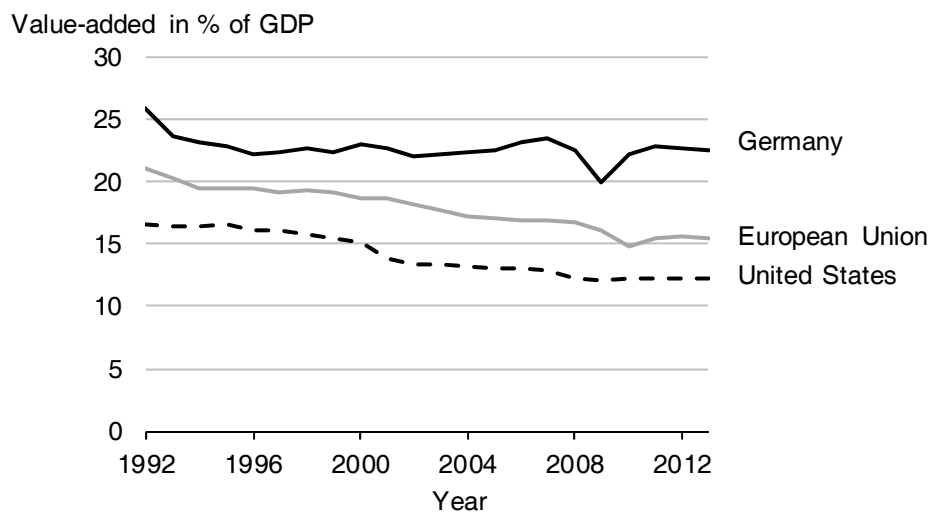
Hypothesis: The relationship between the degree of vertical integration and a firm’s financial performance is an inverted U-shape.

3. Research Methodology

3.1 Data

All data used for the empirical analysis of German corporations in the manufacturing sector were taken from Thomson Reuters Datastream. In some cases, firms' annual financial reports serve as data base because manual correction of the data was required due to false figures or because the required data were not available via Thomson Reuters Datastream. We focus our research on the German manufacturing sector because the share of value-added in percent of the GDP has been nearly unchanged over the last decades and is higher than in other major economies (mean = 23%) as shown in Figure 3. In contrast to Germany, manufacturing firms in the European Union (mean = 18%) and USA (mean = 14%) show a decreasing trend of value-added in percent of the GDP since 1997. Thus, the German manufacturing sector is especially important for our analysis, as it mainly contributes to Germany's GDP and contains highly competitive firms.

Figure 3: Share of value-added of manufacturing industries in % of GDP (Source: The World Bank 2016; U.S. Bureau of Economic Analysis 2017)



The sample covers the time frame from 1993 to 2013. The beginning of the time frame was chosen due to data availability. 2013 represents the last year for which full information was available at the beginning of the data collection. The firms in the

sample belong to the Standard Industrial Classification (SIC) manufacturing division. The sample distribution based on two-digit SIC codes is shown in Table 2.

Table 2: Sample distribution over two-digit SIC Codes

| SIC code | Industry name | No. firms | in % |
|----------|---|-----------|--------|
| 35 | Industrial and Commercial Machinery and Computer Equip. | 90 | 20.7% |
| 36 | Electrical Equipment and Components | 66 | 15.2% |
| 28 | Chemicals and Allied Products | 40 | 9.2% |
| 37 | Transportation Equipment | 35 | 8.1% |
| 20 | Food and Kindred Products | 30 | 6.9% |
| 38 | Measurement Analyzing, Control Instr. and Related Prod. | 30 | 6.9% |
| 32 | Stone, Clay, Glass and Concrete Products | 21 | 4.8% |
| 34 | Fabricated Metal Products | 20 | 4.6% |
| 33 | Primary Metal Industries | 17 | 3.9% |
| 30 | Rubber/Misc. Plastic Products | 16 | 3.7% |
| 39 | Misc. Manufacturing Industries | 14 | 3.2% |
| 23 | Apparel and Other Textile Products | 12 | 2.8% |
| 26 | Paper and Allied Products | 12 | 2.8% |
| 22 | Textile Mill Products | 11 | 2.5% |
| 27 | Printing and Publishing | 8 | 1.8% |
| 24 | Lumber and Wood Products | 7 | 1.6% |
| 25 | Furniture and Fixtures | 5 | 1.2% |
| All | | 434 | 100.0% |

Only complete data sets were reprocessed, i.e. independent as well as dependent variables have to be available. Considering the data criteria mentioned, the sample covers 434 different firms and 3,848 firm years.

3.2 Measurement of Vertical Integration

The measurement of vertical integration has been widely discussed in literature (for example Adelman 1955; Laffer 1969; Maddigan 1981; Lindstrom and Rozell 1993). On the one hand, there are a number of measures which can be easily calculated based on financial statements. On the other hand, there are multidimensional constructs which require primary data to be calculated. Lindstrom and Rozell (1993) prove inconsistencies among existing measures.

One of the most used measurement approaches might be the value-added to sales (*VAS*) approach. According to this, vertical integration is measured as the ratio between value-added and total output of a firm. This measure expresses the share of “goods on own account” on firm’s total output. There are two possibilities to calculate value-added: the first way is the so-called subtractive method. Thereby,

value added is determined as the difference between output and input and expresses the value an economic entity adds to the goods and services received from other entities through own activities. The second way is the so called additive method which sums up all allocated parts of the created wealth, i.e. all expenditures without input character.

The *VAS* approach has been implemented in various studies (Stigler 1951; Adelman 1955; Desyllas 2009; Hutzschenreuter and Gröne 2009; see Lajili et al. (2007) for a survey of studies). *VAS* of a firm according to the subtractive method is calculated as value-added / sales. Value-added is defined as (sales – external purchases). An increase (decrease) of *VAS* implies that the share of external purchases falls (rises) relative to sales. This can be seen as an indicator for a change in degree of vertical integration, i.e. an increase (decrease) of *VAS* is related to an extension (withdrawal) of a firm's upstream or downstream activities in the value chain which leads to an increase (reduction) of a firm's value-added (measured as sales minus external purchases) compared to external purchases. Backward integration will tend to reduce the amount of external purchases while leaving sales constant whereas forward integration will tend to increase sales more than external purchases (Tucker and Wilder 1977). Both backward and forward integration result in an increase of *VAS*. In general, two extreme cases are imaginable: a fully integrated firm which consequently has a *VAS* quotient of 1 and non-integrated firm that has a *VAS* quotient of 0. A fully integrated firm does not need any external purchases to produce an output. *VAS* is calculated as $(\text{Sales} - 0) / \text{Sales} = 1$. In contrast, a non-integrated firm can't produce output without external purchases, i.e. external purchases are equal to output (sales) and value-added is reduced to 0. Consequently *VAS* is 0. Due to its simple way of calculating the ratio with readily available accounting data, we measure the degree of vertical integration with the *VAS* ratio. As the coverage of external purchases in Thomson Reuters Datastream is very poor, value-added is calculated by the additive method, i.e. as the sum of salaries and benefit expense, income taxes, interest expense on debt, dividends and net income.

Another widely used measurement approach of vertical integration is the input-output approach which utilizes national input-output tables and has been implemented in a number of studies (see Lajili et al. (2007)). Maddigan's (1981) Vertical Industry

Connection (VIC) index was one of the first measures of this category. The VIC index assumes that a firm operates in more than one industry and considers that firms of one industry might be simultaneously suppliers and buyers of another industry. The major disadvantage of this approach is the assumption that aggregated national input-output tables are applicable to individual firms (Hutzschenreuter and Gröne 2009; see also for further disadvantages Lindstrom and Rozell (1993)). Besides Harrigan's VIC index, there exist other measures based on input-output tables (e.g. Fan and Lang 2000).

Adelman (1955) suggests the inventory to sales ratio to measure the degree of vertical integration. He argues that "The longer the production line and the more successive processes are operated by one firm, the higher the ratio" (p. 283) whereas the measure could be improved by using work-in-process only. However, the major disadvantage of this measure is that inventory level is also influenced by other factors than vertical integration, mainly different production methods and different manufacturing processes across industries, i.e. a comparison of firms between different industries is not very useful (Lindstrom and Rozell 1993). Inventory to sales ratio as well as Maddigan's VIC index are not used in this study due to their disadvantages.

3.3 Measurement of Performance

Venkatraman and Ramanujam (1986) suggest using a multidimensional measure of performance to improve performance measurement because multidimensional measures are more robust compared to single dimension measures such as ROI or ROS. In the present study, we use Altman's Z-Score as a financial but multidimensional performance metric, helping to achieve more robust results (Altman 1968).

Altman's classic Z-Score was originally developed to predict firm bankruptcy using empirical data from annual reports. Altman investigates a small sample of 33 bankrupt and 33 ongoing publicly held manufacturing firms. After running a multiple discriminant analysis, based on five accounting ratios (X_1, \dots, X_5), the following discriminant function resulted:

$$Z = 1.2X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + 0.999X_5, \quad (1)$$

where X_1 = working capital/total assets; X_2 = retained earnings/total assets; X_3 = EBIT/total assets; X_4 = market value of equity/total debt; X_5 = sales/total assets.

Based on this function, Altman (1968) classifies 95 percent (31 of the bankrupt firms and 32 of the ongoing firms) of his sample correctly while a cut-off value has to be estimated for this classification (Altman 1968). The higher the Z-Score of a firm is, the lower is its risk of bankruptcy (for Altman's sample firms with a Z-Score higher than 2.99 clearly fell into the "non-bankrupt" sector). Although the emerging coefficients of X_1 to X_5 are sample specific they are still used in research and practice (Agarwal and Taffler 2007; Randall et al. 2006; Swamidass 2007; Ellinger et al. 2011; Steinker et al. 2016). In this study, we apply Altman's procedure to our sample in order to re-estimate the coefficients and generate sample specific Z-Scores. We start by identifying all stock listed companies in our sample which filed for bankruptcy ($n = 28$) and the last year of complete data prior to the start of bankruptcy proceedings was chosen. Subsequently, a corresponding number of active (non-bankrupt) firms was randomly selected. Bankrupt and existing firms were matched by size and industry and a t -Test was conducted to measure size comparability. If the null hypothesis of the t -Test was rejected, a new sample was randomly created. We generated five random samples and executed a multiple discriminant analysis to re-estimate the coefficients of X_1 to X_5 (see Table 3).

Table 3: Multiple discriminant analysis for Altman's Z-Score (standardized coefficients)

| Run | WC/TA | RE/TA | EBIT/TA | MC/TL | S/TA | n | Percentage correct | Wilk's Lambda | p-value |
|----------------|-------|--------|---------|-------|-------|----|--------------------|---------------|---------|
| 1 | 0.422 | -0.072 | 0.749 | 0.311 | 0.249 | 56 | 83.9 | 0.709 | 0.003 |
| 2 | 0.603 | 0.056 | 0.529 | 0.419 | 0.226 | 56 | 85.7 | 0.668 | 0.001 |
| 3 | 0.631 | 0.434 | 0.271 | 0.032 | 0.163 | 56 | 76.8 | 0.725 | 0.005 |
| 4 | 0.696 | 0.089 | 0.465 | 0.094 | 0.356 | 56 | 76.8 | 0.782 | 0.027 |
| 5 | 0.537 | 0.258 | 0.451 | 0.268 | 0.198 | 56 | 71.4 | 0.727 | 0.006 |
| Average | | | | | | | 78.9 | | |

Note: Significance of coefficients not reported here. WC/TA = Working capital/total assets; RE/TA = retained earnings/total assets; EBIT/TA = earnings before interest and tax/total assets; MC/TL = market value of capital/total liabilities; S/TA = sales / total assets.

However, it has to be noted that the denominator of X_4 was replaced by total liabilities instead of total debt due to extreme outliers in our sample. Finally, the model with the

best goodness of fit criteria (measured by Wilk's Lambda and percentage of corrected classified firms) was chosen (run 2). The sample specific Z-Score function is as follows:

$$Z = 2.15X_1 + 0.08X_2 + 1.50X_3 + 0.10X_4 + 0.28X_5 - 0.71. \quad (2)$$

3.4 Control Variables

In addition to the value-added to sales ratio, we controlled for a number of firm-level and industry-level variables that may explain changes in firm financial performance and that have been included in prior research. These controls are now described.

Firm size (Employees): Firm size may be a positive predictor of its current performance as large firms generally may have more resources (e.g. Rothaermel et al. 2006; Desyllas 2009; Kotabe and Mol 2009). Firm size is measured by the natural logarithm of the number of employees.

Firm growth (SalesGrowth): To control for firm growth, we include the year-over-year percentage change in sales in our analysis. Firm growth is likely to be positively related to financial performance (e.g. Desyllas 2009; Kotabe and Mol 2009).

Market share (MktShare): Firms with higher market share enjoy many advantages compared to their competitors, and therefore may be able to increase their financial performance (e.g. Rothaermel et al. 2006). Market share is measured as firm's sales divided by the industry sales, with industry defined at the two-digit SIC level

Herfindahl-Hirschman index (HHI): *HHI* is employed to control for industry competitiveness, with industry defined at the two-digit SIC level (e.g. Rothaermel et al. 2006). Highly concentrated industries may restrict a firm's ability to capture value from the market place and therefore decrease financial performance. *HHI* is the sum of the square of all firms' market shares in an industry.

Firm age (Age): Older firms tend to perform better than younger firms (e.g. Rothaermel et al. 2006; Lahiri and Narayanan 2013) because of established routines. Therefore, we control for the age of the firm. Data for the year of foundation of the sample firms was obtained via Thomson Reuters Datastream and Nexis.

Leverage (DebtRatio): In addition, we control for the debt burden of the firm (e.g. D'Aveni and Ilinitch 1992; Desyllas 2009). Leverage could affect firm performance positively as well as negatively. On the one hand, firms have incentives to increase debt ratios as this is associated with higher tax shields. On the other hand, debt decreases managerial flexibility as debt obligations have to be met, thereby negatively impacting profit. Leverage is measured as the ratio of long-term debt to total assets.

Diversification (Diversification): We follow prior research (e.g. Rothaermel et al. 2006) and include an indicator variable that equals 1 if a firm operates in more than one industry segments. Diversification is expected to be positively related to financial performance (e.g. Rumelt 1982).

Environmental dynamism (Dynamicsim): Higher environmental uncertainty is expected to negatively affect financial performance and is therefore included in our analysis. The calculation is based on the approach first suggested by Dess and Beard 1984. First, we summed the sales for all firms in each of the two-digit SIC industries for each year between 1988 and 2013. Then, we used five years of the two-digit SIC industry-level data to calculate environmental uncertainty for the sixth year (for instance, industry sales from 1988 through 1992 were used to estimate environmental uncertainty for 1993). For each year and each industry, we regressed the five previous years' industry sales against year. Dynamism was then measured as the standard error of the regression coefficient of "year" divided by industry-average sales over the five-year period.

Capital intensity (CapitalIntens): We control for differences in financial performance across firms that are due to differences in capital intensity by including the ratio of capital expenditures to sales (e.g. D'Aveni and Ilinitch 1992; Bhuyan 2002).

Export ratio (ExportRatio): As prior research has shown that a firm's export ratio affects its financial performance (e.g. Kotabe and Mol 2009), we control for this fact by including the ratio of a firm's international sales to total sales.

3.5 Method

In order to test the proposed hypothesis which is a concave functional form regarding the degree of vertical integration and firm performance, the following regression model is estimated:

$$\begin{aligned} Perf_{it} = & \beta_0 + \beta_1 VAS_{it} + \beta_2 (VAS_{it})^2 + \beta_3 \ln(Employees_{it}) \\ & + \beta_4 SalesGrowth_{it} + \beta_5 MktShare_{it} + \beta_6 HHI_{jt} \\ & + \beta_7 Age_{it} + \beta_8 DebtRatio_{it} + \beta_9 Diversification_{it} \\ & + \beta_{10} Dynamism_{jt} + \beta_{11} CapitalIntens_{it} + \beta_{12} ExportRatio_{it} \\ & + \sum \delta_i F_i + \sum \gamma_i Y_i + u_{it}, \end{aligned} \quad (3)$$

where $Perf_{it}$ is the performance measure of firm i in year t as measured by Z-Score. VAS_{it} is the value-added to sales ratio. Linear and quadratic terms of the VAS were included in the regression model, thus allowing for a nonlinear relationship to be detected. In addition, firm (F) and year (Y) fixed effects are controlled for (a Hausman test was conducted to test if a fixed effects model is appropriate). Furthermore, we use autocorrelation- and heteroscedasticity-corrected robust standard errors. Since we expect an inverted U-shaped relationship between vertical integration and financial performance, the sign of β_1 is expected to be positive and the sign of β_2 is expected to be negative. The coefficients of VAS allow us to determine the turning point in the relationship between the degree of vertical integration and firm performance. Taking the first derivative of equation (3) and setting it to zero results in the turning point at $-\beta_1/2\beta_2$.

4. Results

As a brief overview of the manufacturing industries (SIC20-SIC39), Table 4 reports descriptive statistics for value-added to sales ratios. Regarding means, the industries with the highest degree of vertical integration are measuring instruments (SIC38) and printing, publishing, and allied industries (SIC27) whereas industries with the lowest degree are food products (SIC20) and leather and leather products (SIC31). Table 5 provides summary statistics and correlations for our variables of interest.

Table 4: Descriptive statistics of value-added to sales ratios

| SIC | Number of firms | Mean | Standard deviation | Minimum | Median | Maximum |
|-------|-----------------|-------|--------------------|---------|--------|---------|
| 20 | 30 | 0.203 | 0.099 | 0.028 | 0.199 | 0.639 |
| 22 | 11 | 0.298 | 0.111 | 0.044 | 0.290 | 0.557 |
| 23 | 12 | 0.286 | 0.100 | 0.077 | 0.279 | 0.873 |
| 24 | 7 | 0.253 | 0.095 | 0.106 | 0.226 | 0.419 |
| 25 | 5 | 0.344 | 0.062 | 0.114 | 0.362 | 0.434 |
| 26 | 12 | 0.253 | 0.099 | 0.018 | 0.263 | 0.723 |
| 27 | 8 | 0.393 | 0.097 | 0.175 | 0.397 | 0.562 |
| 28 | 40 | 0.340 | 0.114 | 0.027 | 0.342 | 0.829 |
| 30 | 16 | 0.336 | 0.093 | 0.014 | 0.332 | 0.652 |
| 32 | 21 | 0.379 | 0.095 | 0.049 | 0.374 | 0.638 |
| 33 | 17 | 0.263 | 0.095 | 0.063 | 0.259 | 0.748 |
| 34 | 20 | 0.377 | 0.094 | 0.135 | 0.370 | 0.706 |
| 35 | 90 | 0.353 | 0.122 | 0.003 | 0.362 | 0.878 |
| 36 | 66 | 0.327 | 0.148 | 0.002 | 0.329 | 0.949 |
| 37 | 35 | 0.289 | 0.089 | 0.024 | 0.284 | 0.568 |
| 38 | 30 | 0.407 | 0.115 | 0.025 | 0.414 | 0.872 |
| 39 | 14 | 0.275 | 0.103 | 0.014 | 0.274 | 0.567 |
| Total | 434 | 0.324 | 0.123 | 0.002 | 0.325 | 0.949 |

Table 5: Correlations among key variables and summary statistics

| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. |
|-------------------------|-------|-------|-------|--------|------|-------|-------|------|-------|-------|-------|------|
| 1. Z-Score | 1.00 | | | | | | | | | | | |
| 2. Value-added to sales | 0.22 | 1.00 | | | | | | | | | | |
| 3. ln(employees) | -0.20 | 0.06 | 1.00 | | | | | | | | | |
| 4. Sales growth | 0.00 | -0.02 | -0.02 | 1.00 | | | | | | | | |
| 5. Market share | -0.13 | -0.07 | 0.46 | -0.01 | 1.00 | | | | | | | |
| 6. HHI | -0.03 | 0.05 | -0.01 | -0.01 | 0.20 | 1.00 | | | | | | |
| 7. Firm age | -0.11 | 0.09 | 0.25 | 0.01 | 0.05 | 0.03 | 1.00 | | | | | |
| 8. Debt ratio | -0.30 | -0.03 | 0.05 | 0.01 | 0.16 | 0.00 | -0.08 | 1.00 | | | | |
| 9. Diversification | -0.14 | 0.00 | 0.22 | -0.01 | 0.08 | -0.06 | 0.04 | 0.06 | 1.00 | | | |
| 10. Dynamism | 0.02 | -0.03 | -0.11 | -0.01 | 0.08 | 0.01 | -0.08 | 0.01 | -0.07 | 1.00 | | |
| 11. Capital intensity | -0.11 | 0.05 | 0.05 | 0.02 | 0.01 | -0.12 | -0.12 | 0.07 | 0.06 | -0.03 | 1.00 | |
| 12. Export ratio | 0.01 | 0.10 | 0.33 | -0.01 | 0.07 | 0.05 | 0.00 | 0.00 | 0.11 | -0.04 | -0.06 | 1.00 |
| Mean | 0.48 | 0.32 | 7.68 | 0.24 | 0.07 | 0.25 | 4.06 | 0.12 | 0.90 | 0.03 | 0.05 | 0.48 |
| Standard deviation | 0.75 | 0.12 | 1.78 | 4.62 | 0.13 | 0.13 | 1.04 | 0.12 | 0.30 | 0.03 | 0.06 | 0.26 |
| Minimum | -3.56 | 0.00 | 0.00 | -0.86 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Median | 0.40 | 0.32 | 7.46 | 0.04 | 0.01 | 0.22 | 4.43 | 0.09 | 1.00 | 0.02 | 0.04 | 0.51 |
| Maximum | 14.60 | 0.95 | 13.22 | 172.54 | 0.89 | 0.87 | 6.56 | 1.75 | 1.00 | 0.36 | 1.22 | 1.00 |

Despite the correlations among the variables, we examined if the results might be biased by multicollinearity. Variance inflation factors of our main variables of interest (VAS and VAS^2) are above 10, indicating that multicollinearity is an issue. However, in accordance with previous literature (Haans et al. 2016), it has to be emphasized that multicollinearity cannot be avoided in polynomial regressions. None of the other independent variable had a variance inflation factor greater than 2. As the generally

accepted range for variance inflation factors concerning individual variables is below 10, we conclude that multicollinearity does not negatively influence our results.

As the concentration on core competencies has been a key management paradigm over the past decades, we plot the degree of vertical integration for our whole sample in Figure 4 and each of the 17 industries in Figure 5 to get descriptive results of the trend in the degree of vertical integration.

Figure 4: Degree of vertical integration for the German manufacturing sector 1993 to 2013

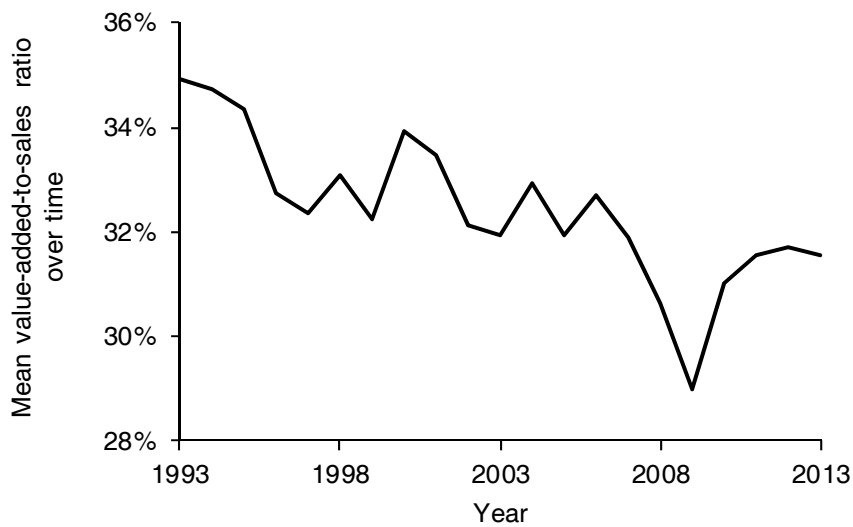
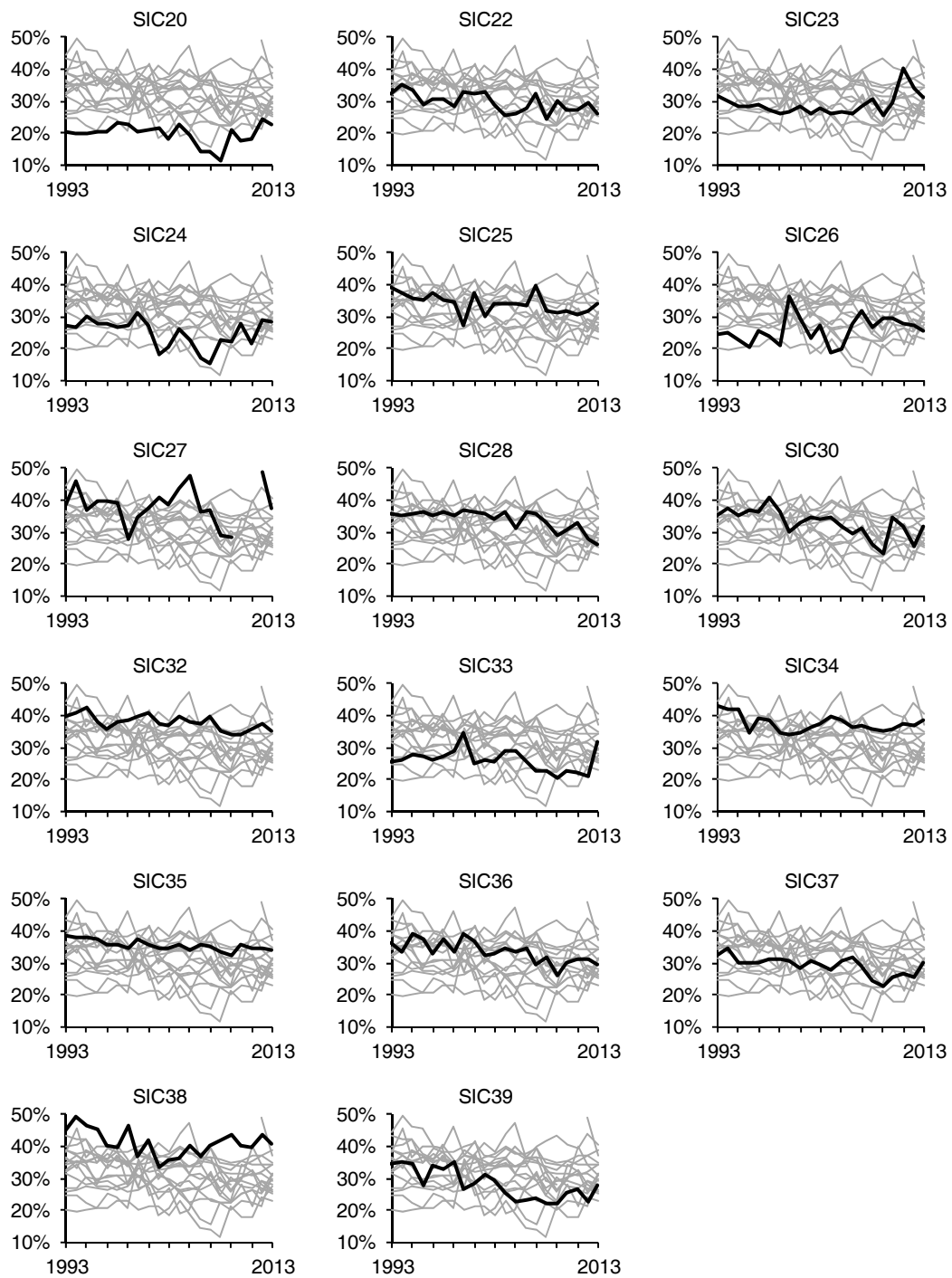


Figure 4 shows that the level of vertical scope has decreased over the last decades, especially until the onset of the recent financial crisis in 2008, indicating that outsourcing was forced on average over the whole manufacturing sector in Germany. A further look at the different industries reports a similar picture in Figure 5: 16 out of 17 industries have reduced their average degree of vertical integration between 1993 and 2008 with a reduction of 18 % on average. The only exception that has a higher vertical scope in 2008 is SIC26 (“Paper and Allied Products”). Since 2008, after the financial crisis, more than 76 % of the industries have increased their degree of vertical integration.

Figure 5: Trends in vertical integration grouped by industries of the German manufacturing sector



Note: This figure shows the average degree of vertical integration for each industry in our sample between 1993 and 2013.

Figure 6 reports the simple average Z-Score for firms grouped by their value-added to sales ratio quintiles (1 = low, 5 = high). The figure illustrates that quintiles 1 and 2

show the lowest Z-Score values whereas quintiles 3 to 5 show an increase in performance. Thus, these results provide initial evidence that higher vertical integration indicates superior financial performance.

Figure 6: Firm performance grouped by value-added to sales quintiles

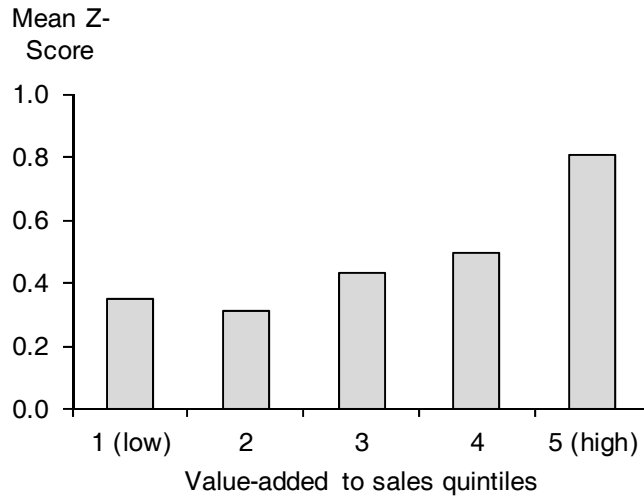


Table 6 summarizes the regression results for the relationship between a firm’s financial performance and vertical scope. In Model 1, we regress financial performance (Z-Score) on a base model of control variables. Results show that larger and older firms, as well as firms with larger debt burdens have lower Z-Scores. The coefficients of the other control variables do not statistically differ from zero. In order to save space, we do not report fixed effects here but they are available upon request.

Model 2 introduces our measure of vertical integration (*VAS*). We find a positive and significant link between the degree of vertical integration and financial performance. That is, as firms vertically integrate, their financial performance increases. However, Model 2 does not include a quadratic term of *VAS*.

Model 3 investigates the hypothesized functional form. Our hypothesis of an inverted U-shaped relationship between the degree of vertical integration and firm performance is confirmed by the regression results. The coefficient of the linear term of *VAS* is positive (and significant) while the coefficient of the squared term of *VAS* is negative (and significant), i.e. there exists an optimal degree of vertical integration indicating a maximum of firm performance. According to the first derivative of our regression equation and to the coefficients of *VAS* and *VAS*², the turning point lies at –

$\beta_1/2\beta_2 = -4.008 / 2*(-2.857) = 0.70$. Thus, the average manufacturing firm would maximize its performance at a degree of vertical integration of 70 %. A deviation from this optimum would lower firm performance.

Table 6: Regression results (dependent variable: Z-Score;)

| | Model 1 | Model2 | Model 3 |
|-------------------------------------|-----------|-----------|-----------|
| Value-added to sales | | 1.853*** | 4.008*** |
| | | (6.97) | (6.44) |
| (Value-added to sales) ² | | | -2.857*** |
| | | | (-4.09) |
| ln(employees) | -0.164*** | -0.139** | -0.151** |
| | (-2.76) | (-2.16) | (-2.35) |
| Sales growth | 0.001 | 0.001 | 0.001 |
| | (0.47) | (1.23) | (1.51) |
| Market share | 0.353 | 0.466 | 0.494* |
| | (1.32) | (1.60) | (1.68) |
| Herfindahl-Hirschman | -0.145 | -0.190 | -0.207 |
| | (-0.79) | (-1.05) | (-1.17) |
| Firm age | -0.331** | -0.393** | -0.397*** |
| | (-2.14) | (-2.55) | (-2.59) |
| Debt ratio | -0.672*** | -0.657*** | -0.657*** |
| | (-3.16) | (-2.85) | (-2.85) |
| Diversification | 0.102* | 0.095 | 0.093 |
| | (1.66) | (1.62) | (1.63) |
| Dynamism | -0.211 | -0.060 | -0.051 |
| | (-0.66) | (-0.20) | (-0.17) |
| Capital intensity | -0.484 | -0.590 | -0.630 |
| | (-1.22) | (-1.34) | (-1.42) |
| Export ratio | -0.167 | -0.136 | -0.123 |
| | (-1.32) | (-1.08) | (-1.00) |
| Constant | 3.230*** | 2.637*** | 2.382** |
| | (3.55) | (2.83) | (2.56) |
| Year effects included | Yes | Yes | Yes |
| Firm fixed effects | Yes | Yes | Yes |
| Observations | 3,848 | 3,848 | 3,848 |
| Number of Firms | 434 | 434 | 434 |
| Within R ² | 0.085 | 0.15 | 0.16 |
| F | 6.514 | 9.76 | 10.319 |

Note: Robust standard errors are in parentheses

*p < 0.1; **p < 0.05; ***p < 0.01

However, as reported by Haans et al. (2016), most empirical studies that investigate an (inverted) U-shaped relationship with the help of regression analyses, miss to report the turning point or to conduct some further analysis to further test the robustness of the results. Consequently, we follow prior research (e.g. Acharya and Pollock 2013) and adopt the method suggested by Lind and Mehlum (2010). The authors propose a three-step procedure after a regression had detected an inverted U-

shaped relationship: (1) The coefficients are in the expected opposite direction, (2) the slope of the curve is sufficiently steep at the left and the right side of the data range, and (3) the turning point of the inverted U-curve is located well within the data range. As shown in Table 6, the first condition is met. The linear term of the value-added to sales ratio is positive and significant (4.008) and the squared term is negative and significant (-2.822). The results for conditions (2) and (3) are shown in Table 7.

Table 7: Test of an inversely U-shaped relationship between vertical integration and firm performance

| | lower bound | upper bound |
|---|-------------|-------------|
| Interval | 0.002 | 0.949 |
| Slope | 3.998 | -1.415 |
| <i>t</i> -value | 6.445 | -1.766 |
| <i>P</i> > <i>t</i> | 0.000 | 0.039 |
| 95% confidence interval - Fieller method | 0.580 | 1.001 |
| Estimated extreme point | 0.701 | |

The slope at the lower bound of the data range of vertical integration is negative and significant and positive and significant at the upper bound. Thus, condition (2) is also met. However, a closer look at the confidence interval and the extreme point shows that condition (3) is not met. In particular, the estimated extreme point is not well within the data range of the value-added to sales ratios. This is caused by our data, because only 21 observations out of our 3,848 firm-year observations are above the estimated extreme point. Furthermore, the upper bound of the 95% confidence interval outside the data range (1.001), as the degree of vertical integration is restricted to values between 0 and 1. After these robustness checks, we conclude that the structure of our data is not sufficient to support the hypothesized inverted U-shaped relationship, as only a few values are above the estimated extreme point.

Robustness Checks

A number of checks were carried out to further assess the robustness of the results (see Appendix 1). First, the natural logarithms of sales were used as alternative proxies for firm size (instead of using the natural logarithm of the number of employees). In both cases, the results were nearly identical and consistent. Second, we use return on sales (measured as $EBIT_t / sales_t$) and return on assets (measured as $EBIT_t / total\ assets_{t-1}$) as an alternative measure for firm performance following prior research. Using return on sales and return on assets as measures for financial performance, the results remain similar to Model 3 of Table 6 (see Appendix 1), i.e. the coefficients are in the expected direction but the extreme point is at the upper bound of the data range. Third, we checked our results for robustness over time. We split our time frame in the periods 1993 to 2002 and 2003 to 2013. Again, the results remained nearly the same. Fourth, we estimate alternative fixed effects at the industry level. Fifth, we conduct the regression analysis with winsorized data at the 1% level. All robustness checks are consistent with our previous analysis, where we found a positive but diminishing relationship.

5. Discussion

Previous research on the relationship between the degree of vertical integration and firm performance has shown a mixed picture. Most of the existing studies investigate a linear relationship. If they found a significant relationship, it could either be positive or negative. There are only a few studies that analyze a non-linear connection (Rothaermel et al. 2006; Kotabe and Mol 2009; Grimpe and Kaiser 2010). The preceding empirical analysis does not support an inverted U-shaped relationship but rather a positive diminishing one between the degree of vertical scope and firm performance. Thus, the maximum point lies at the extreme range of our sample. The results obviously depend on the stage of the outsourcing process of a firm. Various scenarios are imaginable: Thus, there might be a negative relationship between vertical integration and firm performance when firms are in an early stage of their outsourcing process, indicating that they still have a high degree of vertical integration. When firms had an initially degree of vertical integration lower (higher)

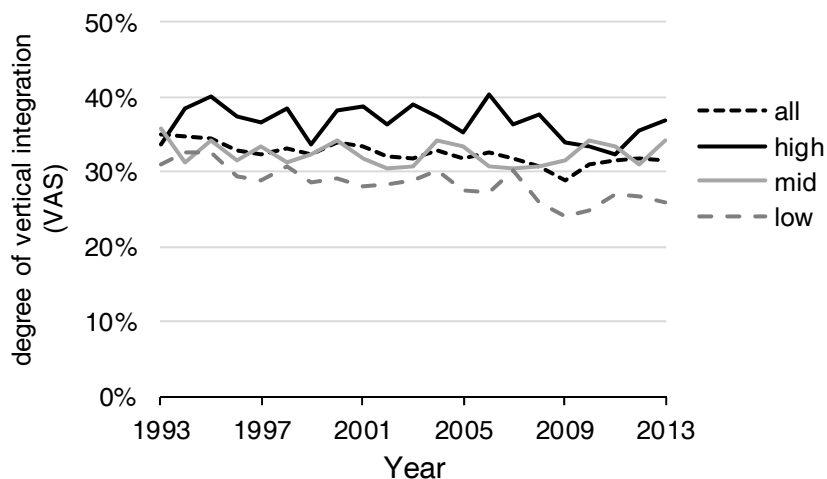
than the optimal level, excessive vertical (dis-)integration beyond the optimal level might lead to a negative (positive) relationship (Kotabe and Mol 2009). As our results show a positive diminishing relationship, it might be possible that firms have outsourced too much of their activities and have fallen below their optimal level of vertical integration.

These results raise questions. The most interesting question is why firms did sharply reduce their degree of vertical integration although this decline is associated with poor financial performance on average, as our results suggest? We provide several arguments (causality; structural inertia, bandwagon effect, management fashions; shareholder value paradox; uncertainty and supply chain control) why managers might have gone too far in reducing the degree of vertical integration.

(Reverse) Causality

To get more insights in the decreasing trend, firms were ranked by financial performance and divided into three quantiles (0-20%, 41-60%, 81-100%). Then the mean *VAS*-ratio ratio was calculated for each year and each performance quantile. The degree of vertical integration over time is shown in Figure 7.

Figure 7: Value-added to sales ratios over time grouped by financial performance



A regression analysis was conducted to detect trends in vertical integration over time. The results are shown in Table 8 (using return on assets and return on sales give similar results, see Appendix 2).

Table 8: Time-series analysis of *VAS* means grouped by Z-Score 1993-2013

| Grouped by | Selection Category | β | SE | <i>T</i> | <i>p</i> | <i>R</i> ² |
|------------|--------------------|-----------|-------|----------|----------|-----------------------|
| Z-Score | Low 20% | -0.003*** | 0.000 | -6.065 | 0.000 | 0.659 |
| | Mid 20% | 0.000 | 0.001 | -0.668 | 0.512 | 0.023 |
| | High 20% | -0.001 | 0.001 | -1.465 | 0.159 | 0.102 |
| | Low-High | -0.002** | 0.001 | -2.348 | 0.030 | 0.225 |
| | All | -0.002*** | 0.000 | -5.367 | 0.000 | 0.603 |

Note: SE, standard error; **p* < 0.1; ***p* < 0.05; ****p* < 0.01.

As shown, low performing firms show a significant decline of vertical integration between 1993 and 2013 ($\beta = -0.003$) whereas no trend at all was detectable for high (and middle) performing firms.

Thus, vertical integration might be a function of performance instead of interpreting performance as a function of vertical integration. There are various arguments which justify vertical integration as a function of performance. First of all, vertical integration is a complex, expensive and hard to reverse strategy (Stuckey and White 1993). Secondly, a high degree of vertical integration offers a number of benefits as it improves coordination and scheduling, reduces foreclosure to inputs, services or markets, increases the opportunity to create product differentiation (Harrigan 1984), builds higher market entry barriers for potential competitors (Mahoney 1992) and helps to develop a market in young industries (Stuckey and White 1993). Firms need to be able to afford these very cost-intense benefits.

As a second argument, there are a number of disadvantages which could arise from a high degree of vertical integration. A high degree of vertical integration increases the operating leverage due to a disadvantageous cost structure (Gilley and Rasheed 2000), increases the required capital as well as bureaucratic costs and the required management capacity and decreases strategic flexibility (Mahoney 1992). Low performing firms may try to reduce costs and risks which arise from these disadvantages by reducing their degree of vertical integration.

Third, Hutzschenreuter and Gröne (2009) show that firms which reduce their degree of vertical integration are faced with higher competitive pressure from foreign competition, i.e. higher competitive pressure could cause vertical disintegration. Based on this result, it is possible that firms are less successful while facing higher competitive pressure and consequently lower profit margins.

Given the positive relationship between the degree of vertical integration and financial performance, our results indicate that the strategy of vertical disintegration of low performing firms has been questionable.

Structural inertia, bandwagon effect and management fashion

Mol and Kotabe (2011) introduce the term “outsourcing inertia” defined as “the slow adaptation by organizations to changing circumstances that accommodate higher outsourcing levels” and propose that firms may suffer from this form of inertia. In general, structural inertia exists if “organizations respond relatively slowly to the occurrence of threats and opportunities in their environments” (Hannan and Freeman 1984). We follow their definition and argue that inertia prevent to respond quickly to changes in business processes after outsourcing manufacturing activities. Outsourcing inertia could be detrimental for business performance. Mol and Kotabe (2011) detect a negative relationship between a firm’s outsourcing inertia and its performance. Furthermore, Desyllas (2009) find time lag effects between vertical disintegration and improvements of business performance. Firms outsource activities in year t , in order to achieve better performance in future periods because they first go through a short performance decline after outsourcing (Desyllas 2009). These results indicate the existence of significant disintegration costs which reduce financial performance at a first glance. Those consist of restructuring costs, costs of organizational redesign or investments in information and communication technologies (Desyllas 2009). Firms need to be able to handle such disintegration costs. Mol and Kotabe (2011) argue that bandwagoning could help overcome initial inertia by providing outsourcing guidelines for managers. However, we propose that a bandwagon effect might lead to even more detrimental outsourcing projects which consequently results in “overriding the system”. Vertical (dis-)integration is not trivial but rather a serious interference in business processes which take a long time and managers certainly looked at best practices in outsourcing decisions, especially of Japanese competitors and their reliance on keiretsu alliances with external suppliers (Womack and Jones 1994). Cabral et al. (2014) find that bandwagon behavior is one reason for outsourcing failure. Their analyses indicate that managers have been influenced by business

schools, scholars, consultants and other managers “who brought that (outsourcing) into the organization” (Cabral et al. 2014; p. 369). Thus, their results highlight the view on vertical disintegration during the 1990s as a management fashion because “[o]utsourcing was a fever” and “[e]verybody was outsourcing” (Cabral et al. 2014, p. 369). Management fashion describes a collective belief that a management technique is new, efficient, and at the forefront of management progress (Abrahamson 1996). This belief increases pressure on organizations to adopt the “management tool” because firms’ stakeholders expect managers to employ modern and efficient techniques to manage their organizations (Meyer and Rowan 1977). But vertical disintegration and the related success is always a firm specific decision and result, i.e. one firm’s success is not a guarantee for disintegration success per se as the circumstances always need to be taken into account. Broedner et al. (2009) point out that there have been too many outsourcing projects which could be detrimental for financial performance. This might be a reason why recent reports such as Bain's Management Tools and Trends 2015 reveal the lowest satisfaction rates among managers in relation to the use of this management tool (Rigby and Bilodeau 2015).

Shareholder value paradox

By the 1990s, the shareholder value conception dominates the behavior of managers. Managers might reduce the degree of vertical integration to reduce capital employed and in order to increase shareholder value. Due to their employment agreement and compensation schemes, managers are often short-term oriented (and impatient) as compensation schemes usually rely on annual accounting-based performance measures (Das et al. 2009). Even if managers wanted to vertically integrate, they would not do that, as this strategy would reduce their compensation. Conducting too many vertical disintegration projects during their tenure would be detrimental for business performance, as the process of vertical disintegration takes a long time and the firm needs time to adapt to new circumstances.

Uncertainty

Another argument concerns the uncertainty to which firms are faced when deciding to vertically disintegrate. On the one side, the uncertainty could be related to a firm’s

initial degree of vertical integration before disintegrating. Figure 2 illustrates the relationship. Assuming that a firm's starting point is A, it would be profitable if the firm vertically integrates. However, an initial degree of vertical integration related to B requires vertical disintegration. But how should firms be aware of their optimal vertical integration level? This question is obviously difficult to be answered.

On the other side, uncertainty could be related to the measurement of costs of vertical (dis-) integration and the characterization of core competencies. Managers may have solely taken production costs (especially labor costs) into account rather than a combination of transaction costs and the competence perspective. Sinn (2005) analyses the decreasing trend of vertical integration in the German manufacturing sector. One of his main arguments for the decreasing trend is the increase of foreign external sourcing (especially from East Europe and China) compared to a more or less low increase of value-added. It is doubtful if managers have taken into account other influencing variables than potential advantageous through lower labor costs. Cost savings through lower labor costs could be (over-) compensated by higher transactions costs or strategic risks related to a loss of control over competencies. Furthermore, labor costs in China and East Europe have increased over the last 20 years so that vertical disintegration has become less attractive. The measurement of transaction costs is obviously difficult. Furthermore, if managers decide to outsource non-core activities, they have to clearly distinguish between core and non-core competencies in a first step as only non-core competencies should be outsourced in order to gain competitive advantage and to improve firm performance. Overall, managers have recognized the uncertainty related to the outsourcing decision as a risk in their supply chains (Kenyon et al. 2016).

Supply chain control

Our previous arguments have shown that low performing firms have reduced their degree of vertical integration significantly for several reasons. We argue that they could not afford a high degree of vertical integration, try to gain cost savings by lowering their degree of vertical integration, are faced to higher competition, structural inertia, shareholder value paradox or uncertainty. Firms that are forced to

reduce their degree of vertical integration might lose control over their supply chain. Hendricks and Singhal (2005) show that supply chain disruptions can cause severe damage to shareholder value, i.e. control of supply chains is a key performance driver. But how could firms with a low degree of vertical integration keep control over their supply chain and be nevertheless successful? One possibility might be a form of quasi-integration like strategic alliances or cooperations. Previous research has shown (Dietl et al. 2009) that firms with a low degree of vertical integration but high control over the value chain through supply chain integration gain competitive advantages. However, those quasi-integrations require investments and management capacities as well and low performing firms have neither capacity for real vertical integration nor quasi-integration to keep their supply chain under control.

5.1 Theoretical Implications

By integrating TCE and the RBV, we provide the following contributions to the literature. First, we shed light on the hitherto often neglected inverted U-shaped relationship between the degree of vertical integration and financial performance. Although TCE and the RBV imply both, advantages and disadvantages of vertical integration, and consequently, resulting in an inverted U-shaped relationship with respect to firm performance, only a few studies investigate this possible functional form (see Lahiri 2016). Our study empirically investigates the theoretical predicted inverted U-shaped relationship between the degree of vertical integration and firm financial performance for a large sample of firms using longitudinal data. In contrast to prior studies which apply regression models (Rothaermel et al. 2006; Kotabe and Mol 2009), our underlying data structure does not allow to detect the hypothesized U-shaped relationship. The way our study is designed also extends prior research methodologically, as it is the first study that conducts further robustness checks to investigate the predicted U-shaped relationship between the level of vertical integration and financial performance after conducting regression models. By using the three step procedure suggested by Lind and Mehlum (2010) and Haans et al. (2016), we can show that the initial detected U-shaped relationship from our regression analysis does not hold for our data range. Thus, our results indicate that the advantages of a higher degree of vertical integration outweigh the disadvantages.

Even if our data structure does not allow supporting the inverted U-shaped relationship between the vertical integration level and financial performance, we argue that the single hypothesizing and investigating of a linear relationship is not adequate.

Second, due to our additional analyses, we offer a more granular view on the decreasing trend of vertical integration during the last decades. A detailed analysis reveals that especially financially low performing firms reduced their degree of vertical integration while financially successful firms still have a high degree of vertical integration. Therefore, our results are in accordance with prior literature which describes vertical integration as a complex, expensive and hard to reverse strategy (Stuckey and White 1993). Obviously, a high degree of vertical integration costs money, but provides a bundle of advantages with respect to firm performance as well. Financially successful firms can afford this expensive strategy and the advantages of a high degree of vertical integration while low performing firms cannot. This might be one reason why low performing firms reduced their degree of vertical integration during the last decades. We provided some theoretical arguments for this observation in the further analysis.

Third, the findings help us understand better how vertical integration is related to financial performance. We extend research on the relationship between the degree of vertical integration and financial performance with respect to German manufacturing firms and thus add to the empirical vertical integration literature. The German manufacturing sector is especially important for our analysis, as it mainly contributes to Germany's GDP and contains highly competitive firms. The share of value-added to GDP in the German manufacturing sector is still on a high level compared to other major economies like the US, UK or the European Union on average (see Figure 3). But more importantly, the German manufacturing sector shows a significant decrease of the degree of vertical integration for almost 20 years beginning in 1990. This is the first study which, on the one hand, investigates an inverted U-shaped relationship between the degree of vertical integration, and on the other and, explains the increasing trend towards vertical disintegration. The latter was denoted by Sinn (2005) as the "bazaar economy". Sinn (2005) argues that vertical disintegration of German manufacturing firms was mainly motivated by lower labor

costs in low-cost countries. Therefore, our finding of a positive but diminishing relationship between the degree of vertical integration and financial performance indicates that German manufacturing firms either have outsourced too much of their activities or have not been able to realize the benefits they desired. One possible explanation is the underestimation of transaction costs (often denoted as the hidden costs of outsourcing (Hendry 1995) that were related to outsourcing towards low-cost countries and unproven suppliers (Gümüş et al. 2012). Furthermore, the appropriate identification of core and non-core competencies is a non-trivial decision for managers. As only outsourcing of non-core competencies leads to competitive advantages (Prahalad and Hamel 1990), German manufacturing firms (in particular low performing firms) may have outsourced wrong activities. Hartman et al. (2017) point out that the revival of vertical integration since the onset of the recent financial crisis is, among others, attributed to firms rethinking their core competencies.

5.2 Managerial Implications

Our results indicate that managers may have gone too far in their vertical disintegration strategy. The results of our study underscore the importance of carefully managing the degree of vertical integration. Managers must be aware that reducing the degree of vertical integration during the last decades has been detrimental for financial performance (on average). Therefore, managers should not believe in an increase of firm performance through vertical disintegration per se, as recommended by some lean management gurus (Lonsdale and Cox 2000). Instead of following management fashions and fads, managers should carefully think about vertical (dis-) integration strategies. A recent research stream examines reasons why firms re-insource or re-integrate activities that have been outsourced before (e.g. Drauz 2014; Hartman et al. 2017). In sum, those reasons consist of hidden costs of outsourcing, external triggers like the recent financial crisis or supply chain disruptions and rethinking of core competencies. These results indicate that managers recognized that the advantages of vertical integration outweigh the disadvantages.

Interestingly, our results suggest that managers have not paid much attention to the benefits of vertical integration or overestimated the benefits of vertical disintegration for a long time. A look at Figure 4 reveals that vertical disintegration

has been a strategy for German manufacturing firms since the beginning of the 1990s until the onset of the recent financial crisis in 2008. Hence, it appears as if managers mostly ignored the detrimental effects of vertical disintegration on financial performance.

6. Conclusions

The present study examines the relationship between vertical integration and financial performance for the German manufacturing firms. For this purpose, regression analysis with panel data is used. Our hypothesized relationship of an inverted U-shape cannot be supported. The results show a positive but decreasing relationship. Further analysis shows a decreasing trend of vertical integration over time, especially since 1993. On closer examination, the decreasing trend mainly emerges because lower performing firms outsourced their activities significantly whereas high performing firms do not show such a development. Overall, our results indicate that German manufacturing firms have gone too far in their vertical disintegration strategy.

Of course, our study has some limitations which open avenues for further research. First, as we have indicated that poor performing firms have reduced their degree of vertical integration more than high and medium performing firms, further analyses might be helpful in the question of causality. Second, by focusing on the manufacturing sector, we provide insights for an industry. However, the degree of vertical integration plays also an important role in other industry sectors, but is largely unexplored. Future research could examine if the hypothesized inverted U-shaped relationship between the degree of vertical integration and financial performance holds for other industry sectors. Third, our analysis provides a general result for manufacturing firms on average. However, it is necessary to investigate the relationship between vertical integration and financial performance on firm, or even better, on plant level to get deeper insights.

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Appendix

Appendix 1: Robustness checks

| | ln(sales) | ROS | ROA | 1992-2002 | 2003-2013 | Industry fixed effects | Winsorized data |
|-------------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|------------------------|----------------------|
| Value-added to sales | 4.008*** (6.44) | 1.004*** (7.90) | 1.374*** (12.02) | 4.040*** (5.17) | 4.138*** (6.24) | 4.008*** (6.44) | 4.094*** (5.58) |
| (Value-added to sales) ² | -2.857*** (-4.09) | -0.463** (-2.40) | -0.959*** (-7.24) | -2.606*** (-2.66) | -2.429*** (-3.15) | -2.857*** (-4.09) | -2.9*** (-2.93) |
| Firm size | -0.151** (-2.35) | 0.001 (0.07) | -0.002 (-0.19) | -0.247*** (-2.71) | -0.149*** (-2.78) | -0.151** (-2.35) | -0.161** (-2.50) |
| Sales growth | 0.001 (1.51) | 0.000*** (2.59) | 0.004*** (3.23) | 0.001 (1.13) | 0.008** (2.14) | 0.001 (1.51) | 0.347*** (4.15) |
| Market share | 0.494* (1.68) | 0.077** (2.20) | 0.098** (1.99) | 0.591 (1.45) | 1.540*** (3.66) | 0.494* (1.68) | 0.401 (-1.3) |
| Herfindahl-Hirschman | -0.207 (-1.17) | -0.041* (-1.87) | -0.052 (-1.61) | -0.172 (-0.91) | -0.978*** (-2.75) | -0.207 (-1.17) | -0.203 (-1.13) |
| Firm age | -0.397*** (-2.59) | -0.004 (-0.30) | -0.041* (-1.89) | -0.687* (-1.87) | -0.202 (-1.05) | -0.397*** (-2.59) | -0.318** (-2.33) |
| Debt ratio | -0.657*** (-2.85) | -0.052 (-1.62) | -0.112*** (-2.64) | -0.483* (-1.84) | -0.227 (-0.84) | -0.657*** (-2.85) | -0.586** (-2.59) |
| Diversification | 0.093 (1.63) | -0.010 (-0.72) | 0.008 (0.60) | -0.002 (-0.02) | 0.157*** (2.69) | 0.093 (1.63) | 0.077 (-1.25) |
| Dynamism | -0.051 (-0.17) | -0.023 (-0.74) | -0.052 (-1.08) | 0.302 (0.38) | -0.085 (-0.34) | -0.051 (-0.17) | -0.038 (-0.12) |
| Capital intensity | -0.630 (-1.42) | -0.036 (-1.05) | -0.086** (-2.07) | -0.487 (-1.64) | -1.214*** (-3.86) | -0.630 (-1.42) | -1.145*** (-3.16) |
| Export ratio | -0.123 (-1.00) | 0.029 (1.60) | 0.022 (1.32) | -0.240 (-1.23) | -0.117 (-0.93) | -0.123 (-1.00) | -0.113 (-0.94) |
| Constant | 2.382** (2.56) | -0.223*** (-3.28) | -0.085 (-0.78) | 4.457** (2.17) | 1.434* (1.82) | 2.382** (2.56) | 2.143** (-2.45) |
| Year effects included | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm fixed effects | Yes | Yes | Yes | Yes | Yes | No | Yes |
| Observations | 3,848 | 3,848 | 3,848 | 1,819 | 2,029 | 3,848 | 3,848 |
| Number of Firms | 434 | 434 | 434 | 434 | 434 | 434 | 434 |
| Within R ² | 0.16 | 0.412 | 0.381 | 0.192 | 0.204 | 0.16 | 0.18 |
| F | 10.319 | 20.315 | 19.291 | 8.397 | 10.741 | 10.319 | 11.784 |

Note: This table shows the results of the robustness checks that were carried out in the study. In the second column we measure firm size with the natural logarithm of sales instead of number of employees (in all other model we measure Firm size with the natural logarithm of the number of employees). In column 3 and 4, we replace our measure of financial performance (Altman's Z-Score) with return on sales and return on assets. A further regression analysis is conducted for two non-overlapping time periods in columns 5 and 6. The regression results in the seventh column are based on a regression with industry fixed effects rather than firm fixed effects. The last column reports regression results based on winsorized data at the 1% level.

Appendix 2: Robustness test of the inverted U-shaped relationship:

(1) ln(sales)

| | Modification: ln(sales) | |
|---|-------------------------|-------------|
| | lower bound | upper bound |
| Interval | 0.002 | 0.949 |
| Slope | 3.998 | -1.415 |
| t-value | 6.445 | -1.766 |
| P>t | 0.000 | 0.039 |
| 95% confidence interval - Fieller method | 0.580 | 1.001 |
| Estimated extreme point | 0.701 | |

(2) Return on sales and return on assets

| | Dependent variable | | | |
|---|--|-------------|-------------|-------------|
| | ROS | | ROA | |
| | lower bound | upper bound | lower bound | upper bound |
| Interval | 0.002 | 0.949 | 0.002 | 0.949 |
| Slope | 1.002 | 0.124 | 1.371 | -0.447 |
| t-value | Extremum outside interval - trivial rejection of H0 | | 12.035 | -2.786 |
| P>t | | | 0.000 | 0.003 |
| 95% confidence interval - Fieller method | 0.722 | 4.656 | 0.629 | 0.857 |
| Estimated extreme point | 1.083 | | 0.716 | |

(3) Time split

| | Modification: time split 1993-2002 | | Modification: time split 2003-2013 | |
|---|---------------------------------------|-------------|---------------------------------------|-------------|
| | lower bound | upper bound | lower bound | upper bound |
| Interval | 0.002 | 0.949 | 0.002 | 0.949 |
| Slope | 4.031 | -0.906 | 4.130 | -0.473 |
| t-value | 5.182 | -0.781 | 6.249 | -0.530 |
| P>t | 0.000 | 0.218 | 0.000 | 0.298 |
| 95% confidence interval - Fieller method | 0.587 | 1.940 | 0.657 | 1.628 |
| Estimated extreme point | 0.775 | | 0.852 | |

(4) Industry fixed effects instead of firm fixed effects

| | Modification: industry fixed effects | |
|---|--------------------------------------|-------------|
| | lower bound | upper bound |
| Interval | 0.002 | 0.949 |
| Slope | 3.998 | -1.415 |
| t-value | 6.445 | -1.766 |
| P>t | 0.000 | 0.039 |
| 95% confidence interval - Fieller method | 0.580 | 1.001 |
| Estimated extreme point | | 0.701 |

(5) Winsorized data

| | Modification: winsorized data | |
|---|--|-------------|
| | lower bound | upper bound |
| Interval | 0.049 | 0.643 |
| Slope | 3.812 | 0.364 |
| t-value | Extremum outside interval - trivial rejection of H0 | |
| P>t | | |
| 95% confidence interval - Fieller method | 0.541 | 1.466 |
| Estimated extreme point | | 0.706 |

**Appendix 3: Time-series analysis of VAS means grouped by ROS and ROA
1993-2013**

(1) Mean value-added to sales grouped by ROS

| Grouped by | Selection Category | β | SE | T | p | R^2 |
|------------|--------------------|-----------|-------|--------|-------|-------|
| ROS | Low 20% | -0.005*** | 0.001 | -9.278 | 0.000 | 0.819 |
| | Mid 20% | -0.002*** | 0.001 | -3.577 | 0.002 | 0.402 |
| | High 20% | 0.001 | 0.001 | 1.418 | 0.172 | 0.096 |
| | Low-High | -0.006*** | 0.001 | -5.557 | 0.000 | 0.619 |
| | All | -0.002*** | 0.000 | -5.367 | 0.000 | 0.603 |

Note: SE, standard error; *p < 0.1; **p < 0.05; ***p < 0.01.

(2) Mean value-added to sales grouped by ROA

| Grouped by | Selection Category | β | SE | T | p | R^2 |
|------------|--------------------|-----------|-------|--------|-------|-------|
| ROA | Low 20% | -0.005*** | 0.001 | -7.569 | 0.000 | 0.751 |
| | Mid 20% | -0.002*** | 0.001 | -3.280 | 0.004 | 0.361 |
| | High 20% | 0.001 | 0.001 | 1.727 | 0.100 | 0.136 |
| | Low-High | -0.006*** | 0.001 | -6.245 | 0.000 | 0.672 |
| | All | -0.002*** | 0.000 | -5.367 | 0.000 | 0.603 |

Note: SE, standard error; *p < 0.1; **p < 0.05; ***p < 0.01.

The Myth of Vertical Disintegration: A Management Paradigm Revisited and Scrutinized from a Capital Market's Perspective in the Wake of the Recent Financial Crisis

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Abstract

The purpose of this paper is to gain deeper insights into the link between vertical integration and a firm's stock market performance as prior knowledge on this relationship is scarce. We investigate the relationship between vertical integration and long-term stock returns by comparing abnormal returns on stock portfolios sorted by their degree of vertical integration. The study is based on data from 2,787 European manufacturing firms from 1993 to 2015, with 19,580 firm-year observations. We find that the capital market's attitude to the degree of vertical integration changed in the course of the recent financial crisis. More precisely, portfolios consisting of firms displaying a low degree of vertical integration generated the highest stock returns before the financial crisis (1993-2007) whereas highly integrated firms performed best after its onset (2007-2015). Further analyses indicate that the stock market learns about the value of vertical integration, i.e. long-term abnormal stock returns disappear as time goes by. The results are discussed in detail, and we not only provide insightful theoretical contributions, but also look at their practical implications.

Keywords: vertical integration, financial crisis, stock returns, market efficiency

1. Introduction

The boundaries of a firm may be mainly described by its degree of vertical integration and are classic issues for researchers and practitioners (e.g. Williamson 1975; Klein et al. 1978; Grossman and Hart 1986; Rigby and Bilodeau 2015). Vertical integration is defined as “the combination, under a single ownership, of two or more stages of production or distribution (or both) that are usually separate” (Buzzell 1983, p. 93). In contrast, vertical disintegration is the process of unbundling supply chain activities that were once undertaken in-house. The degree of vertical integration (or vertical integration level) is, then, defined as the proportion of in-house production in the firm’s total output. Thus, a higher degree of vertical integration means “more in-house production” and a lower degree of vertical integration (i.e. a higher degree of vertical disintegration) means “less in-house production”.¹

Since the beginning of the twentieth century, the degree of vertical integration has been subject to shifting fashions: (1) A hundred years ago, the prevailing wisdom was that vertical integration was beneficial for firm performance, a perception that resulted in a highly integrated firms emerging over this period (Adelman 1955; Laffer 1969; Tucker and Wilder 1977) with Henry Ford’s River Rouge complex leading the way. (2) During the 1980-1990s, a sea change took place towards vertical disintegration, with firms focusing on their core business in order to gain a competitive advantage (Prahalad and Hamel 1990; Lonsdale and Cox 2000). (3) The third wave saw firms seeking control over their supply chains by means of a strategy of quasi-integration, which describes a potentially valuable option that envisages activities being outsourced while the firm simultaneously takes into account its need to exercise some control over its suppliers and distributors via strategic alliances or other forms of cooperation (Blois 1972; Harrigan 1984; Rothaermel et al. 2006). The trend towards vertical disintegration persisted until 2007, i.e. the onset of the recent financial crisis. (4) Since then, the most recent strategic shift has once again been towards vertical integration (Hoberg and Alicke 2013; Drauz 2014; Oshri et al. 2017), a shift triggered by the numerous outsourcing failures that have been a commonplace

¹ As in prior studies, we use the concepts of vertical disintegration and outsourcing synonymously although they differ slightly (e.g. Broedner et al. 2009). Furthermore, the terms “vertical integration” and “degree of vertical integration” are used interchangeably throughout this study.

occurrence in business practice (Drauz 2014; Hartman et al. 2017). For instance, Deloitte (2005, p. 21) argues that only “50 percent of outsourcing in the near future will be successful, with the failures stemming from clients that don't know what they are doing, don't understand outsourcing, or don't understand their own business.” Outsourcing failures were drastically increased by the recent financial crisis, which triggered a huge number of supply chain disruptions that can be attributed to firms outsourcing to low-cost countries and unproven suppliers (Gümüş et al. 2012).

As sourcing and integration strategies are generally recognized to be key drivers of supply chain performance (Chopra and Meindl 2001), it is not surprising that vertical integration and its effects on firm performance is not only relevant for practitioners but are also subject to a growing body of empirical research in the field of strategic and supply chain management (Rothaermel et al. 2006; Shi and Yu 2013). Although prior research has extended knowledge in this field, the conclusions of these studies are inconclusive (see Lahiri (2016) for an overview). Furthermore, most of the empirical studies only use accounting-based metrics to measure firm performance, neglecting the importance of stock returns for major firm stakeholders (Rappaport 1986; Hillman and Keim 2001). While accounting-based metrics make it possible for performance to be investigated at firm level from a productivity perspective, stock returns take into account investors' perceptions of corporate strategy. A number of studies have investigated the effect of outsourcing or integration announcements on stock returns based on the event study approach, which assumes that the market fully incorporates all publicly available information during the (short-term) announcement period (see Willi and Knolmayer (2009) or Mani et al. (2013) for literature reviews pertaining to outsourcing announcements). However, recent research posits that the market may not incorporate qualitative information or intangibles completely in the short-run, resulting in significant long-term abnormal returns (Daniel and Titman 2006) for several reasons (Sorescu et al. 2017): First, if metrics are typically not announced and thus not immediately visible to all investors, stock markets might not be able to price the metric completely in the short-run. Moreover, the relationship between the variable of interest and its impact on firm value is not straightforward, resulting in complex consequences (e.g. Otto and Obermaier 2009). In both cases, additional information is incorporated by the market

as time goes by. For instance, firms with high R&D (Eberhart et al. 2004), high employee satisfaction (Edmans 2011) or high customer satisfaction (Fornell et al. 2016) all earn abnormal long-run stock returns. Moreover, emerging research shows that the stock market fails to fully price supply chain related metrics in investment decisions and that their value is not completely understood by investors even if the latter are in a position to determine the metric of interest with the aid of the publicly available information contained in annual reports (Chen et al. 2005; Alan et al. 2014; Ullrich and Transchel 2017). As vertical integration strategies are key drivers of supply chain performance, with non-straightforward performance implications and complex consequences (Mahoney 1992), we argue that the degree of vertical integration is also related to long-term stock returns.² Furthermore, given the most recent strategic shift towards greater vertical integration since the onset of the recent financial crisis, given the fact that firms with a higher degree of vertical integration experience fewer negative stock market reactions (Hendricks et al. 2009) and given the increasing number of supply chain disruptions experienced during the recent financial crisis (Gümüő et al. 2012), we expect a change in the capital market's attitude to the degree of vertical integration in the wake of the financial crisis.

We already saw several strategic shifts with respect to the degree of vertical integration; the most recent one began during the recent financial crisis. To the best of our knowledge, the effect exercised by the degree of vertical integration on long-term stock returns has not been investigated yet, any more than has the role played by the financial crisis as a moderating event. Given the limited amount of empirical research on the relationship between vertical integration, the recent financial crisis and long-term stock returns this study aims to answer the following questions:

- (1) *What is the relationship between the degree of vertical integration and long-term stock returns?*
- (2) *How did the recent financial crisis affect the relationship between the degree of vertical integration and long-term stock returns?*

² This should not be confused with announcements about a sourcing decision, vertical integration or vertical disintegration. These announcements do not typically reveal the degree of vertical integration per se.

Thus, we predict that the degree of vertical integration is related to long-term stock returns and we conduct an empirical study in which we investigate long-term stock returns yielded by portfolios based on the degree of vertical integration displayed by 2,787 manufacturing firms between 1993 and 2015. In response to the observable strategic shift regarding the degree of vertical integration during the recent financial crisis, we split our sample period into two non-overlapping periods (1993 to June 2007; July 2007 to June 2015). Our data analysis shows that those firms in the European manufacturing sector with the lowest degree of vertical integration generated higher stock returns *before* the onset of the recent financial crisis, whereas a higher degree of vertical integration leads to higher long-term stock returns *after* the financial crisis. Further analysis reveals that outperformance disappears after a three-year holding period suggesting that either the market learns about the value of vertical integration or that vertical integration is related to other metrics which have an impact on stock returns and which are more closely observed by the market (e.g. earnings). As more information becomes available over time, the complex performance outcomes associated with the degree of vertical integration may be reduced.

This study makes several contributions. First, our results show that the degree of vertical integration is significantly related to abnormal long-term stock returns. Second, we show that the recent financial crisis affected the relationship between long-term stock returns as an external trigger and contingency factor that immediately increased uncertainty and triggered a shift in the capital market's attitude to the degree of vertical integration. Third, our results indicate that a higher degree of vertical integration serves as a kind of risk buffer during a crisis or during economic downturns in general.

This paper is organized as follows. Section 2 explains the underlying theory and derives our research hypotheses. Section 3 describes the data and methodology. In Section 4, we present the results and further robustness checks. Section 5 provides the discussion of our results. Section 6 summarizes the findings and draws conclusions.

2. Theory and Development of Hypotheses

2.1 Vertical Integration and Firm Value

This study draws on prior research that broadly investigates how firms determine their degree of vertical integration and how such decisions impact firm performance. Among other perspectives, transaction costs economics (TCE) (Coase 1937; Williamson 1975) and the resource-based view (RBV) of the firm (Penrose 1959; Wernerfelt 1984; Barney 1991) have been used as dominant theoretical perspectives which influence firms' decisions on whether to make or buy. While TCE focuses on transaction costs (search costs, negotiating costs, cost of drawing up a contract, monitoring costs and enforcement costs) as the major determinant of the degree of vertical integration, the RBV interprets the firm as a bundle of strategic resources which are able to create competitive advantage.

Within TCE, asset specificity, frequency of transactions and uncertainty have been identified as the drivers of make-or-buy decisions (Williamson 1991). The basic assumption is that individuals act opportunistically and with bounded rationality. Thus, vertical integration is a means to reduce the costs arising from the opportunism and bounded rationality displayed by firms and their suppliers, from assets specificity, and from the frequency and uncertainty of market exchange (Coase 1937; Williamson 1985).

Within the RBV, strategic management focuses on firms' resources and capabilities as a source of sustainable competitive advantage. Barney (1999) and Leiblein et al. (2002) argue that a rich foundation of competencies and capabilities which is related to a specific activity, makes it more likely that the activity will be undertaken in-house. The related core competence concept (Prahalad and Hamel 1990), which has evolved from the RBV, has been extremely influential in outsourcing practice (McIvor 2009). Core competencies are capabilities which are rare, valuable, difficult to imitate and non-substitutable (Barney 1991). According to this concept, firms should perform core competencies internally, while outsourcing non-core competencies (e.g. Bettis et al. 1992).

The literature reviewed so far examines what the determinants of the degree of vertical integration are. Both TCE and the RBV, provide complementary explanations for the make-or-buy decision and form the underlying theory for the rich body of research on the relationship between vertical integration and firm performance (e.g. Leiblein et al. 2002; Broedner et al. 2009; Kotabe and Mol 2009; McIvor 2009). Numerous studies present evidence supporting the assumption that vertical integration affects firm performance. Empirical literature on the effect of the vertical integration level on operational performance suggests that both a lower degree of vertical integration and a higher degree may be beneficial to operational performance. Forbes and Lederman (2010) find that integrated airlines perform significantly better than non-integrated airlines when operational performance is measured by departure delays. Kenyon et al. (2016) investigate the effect of production outsourcing on operational performance and customer loyalty. Using data from a survey of manufacturing plant managers, they find reductions in operating equipment effectiveness and delivery performance. Furthermore, outsourcing negatively affects customer loyalty when mediated through operational performance. In reviewing 57 empirical studies, Lahiri (2016) reports that the findings on the relationship between vertical integration and performance are inconclusive. While some scholars find a negative relationship between the degree of vertical integration and firm performance (e.g. Rumelt 1982; Desyllas 2009; Kroes and Ghosh 2010), others find it to be positive (e.g. Buzzell 1983; D'Aveni and Ravenscraft 1994; Broedner et al. 2009; Andreou et al. 2016) and still others postulate a negative curvilinear relationship (e.g. Rothaermel et al. 2006; Kotabe and Mol 2009), or even argue that the impact exercised by the degree of vertical integration on firm performance is insignificant (e.g. Mol et al. 2005).

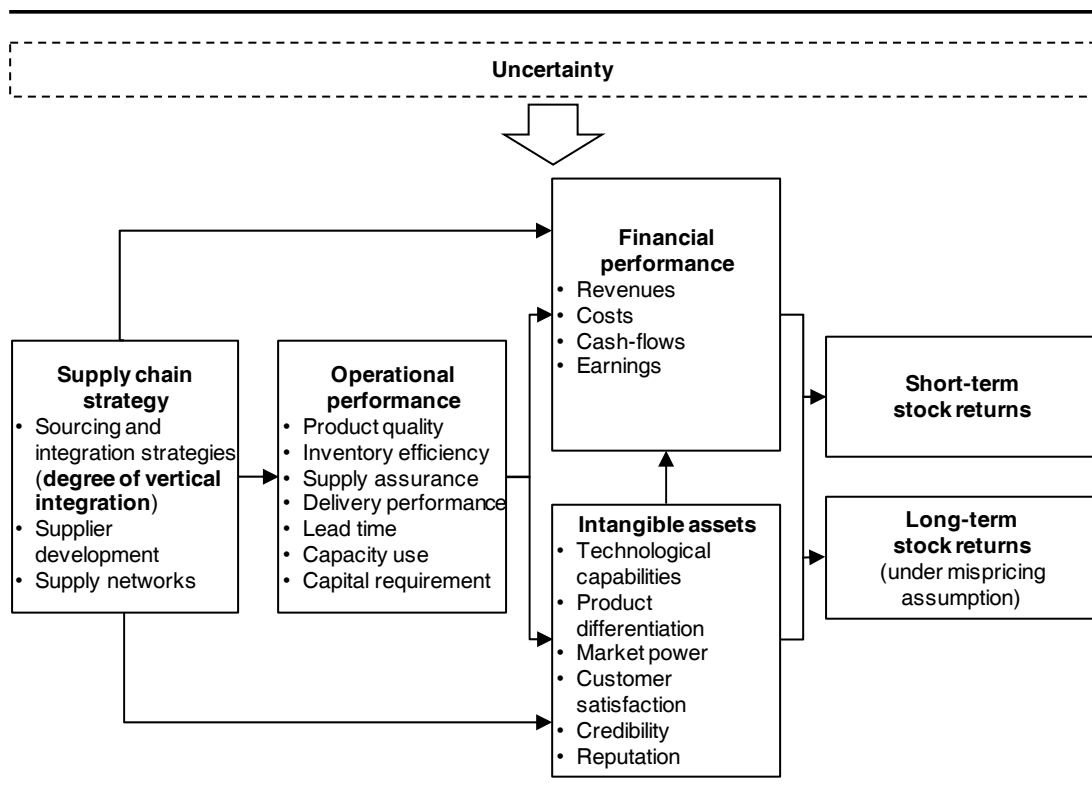
While many studies have so far analyzed the impact of vertical integration on accounting performance measures like return on sales or return on assets, the relationship to stock returns is less well explored, even though traditional accounting metrics have a number of limitations.³ First, they are not forward-looking and they

³ The choice of the performance metric obviously depends on what is to be measured. While traditional accounting-based performance metrics like return on assets measure a kind of productivity at the firm level, stock returns allow investors' perceptions of the corporate strategy to be considered.

are primarily seen as short-term performance measures. In contrast, stock returns allow future performance expectations to be included and are robust in the face of any manipulations by managers. Furthermore, accounting-based performance metrics might not reflect many of the benefits associated with the degree of vertical integration, which may manifest themselves in intangible outcomes and materialize in the long-term (Hillman and Keim 2001; Carton and Hofer 2007). Because of the drawbacks associated with accounting-based performance metrics, a number of research studies have incorporated stock returns the event study methodology (for instance, see Willi and Knolmayer (2009) or Mani et al. (2013) for literature reviews concerning outsourcing announcements). However, most of this literature stream concentrates on announcements pertaining to the outsourcing of support functions (e.g. IT and human resources services) rather than on the degree of vertical integration itself. Furthermore, event studies on outsourcing announcements usually investigate the stock market's reaction within an announcement period of just a few days on the assumption that the market fully incorporates the information during the announcement period. Long-term effects have rarely been investigated (e.g. Mani et al. 2013; Barua and Mani 2018). Moreover, the few long-term studies available mainly concentrate on IT outsourcing announcements and may therefore not generalizable.

It is precisely because of these limitations, that we link the degree of vertical integration to long-term stock returns. Our conceptual framework is summarized in Figure 1. The performance literature summarizes the costs and benefits of vertical integration that are rooted in TCE and RBV (e.g. Buzzell 1983; Harrigan 1984; D'Aveni and Ravenscraft 1994; Gilley and Rasheed 2000). The principal arguments involve the effects on operational performance (e.g. inventory scheduling), intangibles (e.g. product quality) and financial performance (revenues and costs), and are described below. It should be noted that the advantages of vertical integration can be interpreted as the disadvantages of vertical disintegration or outsourcing. Similarly, advantages of outsourcing or vertical disintegration are disadvantages of vertical integration.

Figure 1: Conceptual framework (Source: our own illustration based on Chopra and Meindl (2001) and Hendricks and Singhal (2003))



Vertical Integration and Operational Performance

We first link the degree of vertical integration, as a part of the supply chain strategy, to operational performance. On the one hand, there is a range of arguments for positive performance implications through vertical integration. Vertical integration allows an organization to maintain higher quality standards, as it may have more control over input quality (D'Aveni and Ravenscraft 1994). Besides, vertical integration makes the supply of critical materials more assured and improves coordination between different stages of production (Buzzell 1983; Harrigan 1984). In particular, coordination between production, inventory and logistics scheduling is improved. Consequently, vertical integration can speed up the throughput of materials and information along the supply chain resulting in lower lead times and better delivery performance.

Vertical Integration and Intangible Assets

Operational performance will determine a firm's financial performance and its intangible assets. The latter also affect financial performance, as they are traditionally perceived to be the basis of competitive advantage (Dierickx and Cool 1989; Barney 1991). In line with the resource-based view, vertical integration improves a firm's ability to protect its proprietary products or process technology (Mahoney 1992). Proprietary technologies are unique to a firm, which usually enables the firm to produce a product displaying superior features and gives it a competitive advantage. Vertical integration can also be used to create and exploit market power by building barriers to entry or allowing price discrimination across customer segments (Perry 1978; Stuckey and White 1993). Entry barriers can be increased if the vertically integrated firm gains sole access to scarce resources or if potential entrants have to enter all the stages of the supply chain so as to be able to compete. Price discrimination incentives in favor of vertical integration can be identified if we consider a supplier who sells to two customer segments with different price sensitivities. The supplier can increase his profits by selling products at a high price to the price-insensitive customer and by selling products at a low price to the price sensitive customer. However, the low-price customer might conceivably resell the products at higher prices to the high-price customer. In this scenario, forward integration represents an opportunity for the supplier to prevent reselling in the downstream stages of production. Both higher entry barriers and price discrimination result in a firm generating higher revenues and profits. Furthermore, vertical integration may create credibility for new products (Harrigan 1984). Finally, thanks to the benefits offered by improved product quality, better inventory, superior delivery performance and shorter lead times, vertical integration may increase customer satisfaction and corporate reputation.

Vertical Integration and Financial Performance

Vertical integration affects financial performance both directly and indirectly through its impact on operational performance and intangible assets. The direct effect is mainly driven by cost savings. Vertical integration may reduce transaction costs, as a firm often opts for it so as to reduce its dependency on external suppliers. Vertical

integration is then chosen with a view to reducing the search costs, negotiating costs, the cost of drawing up a contract, the monitoring costs and the enforcement costs that are associated with having external suppliers (Mahoney 1992). Further cost reductions may be achieved by the improved coordination of the production process or by eliminating certain steps and thus reducing the duplication of overhead costs (Buzzell 1983; Harrigan 1984).

Finally, the impact of vertical integration on revenues and costs affects the short-term and long-term cash-flows of a firm and therefore stock returns, as the current market value is based on the sum of the expected future cash-flows (Rappaport 1986). Furthermore, stock returns are also affected by intangible assets (Daniel and Titman 2006) as investors assign a premium to firms that have, among other things, higher customer satisfaction (e.g. Fornell et al. 2016), a better reputation (e.g. Raithel and Schwaiger 2015) or more product differentiation (e.g. Srinivasan et al. 2009).

Disadvantages of Vertical Integration

However, a higher degree of vertical integration has disadvantages as well. First, higher vertical integration may increase production costs if the firm faces increased capital requirement and higher fixed costs (Mahoney 1992; Gilley and Rasheed 2000). Furthermore, highly integrated firms may be faced with excess capacity created by plant size imbalances (Harrigan 1984). One example of this situation is when a firm needs to build excess upstream capacity to ensure that its downstream operations are provided with sufficient supplies in the face of fluctuating demand conditions.

Besides, vertical integration may decrease a firm's flexibility and lead to high exit barriers created by former extensive upstream or downstream investments (Harrigan 1984; Mahoney 1992). Changing technology or market conditions that make products obsolete at one stage of a vertically integrated firm are key drivers of reduced flexibility and higher exit barriers (Buzzell 1983). A lower degree of vertical integration then increases the flexibility with which a firm can deal with variations in technology or demand by switching to suppliers with the new and best technologies (Balakrishnan and Wernerfelt 1986). Furthermore, vertical integration may lead to a

loss of focus and specialization. Integrating upstream or downstream supply chain operations can draw top executives' concentration away from those activities which have previously been characterized as core competencies (Mahoney 1992). Further strategic costs are those associated with a loss of access to the information and knowledge possessed by suppliers and distributors (Harrigan 1984).

Finally, the management of a vertically integrated firm is more complex, and this may result in administrative inefficiencies and higher bureaucratic costs (Mahoney 1992; D'Aveni and Ravenscraft 1994) and thus in lower cash-flows and stock returns.

The role of uncertainty

Prior literature suggests that uncertainty is one of the key factors determining the degree of vertical integration that influences the relationship between vertical integration and performance (e.g. Williamson 1975; Harrigan 1983; Mahoney 1992). As one of the first researchers, Coase (1937) argues that vertical integration is essentially a response to environmental uncertainty and risk. Uncertainty in vertical integration literature encompasses several types of uncertainty, ranging from environmental uncertainty to technological uncertainty or the unpredictability of a partner's behavior (Williamson 1975; Mahoney 1992), all of which result in greater uncertainty along the supply chain. According to TCE, highly uncertain environments lead to incomplete contracts and consequently to rising transaction costs (Williamson 1985). The cost of negotiating, monitoring and enforcing vertical disintegration arrangements increases with uncertainty. Activities are combined in order to decrease dependence on environmental vagaries. In contrast, studies that are based on strategic management and the RBV suggest that firms facing higher uncertainty need to reduce their degree of vertical integration in order to increase flexibility (Harrigan 1985). Empirical studies, too, show a mixed picture: Gilley and Rasheed (2000) find that outsourcing is only beneficial in less dynamic environments (i.e. in the presence of lower uncertainty). Kotabe and Mol (2009) find a negative curvilinear relationship between outsourcing and financial performance. The steepness of the curve increases under conditions of high uncertainty.

In this study, we interpret the recent financial crisis of 2007/2008 as an event that has dramatically increased (supply chain) uncertainty (Hoberg and Alicke 2013).

On the basis of the anecdotal evidence that suggests the degree of vertical integration has risen since the onset of the recent financial crisis (Drauz 2014; Hartman et al. 2017), we argue that firms have recognized the advantages of a greater degree of vertical integration during a crisis and expect the advantages of a greater degree of vertical integration to outweigh the disadvantages. Highly integrated firms are, in general, less dependent on external suppliers and will therefore suffer less from supply bottlenecks. Vertical integration is a way to control supply and demand uncertainties (Miller 1992). This became an especially critical argument during and after the financial crisis, as many suppliers went bankrupt or were faced with delivery problems (Hoberg and Alicke 2013). Furthermore, a lower degree of vertical integration increases the probability of a firm's experiencing supply chain disruptions (Chopra and Sodhi 2004). The increase in outsourcing in the 1990s, in particular to low-cost countries with unproven suppliers, has also increased the probability of firms experiencing supply disruptions (Gümüő et al. 2012). Among other things, this can mainly be attributed to the financial crisis of 2008 and its consequences in the subsequent years. Hendricks et al. (2009) show that firms with a higher degree of vertical integration experience fewer negative stock market reactions to supply chain disruption announcements, indicating that the degree of vertical integration is a buffer against the negative performance implications caused by disruptions. Thus, the advantage of having an assured supply chain numbers among the most important benefits during a crisis. Moreover, prior research has shown that integrated firms have better access to finance and use internal funds to cover a larger proportion of their costs (Görg and Kersting 2017). Therefore, investors are likely to expect that the firm should use vertical integration rather than disintegration during and after a crisis with a view to avoiding or at least reducing uncertainties.

2.2 Mispricing of Vertical Integration on Capital Markets

Prior research on the impact of vertical integration levels on stock returns predominantly uses the event study methodology, based on announcements pertaining to the outsourcing of support functions like IT or human resources services (Strange and Magnani 2017). The underlying assumption is a semi-strong form of market efficiency, i.e. stock prices reflect all publicly available information and instantly

change to reflect new information when it becomes available (Fama 1970). In other words, the assumption is that the market incorporates new information completely during the announcement period. From an efficient market perspective, we should not expect any excess returns if (1) investors are aware of the degree of vertical integration displayed by firms and (2) if investors are able to determine the impact on future stock returns, because this information should be priced into in stock prices soon after it becomes publicly available. However, a growing body of literature shows the opposite, i.e. the market often fails to accurately price new information immediately. Thus, the market is not in line with the (semi) efficient market hypothesis (Fama 1970). Instead, these studies argue that the market misprices the long-term effects of announcements or, as in our case, of specific firm characteristics on financial performance. The market corrects the initial mispricing over time, when other tangible information or unexpected financial outcomes that are related to the announcement or to the firm characteristic of interest become publicly available. The presence of long-term abnormal returns is therefore indicative of market inefficiency (Daniel and Titman 2006). For example, in the operations management literature, Alan et al. (2014) find that inventory productivity is indicative of future stock returns, even though investors could determine the metric of inventory productivity with the help of publicly available information in annual reports. Filbeck et al. (2017) analyze the effect of working capital management practices on long-term stock returns and find that more highly ranked firms realized abnormal high returns compared to less highly ranked firms. Moving to other firm characteristics, employee satisfaction (Edmans 2011), customer satisfaction (Aksoy et al. 2008) and corporate reputation (Raithel and Schwaiger 2015) are also related to abnormal stock returns.

Those studies based on firm characteristics are usually characterized by the following criteria (Sorescu et al. 2017). First, the firm characteristics are typically not announced and are therefore not immediately visible to all investors although they could be determined with the readily available information contained in annual reports. Furthermore, with a non-straightforward performance outcome, complex consequences may result when the variable of the firm characteristic is changed. Finally, the potential outcomes of these firm characteristics may represent intangible information regarding future cash-flows (Daniel and Titman 2006). Consequently,

investors may not accurately incorporate such information without additional information, which only becomes available as time goes by (the so-called “lack of information” hypothesis (Edmans 2011)).

The aforementioned characteristics are all applicable to the degree of vertical integration. The vertical integration level is typically not announced and therefore not visible immediately to investors. As shown in our conceptual framework, the relationship between the degree of vertical integration and financial performance is complex. Furthermore, the performance outcomes (financial and stock market performance) are not straightforward, as both greater vertical integration and less vertical integration might be beneficial under certain circumstances, especially before the onset of the recent financial crisis. Finally, the degree of vertical integration affects a firm’s intangible assets, such as product differentiation, technological knowledge or market power, where more information needs to be accurately incorporated into stock prices. Consequently, we expect long-term abnormal returns that depend on the degree of vertical integration.

We argue that the direction taken by the impact of the vertical integration level on stock returns cannot be determined a priori in times where uncertainty is low, i.e. before the onset of the recent financial crisis. Due to the ambiguous theoretical predictions with regard to a high versus a low degree of vertical integration, it clearly depends on the cash-flow implications. We thus formulate the following alternate hypotheses for the time frame before the onset of the recent financial crisis:

Hypothesis 1: A higher degree of vertical integration is beneficial to long-term stock returns before the onset of the recent financial crisis.

Hypothesis 1 (alternate): A lower degree of vertical integration is beneficial to long-term stock returns before the onset of the recent financial crisis.

However, after the onset of the recent financial crisis, the advantages of high vertical integration levels should outweigh the disadvantages, resulting in higher long-term abnormal stock returns. The recent financial crisis can then be seen as a so-called “meta event” (Konchitchki and O’Leary 2011) that is independent of individual firms

and might have changed the overall stock market's perceptions. It has to be noted that we still expect long-term abnormal returns because the aforementioned criteria (not announced, not immediately visible to investors, complex outcomes and lack of information) still obtain. Thus, we formulate:

Hypothesis 2: A higher degree of vertical integration is positively related to long-term stock returns after the onset of the financial crisis

Based on the learning argument (Brav and Heaton 2002), we expect additional information to be incorporated into stock returns as time goes by. The stock market then learns about the value of the degree of vertical integration. Thus, the value of vertical integration should dissipate gradually into the market. We formulate the following hypothesis:

Hypothesis 3: The value of vertical integration levels dissipate gradually into the market, i.e. long-term stock returns disappear as time goes by.

3. Research Setup

3.1 Measurement of Vertical Integration

To measure the degree of vertical integration, we apply the value-added-to-sales approach developed by Adelman (1955). Value-added is defined as the difference between sales and external purchases when the so called subtraction method is used. Because the database used in this study (Thomson Reuters Datastream) does not provide sufficient information on external purchases, we use the additive method, which sums up all the items that comprise value-added. Therefore, value-added is calculated as the sum of net income (after dividends), interest expense, salaries and benefits expense, income taxes and dividends. Expressed as a percentage of a firm's sales, value-added measures the portion of a firm's sales generated by activities carried out within the firm's boundaries. In general, the value-added to sales ratio is

limited to values between 0 (non-integrated firm) and 1 (fully integrated firm). Thus, a firm with a higher value-added to sales ratio is assumed to produce a higher portion of total output in-house, while a firm with a lower ratio produces a lower portion of total output in-house. This approach seems to be the most commonly used measure for the vertical integration level (see Lajili et al. (2007) for an overview of studies). The popularity of this measure is mainly determined by its computational properties with data from profit and loss accounts.

3.2 Data Description

The data used for the empirical analysis was taken from Thomson Reuters Datastream. We choose a European sample of manufacturing firms that have two-digit SIC (Standard Industrial Classification) codes between 20 and 39 over the period from 1993 to 2015. The selection of included countries is based on the country selection undertaken by Kenneth R. French's website for European risk factors⁴ in order to make an appropriate analysis of risk-adjusted returns possible using the Fama-French-Carhart four factor model (see section 3.3.2). To ensure the quality of the stock return data (i.e., the percentage change in Datastream's month-end total return index) from Datastream, we follow the procedure suggested by Ince and Porter (2006) that has been frequently applied in research (e.g. Watanabe et al. 2013). In order to screen the data for coding errors, any return above 300% that is reversed within one month is set to missing. To be precise, if R_t and R_{t-1} are the monthly returns for month t and $t-1$ respectively, both are set to missing if R_t or R_{t-1} is above 300% and $(1 + R_t)(1 + R_{t-1}) - 1 < 50\%$. Furthermore, we eliminate observations from the end of the sample period to the first non-zero return date, since Datastream keeps padding the last available data after the delisting date. Our final sample includes 19,580 firm-year observations from 2,787 unique firms. Table 1 lists the final distribution of our sample across countries.⁵ Firms in UK, Germany and France account for over 50% of our sample.

⁴ http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html#International

⁵ The sample distribution across industries is reported in Appendix 1.

Table 1: Sample distribution across countries

| Country | Number of firms | Value-added to sales ratio | | | | |
|----------------|-----------------|----------------------------|-------|--------|-------|-------|
| | | Min | Max | Median | Mean | SD |
| United Kingdom | 689 | 0.002 | 0.960 | 0.365 | 0.370 | 0.135 |
| Germany | 453 | 0.014 | 0.961 | 0.328 | 0.327 | 0.123 |
| France | 422 | 0.002 | 0.960 | 0.319 | 0.325 | 0.126 |
| Sweden | 203 | 0.027 | 0.914 | 0.326 | 0.337 | 0.124 |
| Italy | 183 | 0.007 | 0.990 | 0.297 | 0.306 | 0.126 |
| Switzerland | 148 | 0.000 | 0.870 | 0.389 | 0.391 | 0.123 |
| Netherlands | 93 | 0.012 | 0.963 | 0.321 | 0.333 | 0.109 |
| Greece | 90 | 0.020 | 0.786 | 0.224 | 0.234 | 0.120 |
| Denmark | 85 | 0.046 | 0.983 | 0.364 | 0.379 | 0.146 |
| Finland | 84 | 0.005 | 0.927 | 0.320 | 0.338 | 0.141 |
| Norway | 80 | 0.017 | 0.946 | 0.313 | 0.323 | 0.132 |
| Spain | 72 | 0.009 | 0.992 | 0.325 | 0.333 | 0.140 |
| Austria | 70 | 0.002 | 0.909 | 0.330 | 0.331 | 0.106 |
| Belgium | 56 | 0.041 | 0.960 | 0.328 | 0.327 | 0.126 |
| Portugal | 34 | 0.000 | 0.736 | 0.271 | 0.279 | 0.125 |
| Ireland | 25 | 0.017 | 0.795 | 0.278 | 0.280 | 0.122 |
| Total | 2,787 | 0.000 | 0.992 | 0.333 | 0.339 | 0.131 |

3.3 Method

3.3.1 Portfolio Formation Methodology

To test our hypotheses, we use a portfolio formation approach. In each year t , we form portfolios on June 30, using accounting information to calculate the degree of vertical integration for fiscal years ending from January 1 of year $t-1$ to December 31 of year $t-1$. The fiscal year-end cutoff date of December 31 originates from Fama and French (1993) and allows at least six months for the accounting information to reach the market.

The majority of studies that use the portfolio approach adjust their variable of interest for a specific firm to its industry in order to mitigate interindustry effects. In general, there are three alternatives. The first common approach is the standardization of metrics within each industry, which is achieved by subtracting its industry mean and dividing by the industry standard deviation (e.g. Chen et al. 2005; Chen et al. 2007). The second method is based on scaling the variable of interest within each industry, which is achieved by dividing by its industry median.

However, as shown in Alan et al. (2014), these two parametric approaches lead to substantial variations in industry representation across portfolios, especially in the event the data being differently skewed across industries. Consequently, we apply a non-parametric third method similar to that used by Alan et al. (2014) for ranking firms in our sample. At the end of June in year t , we rank firms in each of the 14 industries by their value-added to sales ratio in ascending order and divide each industry into deciles (1 = low, 10 = high). Then we form portfolio i by aggregating the firms with decile rank i in each industry. In contrast to the standardization of variables or scaling by industry medians, this methodology mitigates the impact of differences in the frequency distribution of our metrics (see Alan et al. (2014) for further details).

We start by sorting the firms into deciles according to their value-added to sales ratio between January 1, 1992 and December 31, 1992. On June 30 in 1993, we invest US\$1⁶ in each decile portfolio. Firms remain in a portfolio until June 30 in 1994. After that, we reform our portfolios. This process is repeated year by year. The last date of portfolio formation is June 30 in 2014 based on accounting information from 2013.

In addition to our decile portfolios, we are interested in a zero net investment strategy in order to analyze potential performance spreads between firms with a low and high degree of vertical integration. For this purpose, we take a US\$1 long position in firms that have a high degree of vertical integration (decile 10) and a US\$1 short position in firms that display a low degree of vertical integration (decile 1).

3.3.2 Measurement of Abnormal Portfolio Stock Returns

The methodology so far describes how we build portfolios based on the degree of vertical integration. In a further step, we need to test whether the corresponding portfolio returns are abnormal in order to test Hypothesis 1 (Hypothesis 1_(alternate) respectively) and Hypothesis 2. We apply two approaches that test for abnormal

⁶ All variables in this study are measured in US\$ so as to be consistent with the Fama-French factors. Their stock returns are also based on stock prices in US\$ (see http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/Data_Library/f-f_3developed.html).

returns. First, we use a so-called random portfolio approach in order to check whether portfolio end values significantly differ from their industry peers. Second, we use the Fama-French-Carhart four factor model which controls for commonly known risk factors that are associated with stock returns. These two methods are described below.

Random portfolios

To decide whether the returns yielded by specific decile portfolios are abnormal, we create so-called pseudo-portfolios to determine the normal range of returns for the underlying data set and to compute empirical p -values (Lyon et al. 1999; Chen et al. 2005; Chen et al. 2007). In June 1993, we randomly select 10% of the stocks and invest US\$1 equally among the selected stocks. After a holding period of 12 months, we sell the portfolio and reinvest the money in a new, randomly selected 10% of the stocks in June 1994. This procedure is repeated until the end of the investment periods to obtain the final value for our first random portfolio. In total, we created 100,000 of these pseudo-portfolios. The end values of the 100,000 randomly selected portfolios are compared to the decile portfolio end values using an empirical two-tailed p -value for each decile portfolio. The empirical p -value of decile portfolio i is defined as

$$p_i = \frac{\min(n_i; 100,000 - n_i)}{2 \cdot 100,000} \quad (1)$$

where n_i is the number of random portfolios that have higher end values than decile portfolio i . If the degree of vertical integration is irrelevant, no statistically significant differences should be observed. However, if the degree of vertical integration is significant, then it should generate returns that are in the tails of the distribution created by the random portfolios.

Risk adjusted portfolio returns

Besides the random portfolio approach, we estimate a standard empirical asset pricing framework developed by Fama and French (1993) and augmented by Carhart (1997). This Fama-French-Carhart four-factor model controls for common risk factors that

are associated with stock returns. In detail, we applied the following model for each decile portfolio i :

$$RET_{im} = \alpha_i + \beta_{1i} \cdot RMRF_m + \beta_{2i} \cdot SMB_m + \beta_{3i} \cdot HML_m + \beta_{4i} \cdot UMD_m + \varepsilon_{it} \quad (2)$$

RET_{im} is the equally weighted return yielded by decile portfolio i in month m in excess of a benchmark. We use the risk-free rate and an equally weighted return generated by all manufacturing firms in month m in the sample (i.e. industry benchmark) as two different benchmarks.⁷ The latter is chosen to ensure that portfolio performance does not simply result from manufacturing firms in general realizing high returns over the sample period. Furthermore, using an industry benchmark is more comparable to our portfolio end value approach as the comparison with the random portfolios automatically considers the performance achieved by all manufacturing firms. $RMRF_m$ is the value-weighted market return minus the risk-free rate in month m . SMB_m , HML_m and UMD_m are zero net investment portfolio returns to capture size, value and momentum effects.

The intercept α_i represents the monthly abnormal return of portfolio i in excess of the risk-free rate. The intercept should not differ from zero if the common risk factors fully explain the excess return yielded by portfolio i . Positive (negative) intercepts indicate that portfolio i outperforms (underperforms) its benchmark. We have adjusted the standard errors of the coefficients and applied a heteroskedasticity and autocorrelation consistent OLS estimator (Newey and West 1987).

3.3.3 Longevity of Abnormal Returns

The information about vertical integration returns may dissipate gradually into the market, for example, because the degree of vertical integration may be predictive for other metrics that are valued by investors (e.g. earnings). Hence, the excess returns should disappear over time. Based on the risk -adjusted portfolio returns, we investigate the longevity of abnormal returns in order to test Hypothesis 3. More

⁷ We obtain the data for the risk-free rate and the four risk factors for the European stock market from Kenneth R. French's website (http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html#International).

precisely, we investigate whether, and consequently when information about vertical integration is priced into stock prices.

Prior literature (e.g. Edmans 2011; Alan et al. 2014) mainly investigates the longevity of excess returns in two ways. The first involves tracking portfolio returns for more than one year and using the Fama-French-Carhart four factor model. In particular, we construct portfolios at the end of June in year t , but rather than liquidating them in June of $t + 1$, we hold them for four more years. We calculate monthly average excess returns (over risk-free rate or industry benchmark) yielded by the portfolios in each year of the holding period. For instance, the average portfolio return in the second year is computed using monthly returns from July of year $t + 1$ through June of year $t + 2$.

The second method is the calculation of buy-and-hold abnormal returns (BHARs). A BHAR is the difference between the return on a buy-and-hold investment in a portfolio based on its degree of vertical integration less the return on a buy-and-hold investment generated by a benchmark (e.g. industry benchmark) over the identical period. Specifically, BHARs are calculated as

$$BHAR_{j,s,M} = \prod_{m=s}^M (1 + R_{jm}) - \prod_{m=s}^M (1 + R_{bm}), \quad (3)$$

vertical integration portfolio
benchmark

where R_{jm} is the monthly return of stock j within portfolio 1 to 10 with respect to the degree of vertical integration, R_{bm} is the monthly return of the benchmark, M is the upper bound of the holding period, m the lower bound. s and M are typically chosen to coincide with years (e.g. 1-12, 24-36, 36-48). This is comparable to rebalancing at the start of each year and ensures that returns are not attributed to the outperformance (underperformance) of just a few stocks. The corresponding t -statistic is then based on the average BHAR in portfolio i , the corresponding cross-sectional standard deviation of the BHARs within portfolio i and the number of observations within portfolio i .

The Effect of earnings surprises

Due to the complex, non-straightforward and uncertain impact on financial performance, investors do not fully react to publicly available information about vertical integration either because they are not able to price its effect completely or because they pay little attention to it until it manifests itself in financial performance such as earnings (Edmans 2011). In order to further test Hypothesis 3, we investigate the impact of vertical integration on future accounting performance. However, it should be noted that future accounting performance drives stock returns only when it is unexpected. Expected outcomes in sales or profits should already be incorporated in stock prices (e.g. through reasonable analyst coverage). Thus, we examine the relationship between vertical integration and earnings surprises in line with prior research (e.g. Core et al. 2006; Edmans 2011; Giroud and Mueller 2011) by estimating the following regression:

$$Surprise_{it} = b_0 + b_1 VAS_{it-j} + b_2 BTM_{it-j} + b_3 MC_{it-j} + \varepsilon_{it}, \quad (4)$$

where $Surprise_{it}$ is the one- or two-year earnings surprise for company i at time t . The one-year earnings surprise is the actual earnings per share minus the median Institutional Brokers Estimate System (I/B/E/S) analyst earnings forecast scaled by stock price at fiscal year-end. Most firms in our sample have their fiscal year-end in December and release their annual reports in March or April of the following year. The forecast is taken eight months before fiscal year end for the fiscal year for which the forecast is made. This ensures that the analysts have information about the lagging earnings when they make their forecasts. The two-year earnings surprises are calculated in a similar way, and the forecasts are taken 20 months before the fiscal year-end for which the forecast is made. In line with the literature (Edmans 2011; Giroud and Mueller 2011), forecast errors larger than 10 % of the stock price are removed in order to mitigate the effect of outliers. VAS_{it} is either the portfolio rank of vertical integration of firm i or the continuous degree of vertical integration of firm i one or two periods prior to the forecast period. Using the portfolio rank automatically takes into account the inter-industry differences of vertical integration and mitigates the effect of extreme observations. BTM_{it-j} is the natural logarithm of the book-to-

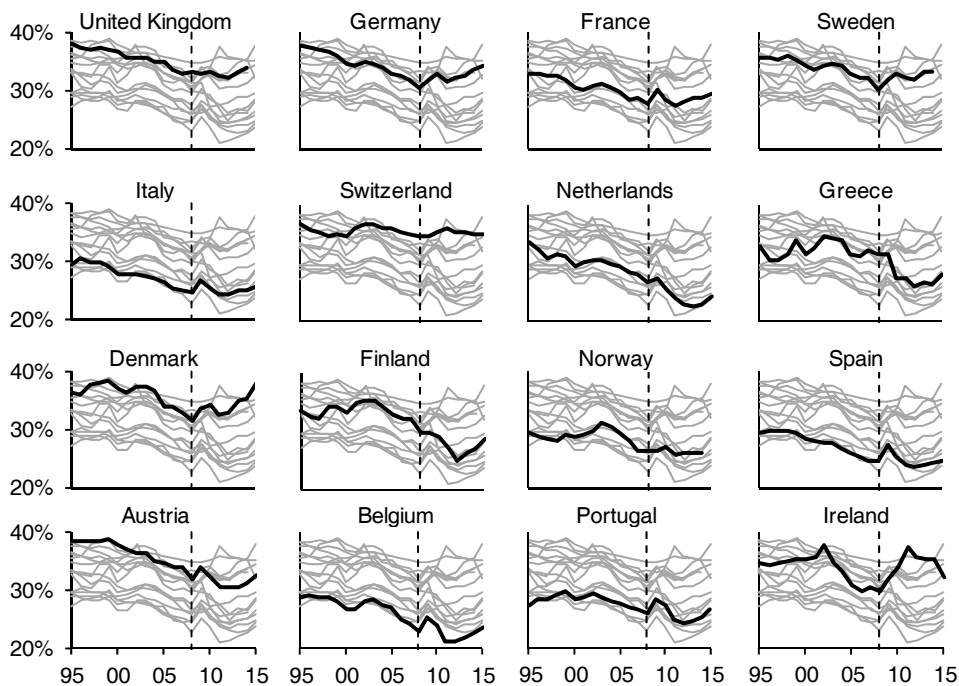
market ratio and MC_{it-j} the logarithm of the market capitalization of firm i either one or two years prior to the forecast period. Equation (4) further includes industry and year fixed effects.

4. Results

4.1 Descriptive Results

As Hypothesis 1 and Hypothesis 2 imply a strategic shift with respect to the degree of vertical integration, we first plot the degree of vertical integration for major European countries between 1995 and 2015 in Figure 2.⁸

Figure 2: Degree of vertical integration over time for major European economies (Source: Our own calculations, based on Eurostat 2017).



Note: This figure shows the degree of vertical integration in the manufacturing sector over time (1995-2015) for major European economies. The ordering is based on the number of firms in each country in our sample. The degree of vertical integration in each year is calculated as the sum of value-added across all firms, divided by the sum of output across all firms in the manufacturing sector. The horizontal axes show the year and the vertical axes the degree of vertical integration. The degree of vertical integration for the country of interest is indicated with a black line. Gray lines show the degree of vertical integration for all the other countries in the sample. The dotted line shows the onset of the financial crisis in 2008.

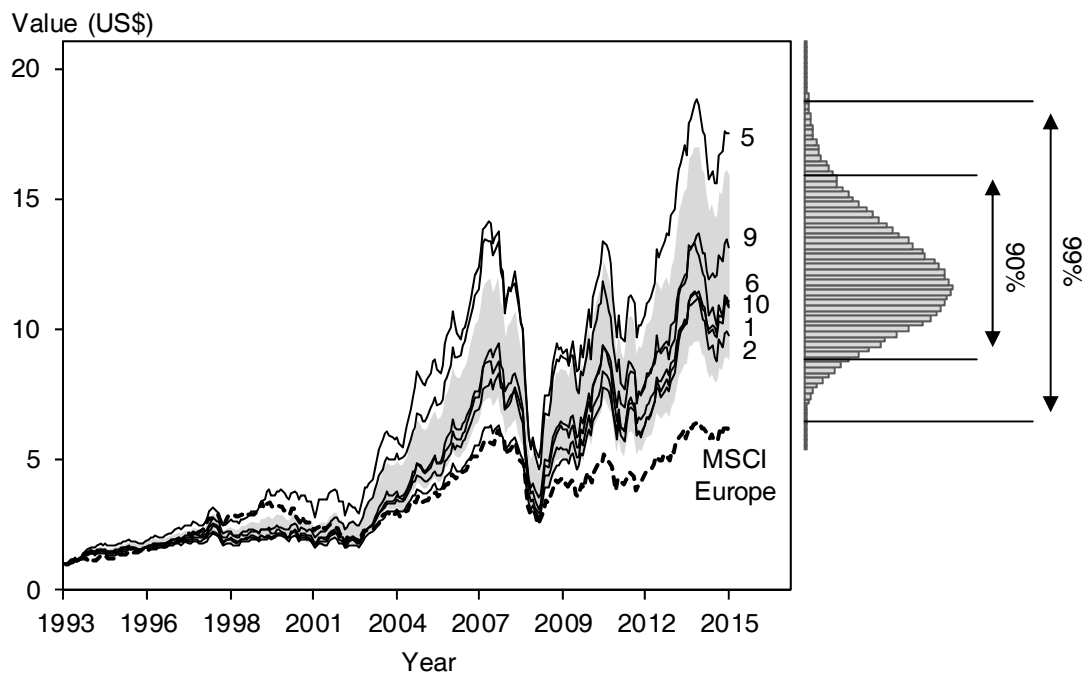
⁸ The time trend for the sample firms in this study is depicted in Appendix 2.

Although the degree of vertical integration substantially differs across countries, an increasing trend towards outsourcing can be observed, on average, until the onset of the recent financial crisis (2007/2008). However, in recent years European manufacturing firms have been increasing their degree of vertical integration more and more, indicating that there has indeed been a strategic shift since the financial crisis. In the following sections we investigate the capital market's attitude to this strategic shift.

4.2 Results for the Random Portfolio Approach

In order to analyze portfolio returns over time, Figure 3 first shows both the development of the vertical integration decile and random portfolio values, and a US\$1 investment in 1993 in the MSCI Europe Index until 2015. The distribution of the final portfolio values in 2015 is shown on the right-hand side of Figure 3.

Figure 3: Decile portfolio and random portfolio values

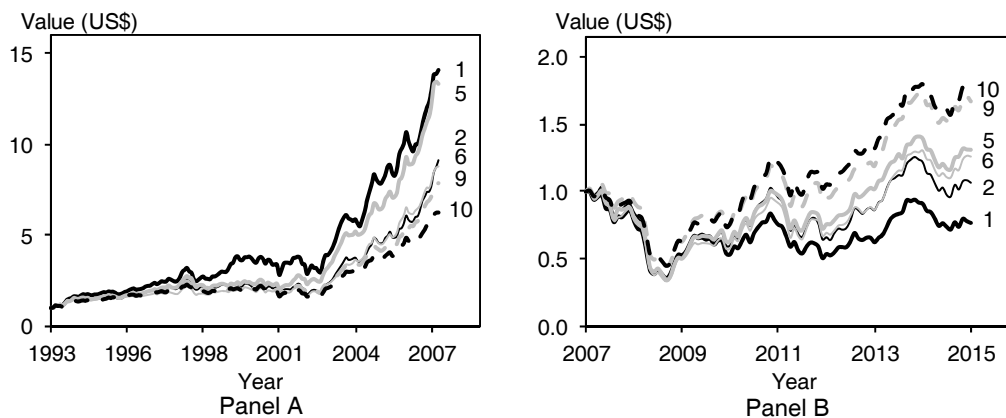


Note: We only depict the two lowest, two highest and two middle portfolios for the sake of readability. The gray-shaded area represents the 90% bandwidth of the 100,000 random portfolios. The histogram on the right is the value distribution of the random portfolios in June 2015 and contains intervals where 90% (8.81, 15.88) and 99% (6.44, 18.75) of the values lie, respectively. The median end value of the 100,000 random portfolios is 11.82. The development of a US\$1 investment in the MSCI Europe Index in 1993 is plotted as a benchmark.

Overall, the portfolio values slowly increased during the 1990s, decreased during the dotcom crisis in 2000 and 2001 and increased afterwards until the onset of the recent financial crisis. After a sharpe decline during the financial crisis between 2007 and 2009, portfolio values increased again until 2015. It's noteworthy that all decile portfolios have performed better than the MSCI Europe since the early 2000s. This is primarily because the MSCI Europe also includes financial and technology firms which have been hit even harder during the financial crisis and the dot-com crisis in the early 2000s, respectively.

However, the investigation of Hypothesis 1 (Hypothesis 1_(alternate)) and Hypothesis 2 requires a time-split of our whole time frame into two non-overlapping sub-periods. The first covers the time frame from June 30 in 1993 to June 30 in 2007. For the second sub-period (post-crisis), we re-started by investing US\$1 at the end of June 2007 and followed our investment strategy until June 2015. The portfolio values over the sub-periods are shown in Figure 4.

Figure 4: Decile portfolio values before and after the onset of the financial crisis



Note: We only depict the two lowest, two highest and two middle portfolios for the sake of readability. Portfolio 1 shows the best performance before June 2007, whereas portfolio 10 performed worst (Panel A). After the onset of the crisis, the picture reversed (Panel B).

Vertical integration decile portfolio 1 has the highest portfolio end value at 14.11⁹ at the end of the pre-crisis period, while decile portfolio 10 has the lowest end value at 6.26 (Panel A of Figure 4). The picture has reversed for the period after the onset of the financial crisis, i.e. vertical integration decile portfolio 1 performed worst (end

⁹ This value is in US\$. We will not add the currency to the end values in the rest of the paper.

value of 0.77) and decile and 10 performed best (end value of 1.75, see Panel B of Figure 4).

The results so far indicate that the least vertically integrated firms (decile 1) had higher stock returns before the onset of the recent financial crisis, while the most highly vertically integrated firms (decile 10) had higher stock returns after the onset of the financial crisis. In the next step, we have to check to see whether the portfolio returns are abnormal by comparing them with the portfolio end values of the 100,000 random portfolios. The gray-shaded area in Figure 3 represents the interval where 90% of the random portfolio values lie within. If decile portfolio values with respect to the degree of vertical integration are outside the 90% interval, then the decile portfolio values are denoted as abnormal.

Table 2 shows the portfolio end values of the decile portfolios based on the degree of vertical integration for the whole time frame (Panel A: 1993-2015), the pre-crisis period (Panel B: 1993-2007) and the post-crisis period (Panel C: 2007-2015).¹⁰

Table 2: Portfolio values in US\$ at the end of the assumed investment period

| Portfolio rank of vertical integration | end-value of a US\$1 investment | | |
|--|---------------------------------|--------------------|--------------------|
| | Panel A: 1993-2015 | Panel B: 1993-2007 | Panel C: 2007-2015 |
| 10 (high) | 10.93 | 6.26*** | 1.75*** |
| 9 | 13.14 | 7.88 | 1.67*** |
| 8 | 12.93 | 8.24 | 1.57** |
| 7 | 13.14 | 9.52 | 1.38 |
| 6 | 11.08 | 8.80 | 1.26 |
| 5 | 17.48** | 13.35** | 1.31 |
| 4 | 10.83 | 9.04 | 1.20 |
| 3 | 9.39 | 8.77 | 1.07 |
| 2 | 9.74 | 9.14 | 1.07* |
| 1 (low) | 10.84 | 14.11*** | 0.77*** |

Note: To determine the significance of portfolio end values of portfolio i , we compute the empirical p value as $\min(n_i; 100,000) / (2 \cdot 100,000)$, where n_i is the number of random portfolios with higher end values than portfolio i .

*, **, and *** denote statistical significance at 10%, 5%, and 1% levels, respectively.

We first start by comparing the portfolio end values obtained over the whole investment period from 1993-2015 with the 100,000 end values generated by the random portfolios (see Panel A of Table 2). Results show that slightly lower than

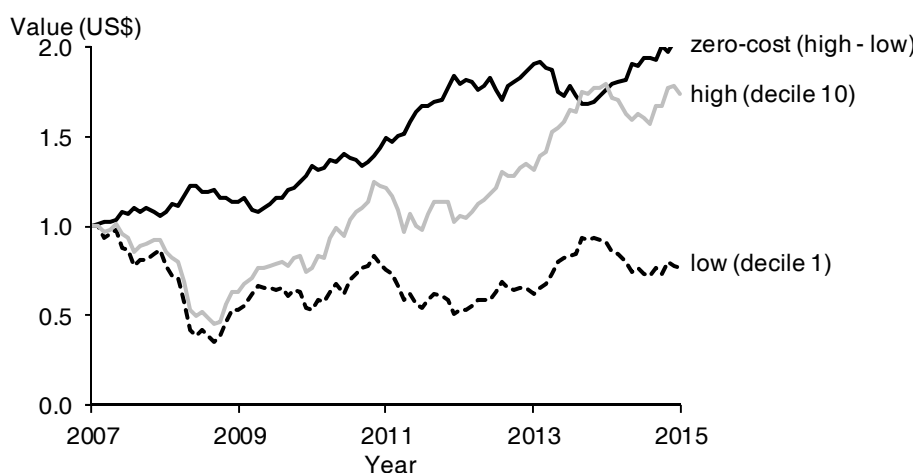
¹⁰ It should be noted that the end values shown are exactly the same at the end of the time frames shown in Figure 3 and Figure 4).

average vertical integration (portfolio 5) leads to abnormally high stock returns over the entire period from 1993 to 2015 at a 5% significance level (end value of 17.48). Portfolios consisting of firms with a comparatively low degree of vertical integration (portfolios 1 to 4) performed worst (10.84, 9.74, 9.34, 10.83).

Panel B of Table 2 indicates that firms with a low degree of vertical integration yield the highest long-term stock returns before the financial crisis (abnormal end value of 14.11). Furthermore, portfolio 5 shows significantly high end values, as well. In contrast, more highly ranked portfolios (8, 9 and 10) have poorer returns whereas only the end value of portfolio 10 is significant (end value of 6.26). A further time split (not reported here) of the first sub-period into two equal, non-overlapping periods (June 1993 to June 2000; end of June 2000 to June 2007) reveals that the outperformance of portfolio 1 is mainly driven by the high returns until 2000 (the beginning of the dot com crisis), whereas the outperformance of portfolio 5 results from high returns between 2000 and 2007. The poor stock returns of portfolio 10 exist in all sub-periods until June 2007. Furthermore, more highly ranked portfolios (i.e. 8-10) have significantly low end values in the 1990s.

After the onset of the financial crisis, firms with a higher degree of vertical integration (portfolios 8-10), compared to industry peers generated positive abnormal returns (see Panel C of Table 2). The less highly ranked portfolios (i.e. 1-3) have the lowest stock returns, while portfolio 1 (end value of 0.77) and portfolio 2 (end value of 1.07) have significantly poor returns. Furthermore, the highest ranked firms with respect to vertical integration (portfolio 9 and 10) have overcome the financial crisis pretty well compared to less highly ranked firms (see Figure 5). During the crisis, they lost only 37% of their initial stock value during the crisis from June 2007 to June 2009, whereas the other portfolios lost 48% on average. Furthermore, Figure 5 presents a US\$1 investment in zero-cost portfolio with a long position in decile 10 and a short position in decile 1. This investment results in an even higher portfolio end value in 2015 and transpires to have been a strategy that did not just protect value during the financial crisis, but actually enhanced it.

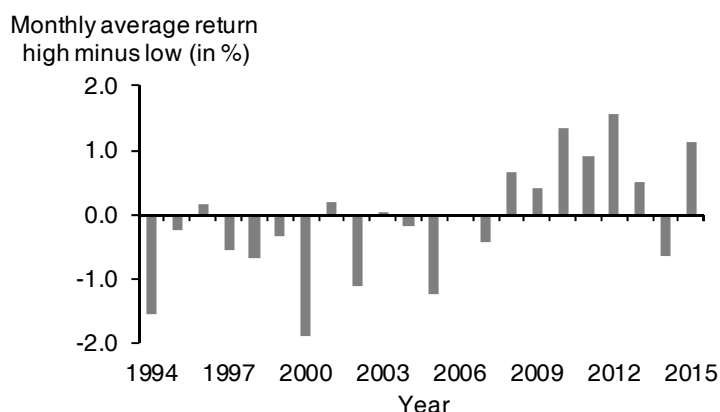
Figure 5: Portfolio values for vertical integration decile portfolio 1, 10 and a zero-cost portfolio during and after the recent financial crisis



4.3 Risk Adjusted Portfolio Returns

The above subsection has demonstrated that the returns from vertical integration, based on the random portfolio approach, were higher for highly integrated firms after the onset of the crisis, but higher for the least highly integrated firms before the crisis. To examine further the relationship between the lowest and highest decile portfolios (decile 1 and decile 10), based on the degree of vertical integration, Figure 6 presents the time series averages of mean monthly excess returns on the zero-cost portfolio with a long position in decile 10 and short position in decile 1 and indicates systematic variation over time.

Figure 6: Monthly Average Returns of Zero-Cost Portfolios



Note: The first monthly average return for the year 1994 is calculated as the average monthly return between July 1993 and June 1994.

Analysis of the portfolio performance reveals that least highly (most highly) vertically integrated firms outperform the most highly (least highly) integrated firms before (after) the crisis, indicating that an extreme low degree of vertical integration has been beneficial for stock returns before the onset of the financial crisis and that a high degree has been beneficial afterwards.

It would seem reasonable to conclude that the results were essentially driven by the degree of vertical integration and that investors were not able to incorporate its effect fully into their investment decisions. However, the question remains whether vertical integration might be serving as a proxy for a known risk factor that diminishes portfolio returns or whether vertical integration itself explains future stock returns. We appraise the four factor Fama-French-Carhart model in order to investigate how robust our findings are after controlling for various risk factors (Fama and French 1993; Carhart 1997).

We regress the portfolio returns in excess of two benchmarks, i.e. in excess of the risk-free rate (Panel A of Table 3) and in excess of the equally weighted stock return across all manufacturing firms in each month (Panel B of Table 3) for the whole time frame (1993-2015), the pre-crisis period (1993-2007) and the post-crisis period (2007-2015). The intercept α is the monthly abnormal return of portfolio i in excess of one of the two benchmarks. If the Fama-French-Carhart factors (i.e. *RMRF*, *SMB*, *HML*, *UMD*) entirely explain the excess return yielded by portfolio i , then α should not be significantly different from zero. Panel A of Table 3 shows that more highly vertically integrated firms (portfolio 5-10) and portfolio 1 realized significant excess returns over the risk-free rate in the period from 1993 to 2015. The monthly abnormal return yielded by decile portfolio 1 is 0.29 while those of the higher ranked portfolios range between 0.25 (portfolio 6) and 0.37 (portfolio 5). Portfolio 1 yielded abnormally high returns before the financial crisis ($\alpha = 0.49$), whereas more highly vertically integrated firms (portfolios 4-10) have been successful since the financial crisis, with monthly abnormal returns ranging from 0.35 (portfolio 4) to 0.61 (portfolio 10). Furthermore, a zero-cost portfolio with a long position in decile 10 and a short position in decile 1 was a value-destroying strategy during before the crisis ($\alpha = -0.52$). However, after the crisis, this strategy leads to the highest monthly excess returns ($\alpha = 0.68$).

Table 3: Fama-French-Carhart four factor regression results for portfolios consisting of firms based on their degree of vertical integration

| Portfolio rank | excess returns over | | | | | | | | | |
|----------------------------|-------------------------|----------|----------|----------|----------|-----------------------------|----------|----------|----------|-------|
| | Panel A: risk-free rate | | | | | Panel B: industry benchmark | | | | |
| | α | RMRF | SMB | HML | UMD | α | RMRF | SMB | HML | UMD |
| <i>Period: 1993 - 2015</i> | | | | | | | | | | |
| 10 (high) | 0.30*** | 0.86*** | 0.63*** | 0.11** | -0.10*** | 0.04 | -0.11*** | -0.13*** | -0.13*** | 0.02 |
| 9 | 0.36*** | 0.90*** | 0.67*** | 0.16** | -0.11*** | 0.10 | -0.08*** | -0.09*** | -0.09* | 0.01 |
| 8 | 0.30*** | 0.93*** | 0.73*** | 0.25*** | -0.11*** | 0.04 | -0.05*** | -0.03 | 0.01 | 0.01 |
| 7 | 0.31*** | 0.93*** | 0.69*** | 0.22*** | -0.10*** | 0.04 | -0.04*** | -0.06* | -0.03 | 0.02 |
| 6 | 0.25** | 1.00*** | 0.81*** | 0.25*** | -0.14*** | -0.02 | 0.02 | 0.05* | 0.01 | -0.02 |
| 5 | 0.37*** | 0.97*** | 0.71*** | 0.36*** | -0.11*** | 0.10 | -0.01 | -0.05 | 0.12*** | 0.01 |
| 4 | 0.17 | 1.02*** | 0.78*** | 0.34*** | -0.11*** | -0.09 | 0.04*** | 0.02 | 0.10*** | 0.01 |
| 3 | 0.17 | 1.03*** | 0.79*** | 0.26*** | -0.14*** | -0.09 | 0.05*** | 0.04 | 0.02 | -0.02 |
| 2 | 0.11 | 1.05*** | 0.88*** | 0.33*** | -0.10*** | -0.15* | 0.08*** | 0.13*** | 0.09*** | 0.02 |
| 1 (low) | 0.29* | 1.06*** | 0.86*** | 0.15** | -0.17*** | 0.02 | 0.08* | 0.11* | -0.09 | -0.05 |
| Zero-cost | 0.02 | -0.19*** | -0.23*** | -0.04 | 0.07 | 0.02 | -0.19*** | -0.23*** | -0.04 | 0.07 |
| <i>Period: 1993 - 2007</i> | | | | | | | | | | |
| 10 (high) | -0.03 | 0.89*** | 0.65*** | 0.25*** | -0.10*** | -0.13 | -0.11*** | -0.09* | -0.09*** | 0.03 |
| 9 | 0.13 | 0.90*** | 0.66*** | 0.30*** | -0.16*** | 0.04 | -0.10*** | -0.07* | -0.05 | -0.03 |
| 8 | -0.01 | 0.95*** | 0.71*** | 0.41*** | -0.12*** | -0.10 | -0.05* | -0.03 | 0.06* | 0.01 |
| 7 | 0.09 | 0.98*** | 0.70*** | 0.36*** | -0.12*** | 0.00 | -0.02 | -0.04 | 0.02 | 0.01 |
| 6 | 0.09 | 0.99*** | 0.76*** | 0.36*** | -0.16*** | 0.00 | -0.01 | 0.02 | 0.01 | -0.03 |
| 5 | 0.20 | 0.99*** | 0.66*** | 0.46*** | -0.09** | 0.10 | -0.01 | -0.08* | 0.11* | 0.04 |
| 4 | -0.08 | 1.06*** | 0.76*** | 0.47*** | -0.11*** | -0.18* | 0.06*** | 0.02 | 0.12*** | 0.02 |
| 3 | 0.07 | 1.03*** | 0.71*** | 0.32*** | -0.14*** | -0.02 | 0.03 | -0.02 | -0.03 | -0.01 |
| 2 | -0.06 | 1.09*** | 0.88*** | 0.42*** | -0.11*** | -0.16 | 0.09*** | 0.14*** | 0.07* | 0.02 |
| 1 (low) | 0.49** | 1.12*** | 0.87*** | 0.13 | -0.19*** | 0.40* | 0.11*** | 0.13*** | -0.22* | -0.06 |
| Zero-cost | -0.52** | -0.22*** | -0.21*** | 0.13 | 0.09 | -0.52* | -0.22*** | -0.21*** | 0.13 | 0.09 |
| <i>Period: 2007 - 2015</i> | | | | | | | | | | |
| 10 (high) | 0.61*** | 0.91*** | 0.63*** | -0.14** | -0.12*** | 0.25*** | -0.10*** | -0.23*** | -0.20*** | -0.01 |
| 9 | 0.53*** | 0.98*** | 0.76*** | -0.10 | -0.04 | 0.17* | -0.03 | -0.10* | -0.16* | 0.07 |
| 8 | 0.55*** | 0.99*** | 0.85*** | -0.05 | -0.11** | 0.19 | -0.02 | -0.02 | -0.11* | 0.00 |
| 7 | 0.38*** | 0.97*** | 0.78*** | -0.03 | -0.08** | 0.02 | -0.04* | -0.08* | -0.09* | 0.03 |
| 6 | 0.36*** | 1.08*** | 0.95*** | 0.00 | -0.11*** | 0.00 | 0.07*** | 0.09* | -0.06 | 0.00 |
| 5 | 0.46*** | 1.00*** | 0.84*** | 0.13 | -0.16*** | 0.10 | -0.01 | -0.02 | 0.07 | -0.05 |
| 4 | 0.35** | 1.05*** | 0.88*** | 0.11 | -0.13*** | -0.01 | 0.04* | 0.02 | 0.05 | -0.02 |
| 3 | 0.25 | 1.07*** | 1.00*** | 0.14 | -0.12** | -0.12 | 0.05* | 0.14* | 0.08 | -0.01 |
| 2 | 0.24* | 1.06*** | 0.95*** | 0.21** | -0.10** | -0.12 | 0.05* | 0.09 | 0.15* | 0.01 |
| 1 (low) | -0.06 | 0.98*** | 0.94*** | 0.30*** | -0.13*** | -0.43*** | -0.03 | 0.08 | 0.24*** | -0.02 |
| Zero-cost | 0.68*** | -0.07* | -0.31*** | -0.44*** | 0.01 | 0.68*** | -0.07* | -0.31*** | -0.44*** | 0.01 |

Note: *RMRF*, *SMB*, *HML* and *UMD* are the Fama-French-Carhart factors.

*, **, and *** denote statistical significance at 10%, 5%, and 1% levels.

Furthermore, the relationship between the portfolio rank of vertical integration and returns seems to be much stronger after the onset of the recent financial crisis as there is a monotonic increase in excess returns across all portfolios.

In excess of the industry benchmark (Panel B of Table 3), the results do not show any outperformance between 1993 to 2015. However, the results for the pre- and post-crisis periods remain qualitatively unchanged. During 1993 to 2007, vertical integration decile portfolio 1 yields significant monthly abnormal returns ($\alpha = 0.40$). During 2007 to 2015, portfolio 1 shows significantly poor abnormal returns ($\alpha = -0.43$), while portfolios 9 and 10 yield significantly positive monthly abnormal returns (0.17 and 0.25, respectively). These results indicate that the outperformance displayed

by decile portfolio 1 and the more highly ranked portfolios 9 and 10 is not simply the result of manufacturing firms in general realizing high returns over the sample period.

According to Hypothesis 1_(alternate) we expected a lower degree of vertical integration to be beneficial for long-term stock returns in the pre-crisis period, i.e. the lower the degree of vertical integration the higher the long-term stock returns. Sure enough, if we take into account the results of the random portfolio approach and the Fama-French-Carhart regression simultaneously, it transpires that it is, in fact, only the portfolio consisting of firms with the lowest degree of vertical integration (decile portfolio 1) that yields long-term stock returns. The results for the post-crisis period are consistent with Hypothesis 2, as higher vertical integration is associated with higher long-term stock returns, i.e. the abnormal stock returns increase with the portfolio rank. Thus, the existence of long-term stock returns indicate that the stock market was not able to completely incorporate the information about the degree of vertical integration immediately after it become publicly available through annual reports. This result holds for both sub-periods, i.e. the pre-crisis as well as the post-crisis period, and suggests stock market inefficiency. Under an efficient market hypothesis (Fama 1970), we should not find any long-term abnormal returns, because stock markets are assumed to be able to evaluate new information immediately.

4.4 Results for the Longevity of Outperformance

Longevity of outperformance

To explore when the information about the degree of vertical integration is incorporated into stock prices, we hold the portfolios for four more years instead of liquidating them after one year. We then re-run the Fama-French-Carhart four factor regression for holding periods of two, three, four and five years in order to test for potential abnormal monthly returns. The intercepts α of the Fama-French-Carhart four factor regression for a holding period up to five years in excess of the risk-free rate are reported in Panel A of Table 4 and in excess of the industry-benchmark in Panel B of Table 4.

Table 4: Abnormal returns of decile portfolios formed on the basis of the degree of vertical integration up to five years after portfolio formation

| Portfolio rank | Panel A: Excess of risk-free rate | | | | | Panel B: Excess of industry benchmark | | | | |
|----------------------------|-----------------------------------|---------|---------|--------|---------|---------------------------------------|----------|----------|---------|---------|
| | Holding periods | | | | | Holding periods | | | | |
| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
| <i>Period: 1993 - 2007</i> | | | | | | | | | | |
| 10 (high) | -0.03 | -0.28** | -0.15 | -0.25 | -0.20 | -0.13 | -0.31*** | -0.16 | -0.25* | -0.21 |
| 9 | 0.13 | -0.07 | -0.11 | -0.27 | -0.24 | 0.04 | -0.10 | -0.12 | -0.27 | -0.26 |
| 8 | -0.01 | -0.11 | -0.17 | -0.17 | -0.32* | -0.10 | -0.14 | -0.18 | -0.17 | -0.34** |
| 7 | 0.09 | 0.08 | -0.03 | -0.17 | -0.10 | 0.00 | 0.05 | -0.04 | -0.18 | -0.12 |
| 6 | 0.09 | 0.04 | -0.18 | -0.12 | -0.04 | 0.00 | 0.01 | -0.19 | -0.12 | -0.06 |
| 5 | 0.20 | -0.01 | 0.07 | 0.14 | -0.33 | 0.10 | -0.04 | 0.06 | 0.14 | -0.35* |
| 4 | -0.08 | -0.12 | -0.33** | -0.32 | -0.38** | -0.18* | -0.15 | -0.34** | -0.32 | -0.40** |
| 3 | 0.07 | -0.16 | -0.04 | 0.01 | -0.12 | -0.02 | -0.18* | -0.05 | 0.01 | -0.14 |
| 2 | -0.06 | -0.05 | -0.27* | -0.17 | 0.16 | -0.16 | -0.08 | -0.28* | -0.17 | 0.14 |
| 1 (low) | 0.49** | 0.20 | 0.07 | 0.11 | -0.03 | 0.40* | 0.18 | 0.06 | 0.11 | -0.04 |
| Zero-cost | -0.52** | -0.48* | -0.22 | -0.36 | -0.17 | -0.52* | -0.48* | -0.22 | -0.36 | -0.17 |
| <i>Period: 2007 - 2015</i> | | | | | | | | | | |
| 10 (high) | 0.61*** | 0.62*** | 0.38** | 0.31** | 0.30** | 0.25*** | 0.26* | 0.10 | 0.13 | 0.07 |
| 9 | 0.53*** | 0.55*** | 0.22 | 0.10 | 0.02 | 0.17* | 0.19* | -0.06 | -0.08 | -0.21 |
| 8 | 0.55*** | 0.48** | 0.30* | 0.08 | 0.18 | 0.19 | 0.12 | 0.01 | -0.09 | -0.05 |
| 7 | 0.38*** | 0.49** | 0.25 | -0.07 | -0.16 | 0.02 | 0.13 | -0.03 | -0.25 | -0.39** |
| 6 | 0.36*** | 0.28 | 0.28 | 0.03 | 0.14 | 0.00 | -0.08 | 0.00 | -0.15 | -0.09 |
| 5 | 0.46*** | 0.47*** | -0.07 | 0.07 | 0.39 | 0.10 | 0.11 | -0.36*** | -0.11 | 0.16 |
| 4 | 0.35** | 0.27 | 0.07 | 0.04 | 0.13 | -0.01 | -0.09 | -0.21 | -0.14 | -0.11 |
| 3 | 0.25 | 0.35** | 0.21 | 0.17 | -0.24 | -0.12 | -0.01 | -0.08 | -0.01 | -0.47** |
| 2 | 0.24* | -0.08 | -0.06 | -0.11 | 0.07 | -0.12 | -0.44*** | -0.35** | -0.28 | -0.17 |
| 1 (low) | -0.06 | -0.21 | -0.34 | -0.43* | -0.05 | -0.43*** | -0.57** | -0.62** | -0.61** | -0.29 |
| Zero-cost | 0.68*** | 0.83*** | 0.72** | 0.74** | 0.36 | 0.68*** | 0.83*** | 0.72** | 0.74** | 0.36 |

*, **, and *** denote statistical significance at 10%, 5%, and 1% levels.

It should be noted that the monthly abnormal return for the holding period of one year is exactly the same as in Table 3. Besides, results show that negative (positive) abnormal returns in general increase (decrease) over time and that zero-cost portfolios do not generate abnormal returns beyond year 2 in the pre-crisis period and beyond year 4 in the post-crisis period. Furthermore, the significant outperformance of portfolio 1 between 1993 and 2007 disappears beyond year 1, while the outperformance displayed by the more highly ranked portfolios between 2007 and 2015 disappear as time goes by, except in the case of portfolio 10 in excess of the risk-free rate.

Our second method to test for the longevity of abnormal returns is the Buy-And-Hold-Abnormal-Return which calculates the return generated by a buy-and-hold investment in a portfolio based on its degree of vertical integration less the return on a buy-and-hold investment in a benchmark (e.g. industry benchmark) over the identical period. The results of the BHAR analysis in Table 5 are consistent with the findings of the Fama-French-Carhart four factor regression for a holding period up to five years.

Table 5: Buy and hold abnormal returns (BHARs) for decile portfolios

| Portfolio | Panel A: Months (period 1993-2007) | | | | | Panel B: Months (period 2007-2015) | | | | |
|-----------|------------------------------------|---------------------|------------------|------------------|------------------|------------------------------------|--------------------|--------------------|------------------|-------------------|
| | 1-12 | 13-24 | 25-36 | 37-48 | 49-60 | 1-12 | 13-24 | 25-36 | 37-48 | 49-60 |
| 10 (high) | -0.03** (-2.48) | -0.04*** (-3.73) | -0.01 (-1.03) | -0.01 (-0.83) | 0.01 (0.87) | 0.03** (2.10) | 0.04** (2.50) | 0.02 (1.18) | 0.01 (0.56) | 0.01 (0.32) |
| 9 | -0.01 (-1.08) | -0.01 (-0.77) | 0.01 (0.70) | 0.01 (0.81) | 0.02 (1.49) | 0.03* (1.66) | 0.05** (2.26) | 0.00 (0.11) | 0.02 (1.13) | -0.01 (-0.17) |
| 8 | -0.01 (-0.54) | -0.02 (-1.44) | -0.01 (-0.75) | 0.00 (0.06) | 0.01 (0.45) | 0.02 (1.16) | 0.04 (1.64) | 0.04 (1.56) | 0.01 (0.55) | 0.02 (0.57) |
| 7 | 0.00 (-0.35) | -0.01 (-1.19) | -0.01 (-0.72) | -0.01 (-0.90) | 0.03* (1.65) | 0.00 (0.06) | 0.02 (1.22) | 0.00 (0.06) | 0.02 (0.72) | -0.04* (-1.86) |
| 6 | 0.00 (-0.09) | 0.02 (1.41) | 0.00 (-0.14) | 0.02 (1.20) | 0.00 (-0.25) | 0.01 (0.78) | -0.01 (-0.39) | 0.03 (1.27) | 0.02 (0.63) | -0.01 (-0.28) |
| 5 | 0.04*** (3.01) | 0.01 (0.40) | 0.01 (0.83) | 0.01 (0.59) | -0.01 (-1.05) | 0.00 (0.16) | 0.04 (1.49) | 0.01 (0.32) | -0.01 (-0.41) | 0.10** (2.03) |
| 4 | 0.01 (0.75) | 0.00 (-0.25) | -0.01 (-0.86) | -0.01 (-1.06) | -0.01 (-0.49) | 0.00 (-0.18) | 0.01 (0.24) | 0.01 (0.39) | 0.04 (1.45) | 0.00 (-0.14) |
| 3 | 0.00 (0.22) | 0.00 (-0.25) | 0.01 (0.54) | 0.01 (0.34) | 0.01 (0.81) | 0.00 (0.15) | 0.02 (0.86) | 0.03 (1.08) | 0.01 (0.57) | 0.03 (0.71) |
| 2 | 0.02 (1.37) | 0.00 (0.21) | -0.02 (-1.36) | 0.02 (1.06) | 0.02 (1.00) | -0.01 (-0.34) | -0.02 (-0.81) | -0.04* (-1.74) | -0.01 (-0.42) | 0.04 (1.00) |
| 1 (low) | 0.04** (2.43) | 0.03 (1.63) | 0.00 (0.19) | 0.01 (0.36) | -0.01 (-0.42) | -0.06*** (-2.80) | -0.07** (-2.51) | -0.07** (-2.43) | -0.01 (-0.34) | 0.02 (0.65) |

The table reports the buy-and-hold-abnormal-returns (BHAR) for decile portfolios. For this purpose, we first geometrically compound the unadjusted returns of the decile portfolio from months 1-12, 13-24, 25-36, 37-48, 49-60 and then subtract the geometrically compounded industry benchmark return over the same period.

t-statistics are in parentheses and are calculated as the mean BHAR of decile *i* divided by the corresponding standard error.

*, **, and *** denote statistical significance at 10%, 5%, and 1% levels, respectively.

Regarding the first time frame (Panel A of Table 5), the most highly ranked firms show a significant underperformance in year 1 and year 2 after portfolio formation from 3% and 4%, respectively, are close to zero after year 2 and subsequently become insignificant. The least highly ranked firms only have significantly high returns in year 1, but the returns decrease over time and become insignificant. The BHARs after the onset of the crisis (Panel B of Table 5) show the significant outperformance displayed by higher portfolio ranks, with returns between 3% and 5% and significantly lower returns for decile portfolio 1.

Both results of the Fama-French-Carhart four factor regression and the BHAR suggest that the stock market slowly learns about the value of vertical (dis-) integration, for example, because vertical integration starts to have an impact on other tangible metrics. Thus, Hypothesis 3 is confirmed.

Vertical integration and earnings surprise

Our results are consistent with previous research about supply chain related metrics like inventories (e.g. Alan et al. 2014) or research about intangibles like employee satisfaction (e.g. Edmans 2011) or customer satisfaction (e.g. Fornell et al. 2016) and their effects on stock returns. Due to the complex, non-straightforward and uncertain impact on financial performance, investors do not fully react to publicly available information about vertical integration either because they are not able to price its effect completely or because they pay little attention to it until it manifests itself in financial performance measures, such as earnings. In order to analyze the latter channel and to explain the results of the longevity analysis of abnormal returns shown in Table 4 and Table 5, we investigate whether the degree of vertical integration is related to earnings surprises. Table 6 presents the results.

Table 6: The effect of vertical integration on earnings surprises

| | VAS Rank | | | Continuous VAS | | |
|---------------------------------|----------------------|---------------------|----------------------|----------------------|---------------------|----------------------|
| | 1993-2015 | 1993-2006 | 2007-2015 | 1993-2015 | 1993-2006 | 2007-2015 |
| <i>Panel A: 1-year earnings</i> | | | | | | |
| VAS | 13.560*** (6.04) | 12.020*** (4.12) | 13.050*** (3.62) | 0.550*** (5.92) | 0.500*** (4.38) | 0.570*** (3.50) |
| Book-to-Market | 0.050 (0.11) | 0.870* (1.70) | -1.530** (-2.12) | 0.010 (0.01) | 0.880* (1.72) | -1.600** (-2.22) |
| Market Cap | -0.640*** (-4.22) | -0.410** (-2.10) | -1.000*** (-4.06) | -0.630*** (-4.18) | -0.410** (-2.09) | -0.990*** (-4.02) |
| N | 13,917 | 8,566 | 5,351 | 13,917 | 8,566 | 5,351 |
| <i>Panel B: 2-year earnings</i> | | | | | | |
| VAS | 39.480*** (7.41) | 20.370*** (3.02) | 51.870*** (6.04) | 1.620*** (7.25) | 0.920*** (3.50) | 2.470*** (6.35) |
| Book-to-Market | -1.380 (-1.39) | 2.660** (2.26) | -6.450*** (-3.74) | -1.500 (-1.52) | 2.750** (2.34) | -6.450*** (-3.75) |
| Market Cap | 1.330*** (3.67) | 1.710*** (3.81) | 0.770 (1.31) | 1.350*** (3.72) | 1.710*** (3.80) | 0.790 (1.35) |
| N | 13,028 | 7,328 | 5,700 | 13,028 | 7,328 | 5,700 |

Regressions of earnings surprises on either the portfolio rank of vertical integration or the continuous vertical integration (*VAS*) of the firm and control variables calculated at the most recent fiscal year-end. A 1-year (2-year) earnings surprise is the actual EPS minus the Institutional Brokers Estimate System (I/B/E/S) median analysis forecast 8 (20) months prior to the end of the forecast period scaled by the stock price. All regressions contain a constant and industry and year fixed-effects, which are not reported for the sake of brevity. All coefficients are multiplied by 1,000.

*, **, and *** denote statistical significance at 10%, 5%, and 1% levels, respectively. T-statistics are in parentheses

The effects of vertical integration (rank and continuous) are positive and significant over all sub-periods and in each panel (one- and two-year earnings surprises). This means that firms with a higher degree of vertical integration yield higher earnings than analysts expected. Thus, analysts underestimated the value of vertical integration with respect to a firm's financial performance. It is interesting to note that the effect of vertical integration and earnings surprises is also positive before the financial crisis. This might be one reason why we only observe a weak outperformance by the least highly ranked firms in the first time frame. The results further confirm Hypothesis 3, as the outperformance of more highly ranked portfolios can be explained up to a point by the unexpected manifestation in earnings and disappears as time goes by. The positive effect of vertical integration on earnings surprises suggests that the value of vertical integration dissipates slowly into the market because investors take account of the tangible outcomes of vertical integration (e.g. earnings) rather than information about vertical integration per se.

As a further robustness test, we investigate whether stock returns on earnings can explain the effect of vertical integration on stock returns by using the Fama-French-five-factor model (Fama and French 2015), which enables us to consider past financial performance in the model. The five-factor model extends the traditional three-factor model by a profitability factor (RMW, robust minus weak) and an investment factor (CMA, conservative minus aggressive). Profitability is measured as annual revenues minus cost of goods sold, interest expense, and selling, general, and administrative expenses, all divided by book equity at the end of fiscal year $t-1$. The profitability factor is the difference between the returns on diversified portfolios of stocks with robust and weak profitability. The investment factor is the difference between the returns on diversified portfolios of the stocks of low and high investment firms. If vertical integration has an effect through earnings, the excess returns (intercepts) of the Fama-French-Carhart four-factor model of Panel A of Table 3 should decrease or be eliminated. The results are shown in Table 7.

Table 7: Monthly abnormal returns over risk-free rate using the Fama-French Five-Factor Model (i.e. the intercept of the Fama-French Five Factor model)

| Portfolio rank | Panel A: 1993-2015 | Panel B: 1993-2007 | Panel C: 2007-2015 |
|----------------|-----------------------|-----------------------|-----------------------|
| 10 (high) | 0.14 | -0.20 | 0.57*** |
| 9 | 0.15 | -0.11 | 0.54*** |
| 8 | 0.05 | -0.24 | 0.46*** |
| 7 | 0.11 | -0.07 | 0.25 |
| 6 | 0.03 | -0.10 | 0.35** |
| 5 | 0.10 | -0.05 | 0.42** |
| 4 | -0.05 | -0.29* | 0.32** |
| 3 | 0.02 | -0.05 | 0.18 |
| 2 | -0.04 | -0.18 | 0.15 |
| 1 (low) | 0.14 | 0.35 | -0.27 |
| Zero-cost | -0.01 | -0.55*** | 0.84*** |

*, **, and *** denote statistical significance at 10%, 5%, and 1% levels

The formerly abnormal returns over the risk free rate for the period from 1993 through 2015 (Panel A) disappear as does the outperformance displayed by portfolio 1 between 1993 and 2007 (Panel B). The abnormal returns between 2007 and 2015 (Panel C) are lower than in the Fama-French-Carhart four-factor model. We conclude that earnings mitigate the effect of vertical integration on stock returns. This means that the degree of vertical integration is related to earnings.

As the longevity analysis has shown that the long-term stock returns disappear as time goes by and that the degree of vertical integration is positively related to earnings surprises, we conclude that the stock market learns about the value of the vertical integration level through unexpected earnings.

4.5 Further Analysis

Firm characteristics regression according to Fama and MacBeth (1973)

To account for the possibility that a correlation with a combination of firm characteristics other than size, book-to-market or momentum variables might influence the relationship between vertical integration and stock returns, we conduct cross-sectional regressions according to Fama and MacBeth (1973). This approach helps us to test whether vertical integration has predictive power, after controlling for a wider range of known drivers of stock returns (see Fama and French (2008); Edmans (2011) and Alan et al. (2014) for an overview of possible control variables). We run the following regression model:

$$R_{im} = \alpha_i + \beta_1 \cdot VAS_{im} + \beta_2 \cdot \mathbf{Z}_{im} + \varepsilon_{im}, \quad (5)$$

where R_{im} is the excess return enjoyed by firm i in month m on its vertical integration (either the portfolio rank or the continuous value) and a vector of firm characteristics from the previous fiscal year, which are described below. The degree of vertical integration or the portfolio rank with respect to the degree of vertical integration (VAS) and the controls are held constant from July in year t through the June in year $t + 1$. This framework is consistent with our portfolio formation procedure. After obtaining regression coefficients for each independent variable in each month, we calculate the time-series averages of these regression coefficients and use their time-series standard errors to compute t -statistics.

Our controls are as follows: $Ret(m - 1)$ is the most recent one-month return. $Ret(m - 12)$ is the cumulative stock return from month $m - 12$ to month $m - 2$, skipping the most recent month. *Accruals* are measured as income before extraordinary items minus operating cash-flow and minus extraordinary items, scaled by total assets of the previous fiscal year. *Market Cap* is the natural logarithm of firm i 's market capitalization and serves as a proxy for size. *Book-to-Market* is the log of firm i 's book-to-market ratio. *Operating Leverage* is measured by net fixed assets scaled by previous fiscal year total assets. *Abnormal Capex* is defined as the capital expenditures (scaled by sales) undertaken in the current fiscal year divided by the mean capital expenditures (scaled by sales) undertaken in the last three fiscal years. *Asset Growth* is the change in the natural logarithm of total assets from year $t - 1$ to $t - 2$. *Profitability* is net income divided by the book value of equity in the previous fiscal year.

Panel A in Table 8 reports the results of the Fama and MacBeth (1973) regression for the portfolio rank with respect to the degree of vertical integration while Panel B contains the results for the continuous degree of vertical integration.

Table 8: Fama and MacBeth (1973) Cross-Sectional Regression Results

| Variable | Panel A: VAS rank | | | Panel B: Continuous VAS | | |
|--------------------|----------------------|----------------------|----------------------|-------------------------|----------------------|----------------------|
| | 1995-2015 | 1995-2007 | 2007-2015 | 1995-2015 | 1995-2007 | 2007-2015 |
| VAS | 0.026* (1.82) | -0.020 (-1.12) | 0.096*** (4.61) | 0.249 (0.74) | -0.648 (-1.41) | 1.596*** (3.52) |
| Ret(m-1) | -4.283*** (-6.91) | -4.645*** (-5.57) | -3.741*** (-4.11) | -4.264*** (-6.90) | -4.612*** (-5.55) | -3.742*** (-4.11) |
| Ret(m-12) | 16.835*** (4.65) | 19.194*** (4.55) | 13.297** (2.07) | 17.030*** (4.71) | 19.179*** (4.54) | 13.806** (2.14) |
| Accruals | -2.443*** (-4.80) | -1.985*** (-2.94) | -3.131*** (-4.08) | -2.420*** (-4.79) | -2.005*** (-2.97) | -3.042*** (-4.04) |
| Market Cap | 0.003 (0.07) | -0.012 (-0.23) | 0.024 (0.44) | 0.005 (0.13) | -0.011 (-0.22) | 0.029 (0.54) |
| Book-to-Market | 0.262*** (3.63) | 0.325*** (3.40) | 0.167 (1.53) | 0.259*** (3.55) | 0.323*** (3.36) | 0.164 (1.47) |
| Operating Leverage | -0.618*** (-3.20) | -0.335 (-1.22) | -1.043*** (-4.20) | -0.555*** (-2.87) | -0.339 (-1.23) | -0.879*** (-3.56) |
| Abnormal Capex | -0.080** (-1.98) | -0.075 (-1.25) | -0.088* (-1.89) | -0.082** (-2.04) | -0.077 (-1.30) | -0.089* (-1.91) |
| Asset Growth | -0.287 (-1.37) | -0.229 (-0.80) | -0.376 (-1.25) | -0.297 (-1.42) | -0.247 (-0.87) | -0.372 (-1.23) |
| Profitability | 0.127 (0.98) | 0.108 (0.74) | 0.154 (0.65) | 0.152 (1.18) | 0.135 (0.93) | 0.178 (0.75) |

We regress individual monthly excess stock returns (stock return minus the risk-free rate) on the variables shown above. The coefficients are the time-series averages of the cross-sectional coefficients for each month and are multiplied by 100. $Ret(m-1)$ is the most recent one-month return. $Ret(m-12)$ is the cumulative stock return from month $m-12$ to month $m-2$, skipping the most recent month. t -statistics are in parentheses and are based on the time-series standard errors for the monthly slopes. As there are no figures available for accruals before 1993, we start our analysis in July 1995. The control variables were then taken from the fiscal year 1994.

*, **, and *** denote statistical significance at 10%, 5%, and 1% levels, respectively.

Regarding Panel A, our results show that the portfolio rank is positively related to excess stock returns over the whole time frame (1995-2015). We do not observe a significant relationship between the degree of vertical integration and excess stock return during the pre-crisis period, but we do observe a significantly positive relationship after the financial crisis (2007-2015). Thus, the post-crisis results drive the results for the whole time frame. Regarding the continuous degree of vertical integration (Panel B of Table 8), we only find a significant relationship in the post-crisis period.

In summary, this analysis shows that the excess stock returns yielded by the least highly vertically integrated firms (decile 1) are subsumed (Panel B of Table 8) by other firm characteristics (past return, accruals, market capitalization, book-to-market ratio, abnormal capital expenditures, asset growth and profitability) that are

well-known to explain excess stock returns. However, the post-crisis excess returns cannot be explained by other firm characteristics that related to stock returns. This observation is in line with the results yielded by the end value analysis and the Fama-French-Carhart four factor regression, as the relationship between vertical integration and abnormal stock returns was much weaker for the first sub-period.

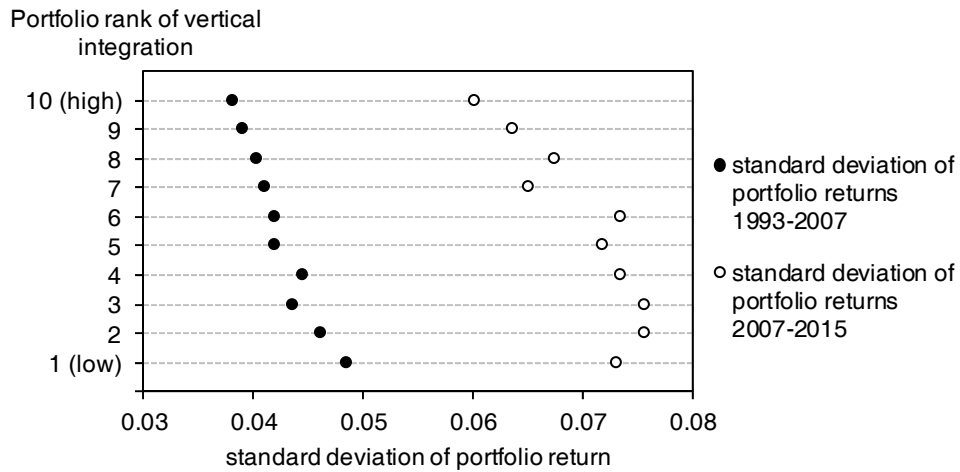
Vertical integration, stock returns and business cycles

Our results so far have shown significant positive long-term abnormal returns for the least highly ranked portfolio of vertical integration before the onset of the recent financial crisis and significant positive long-term abnormal returns for more highly ranked portfolios after the onset of the financial crisis. Therefore, the recent financial crisis has been a meta event (Konchitchki and O'Leary 2011) that is independent of individual firms and may have changed the overall stock market's perceptions.

A closer look at the portfolio returns in Figure 4 suggests that the stock returns generated by less highly vertically integrated firms seem to be more sensitive to economic downturns and upswings. Figure 4 already indicates that less highly ranked firms have lower returns during economic and stock market downturns like the dotcom crisis or the recent financial crisis. This observation is supported by the Fama-French-Carhart four-factor model presented in Table 3. The results show that the coefficient of the market factor (β -factor) is higher for less highly ranked firms, suggesting that firms with a lower degree of vertical integration are characterized by higher systematic risk.

In contrast, low vertical integration portfolios generate higher returns during periods of economic upswings before the financial crisis (1990s, 2003 to 2007). In order to analyze the volatility of portfolio returns, we compute their standard deviation. Figure 7 shows that the standard deviation is higher (lower) for low (high) ranking firms over the two sub-periods of our sample period. This result indicates that stock market risk increases when the degree of vertical integration decreases in general.

Figure 7: Standard deviation of portfolio returns



Based on this observation and because market conditions in general could affect investors' trading behavior (Gervais and Odean 2001; Glaser and Weber 2009), we further test to see whether the results are related to business cycles. We follow Bhardwaj and Brooks (1993) and Kim and Burnie (2002) to determine bull and bear market cycles. A month is defined as bull (bear) if the market return (Fama/French market factor) in that month is higher (or lower) than the median market return over the entire period. Table 9 reports portfolio end values for bull (Panel A) and bear market cycles (Panel B) generated by the method described above.

Table 9: Portfolio end values for bull and bear market cycles

| Portfolio rank of vertical integration | end-value of a US\$1 investment | |
|--|---------------------------------|--------------------------|
| | Panel A: bullish periods | Panel B: bearish periods |
| 10 (high) | 177.90*** | 0.06*** |
| 9 | 207.61*** | 0.06*** |
| 8 | 243.14* | 0.05** |
| 7 | 245.18* | 0.05** |
| 6 | 309.15 | 0.04 |
| 5 | 373.17 | 0.05 |
| 4 | 365.09 | 0.03* |
| 3 | 357.34 | 0.03*** |
| 2 | 452.14*** | 0.02*** |
| 1 (low) | 546.51*** | 0.02*** |

Note: To determine the significance of portfolio end values of portfolio i , we compute the empirical p value as $\min(n_i; 100,000) / (2 \cdot 100,000)$, where n_i is the number of random portfolios with higher end values than portfolio i .

A month is defined as bull (bear) if the market return (Fama/French market factor) in that month is higher (lower) than the median market return over the entire period.

*, **, and *** denote statistical significance at 10%, 5%, and 1% levels.

Portfolio 1 and portfolio 2 are more sensitive to market-wide risks as they produce the highest end value during bullish periods (546.51 and 452.14 respectively) and the lowest end value during bearish market cycles (both 0.02). However, the opposite picture emerges for the more highly ranked portfolios 7-10. Their returns are significantly lower during bullish periods (end values of 245.18, 243.14, 207.61, and 177.90) but they were able to withstand bearish periods (end values of 0.05 and 0.06) better than other portfolios, which suggests that they display less sensitivity to market-wide movements. As firms with higher business risks are more affected by recessions than firms with lower business risks, we conclude that lower vertical integration increases business risk.

In summary, the analysis of stock returns for portfolios based on the degree of vertical integration during bullish and bearish periods shows that a low degree of vertical integration could be beneficial in economic upswings and value destroying during economic downturns. In contrast, a high degree of vertical integration could be value protecting during economic downturns but less beneficial in upswings. Thus, the relationship between the degree of vertical integration and long-term stock returns could be transferred from the meta-event of a financial crisis to economic conditions in general. Furthermore, this result suggests that the degree of vertical integration could indeed be interpreted as a risk factor.

5. Discussion

Theoretical implications

We have presented empirical support for a changing capital market's attitude on a strategic shift with respect to the degree of vertical integration during the recent financial crisis. Our results contribute to the vertical integration and supply chain management literature in several ways.

First, with respect to the first research question, we deepen the insights from previous studies that investigate the relationship between vertical integration and short-term stock returns and show that the degree of vertical integration is related to abnormal long-term stock returns as well. The significant relation to abnormal long-term stock returns suggests that investors may have difficulties in determining the

value of the degree of vertical integration in the short-run. This is consistent with findings of prior studies that investigate stock market's reaction to vertical integration in the short-run, as their results so far have been inconclusive, i.e. some find a positive relationship (e.g. Lubatkin 1987; Hendricks et al. 2009), while others find a negative relationship (e.g. Raassens et al. 2014). The existence of abnormal long-term stock returns shows that investors correct their initial perception over time. Therefore, our results indicate the existence of stock market inefficiency (Kothari and Warner 2007) as investors fail to completely incorporate information about the degree of vertical integration immediately (Fama 1970). The inefficiency occurs because the relationship between the degree of vertical integration and firm performance is a rather complex issue due to ambiguous theoretical predictions, which result in complex and non-straightforward performance outcomes (e.g. Otto and Obermaier 2009). Difficulties in determining the value of vertical integration arise from its effect on operational performance, intangible assets and financial performance. These are a lot of variables related to supply chain risk which have to be captured by investors when pricing the value of vertical integration. Thus, investors may not be able to price such information completely without additional information that only becomes available as time goes by (so called "lack of information" hypothesis (Edmans 2011)). Our analysis of the longevity of long-term abnormal stock returns confirms this hypothesis, as the long-term abnormal returns disappear after two or three years. Thus, the results indicate that the degree of vertical integration contributes to explain value creation logic, especially during and after events which affect environmental and supply chain uncertainty.

Second, we provide the first study that investigates the impact of the recent financial crisis on the relationship between vertical integration and stock returns, and we show that the capital market's attitude to the degree of vertical integration changed after the onset of the recent financial crisis. The least highly (most highly) integrated firms yielded the highest (lowest) stock returns before the financial crisis while high (low) integrated firms yielded the highest (lowest) stock returns since the financial crisis. Both abnormal long-term stock returns of lowest vertically integrated firms in the pre-crisis period and of higher integrated firms in post-crisis period, indicate that investors adjusted their initial (i.e. short-term) value assessment of the

degree of vertical integration upwards over time. The change of investors' perception during the financial crisis can be explained by the increased uncertainty caused by the crisis, which affects low vertically integrated firms more than high integrated firms (Hendricks et al. 2009; Hoberg and Aliche 2013). Investors may have recognized the benefits of a high degree of vertical integration during times of crisis and have changed their perceptions.

However, results for the pre-crisis period suggest a discrepancy between (expected) financial performance (measured by earnings surprises) and stock market performance. The effect on earnings surprises is higher for higher ranked firms over the whole time frame and in each sub-period (i.e. even before the financial crisis) which contradicts the abnormal returns of the least highly ranked portfolios and the lowest portfolio end values of firms with the most highly degree of vertical integration. Given the above findings, it might be the case that the stock market erroneously believes that the least highly vertically integrated firms are the most valuable, whereas the most highly integrated firms have the lowest value and that it therefore reacts irrationally to the extreme values of vertical integration levels. As mentioned earlier, the outperformance displayed by the least highly ranked portfolios was mainly driven by outperformance during the 1990s. Interestingly, this was the time when vertical disintegration started to progress towards becoming a management paradigm and when it was extensively propagated by lean management gurus (Lonsdale and Cox 2000). Investors might have erroneously expected performance improvements for firms with the lowest degree of vertical integration, even though these firms do not show such improvements on average. However, there are certainly less highly integrated firms that have been successful in the past and could serve as best practices. But the generalizability of such best practices cannot be assumed per se and irrational speculation may be feeding these results. Finance literature has long recognized that stock price movements may also be influenced by factors unrelated to fundamental value (i.e. the present value of future cash-flows), such as irrational speculation (e.g. Roll 1988). Such irrational speculation may be the result of fashions and fads that can influence investors' perceptions (Lee 2001). For instance, Cabral et al. (2014) show that firms have often outsourced activities because "everybody was

outsourcing” (p. 368) and because “outsourcing was a fever” (p. 369) without considering the peculiarities of their own business environment.

Third, we contribute to literature by showing that a high degree of vertical integration mitigates the negative impact of an overall economic downturn. Thus, our study contributes to supply chain risk theory (see Ho et al. (2015) for an overview) by showing that a higher degree of vertical integration is a kind of risk buffer. Prior research has shown that greater vertical integration decreases the probability of a firm’s experiencing supply chain disruptions (Blackhurst et al. 2005; Hendricks et al. 2009) and consequently reduces supply chain risks, which in particular occur during economic downturns such as the recent financial crisis, because it makes the firm less dependent on other organizations (Norrman and Jansson 2004). Obviously, a lower degree of vertical integration may cause more supply chain disruptions because those firms are more dependent on suppliers. One of the main motives for firms to improve their supply chain risk management was the high number of supplier bankruptcies during the financial crisis (Hoberg and Alicke 2013). The bankruptcy of one or more suppliers may cause severe damage on business operations due to supply bottlenecks. Especially, Blome and Schoenherr (2011) find out that supply chain risk management was further emphasized by the financial crisis.

This might be one reason why insourcing, and, consequently, a greater degree of vertical integration have been identified as one response to external trigger events such as crises or natural disasters (Drauz 2014; Hartman et al. 2017). The above interpretation is in line with descriptive statistics (Figure 2) that the overall degree of vertical integration had decreased until the onset of the recent financial crisis, but that it had increased afterwards. As we have shown above, greater vertical integration could serve as a kind of risk buffer (often denoted as “operational slack” (e.g. Hendricks et al. 2009) during a financial crisis (or economic downturns in general), as more highly ranked firms lost only 37% of their initial stock value from June 2007 to June 2009 whereas other portfolios lost 48% on average. The consequences of supply chain disruptions during and after the financial crisis may have persisted for several years in these firms leading to outperformance (underperformance) of higher (lower) ranked portfolios after the crisis.

Managerial implications

Previous research has shown that managers are often not satisfied with the performance outcomes of vertical integration decisions (Deloitte 2005; Drauz 2014; Rigby and Bilodeau 2015; Hartman et al. 2017). Our results provide some interesting managerial implications that could help managers to foster understanding of the relationship between the degree of vertical integration and firm performance.

First, our study could help managers to understand that strategic supply chain structure decisions, such as determining the degree of vertical integration, affect long-term stock returns. We address vertical integration as an important factor of explaining abnormal long-term stock returns. Thus, managers should take into account this relationship when determining a firm's strategy. Furthermore, managers should communicate and explain the structure of a firm's supply chain and especially the degree of vertical integration to investors. Thus, investors could incorporate this information into their investment decisions. However, given the complex and non-straightforward performance outcomes, determining the degree of vertical integration is not a trivial decision for managers. Furthermore, because vertical integration strategies have been subject to shifting fashions, managers need to know the effects of low and high vertical integration levels on financial and stock market performance under varying environmental conditions. During times of low uncertainty, a low degree of vertical integration may indeed be beneficial to stock returns. In contrast, during times of crisis and economic downturns, a higher degree of vertical integration serves as a risk buffer against performance declines.

Second, managers should therefore not believe the management paradigm of vertical disintegration per se. The trend towards vertical disintegration during the 1990s is somewhat confusing compared to our results. Although the portfolio consisting of firms with the lowest degree of vertical integration outperformed until the financial crisis, and especially during the 1990s, we cannot explain this result with a link to fundamental firm value (i.e. the present value of discounted future cash-flows). The analysis of earnings surprises indicates that a greater degree of vertical integration was beneficial to earnings during the whole time frame investigated. Thus, a lower degree of vertical integration was not beneficial to financial performance. Nevertheless, the stock market rewards less highly integrated firms with higher stock

returns which we partly explain with irrational speculation. However, we argue that a low degree of vertical integration might be beneficial under specific circumstances. This might be the case when managers clearly distinguish between core and non-core competencies and when they consider the hidden costs of vertical disintegration (Hendry 1995). Thus, managers have to well think out strategic supply chain structure decisions.

Limitations and avenues for further research

Despite the importance of our findings, there are certain limitations, which offer future research directions. Although we provide interesting results for the European manufacturing sector in general, a detailed analysis of different countries could be interesting. Our descriptive statistics reveal that the degree of vertical integration differs across countries. Future research could address these issues by analyzing the relationship between vertical integration and long-term stock returns for different countries. Moreover, future research could investigate the research questions based on a sample of US firms, as the majority of prior studies concentrate on US firms (Lahiri 2016).

Second, our analysis links the degree of vertical integration directly to stock returns. However, our research framework has shown that the linkage between the degree of vertical integration and stock returns is rather complex. The degree of vertical integration affects operational performance, intangible assets and financial performance, before affecting stock returns. Thus, our study analyzes in fact a very important relationship, but does not measure empirically the whole causal logic between vertical integration and stock returns. Future research can address this issue by using more appropriate methods to investigate the whole causal logic.

6. Conclusion

Our results show that the recent financial crisis has changed the capital market's attitude on the relationship between the degree of vertical integration and stock returns. We find that firms with the lowest degree of vertical integration yielded abnormal long-term stock returns before the crisis, whereas firms with a higher

degree of vertical integration have performed best since the crisis, indicating that a more dynamic environment and higher uncertainty have a significant impact on the relationship between vertical integration and long-term stock returns. Our results are robust to a variety of commonly known risk factors such as size, value or momentum, i.e. abnormal returns cannot be explained by the Fama-French-Carhart four-factor model (Fama and French 1993; Carhart 1997). Even after controlling for a wider range of known firm characteristics as drivers of stock returns, the results remain stable. A longevity analysis of excess returns shows that the excess returns disappear after a few periods, indicating that investors either learn about the degree of vertical integration or that vertical integration starts to have an impact on other tangible metrics.

In sum, shareholders rewarded the least highly vertically integrated firms in the 1990s. However, since 2007 they have rewarded firms with a greater degree of vertical integration. Strategically, our analysis emphasizes the importance of strategic supply chain structure decisions under different environmental circumstances. In the light of the lessons learned about the value-protecting strategy during and after the financial crisis, these results highlight the importance of taking a dynamic view on decisions about the degree of vertical integration.

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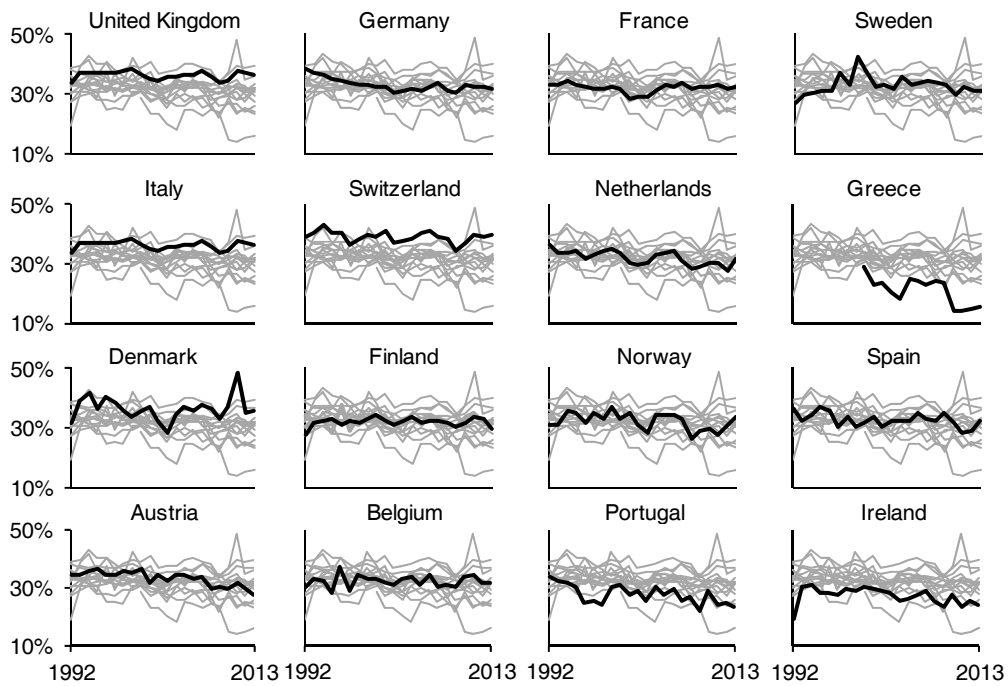
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Appendix

Appendix 1: Sample distribution across industries

| SIC | Number of firms | Min | Max | Median | Mean | SD |
|-------|-----------------|-------|-------|--------|-------|-------|
| 35 | 391 | 0.007 | 0.961 | 0.358 | 0.357 | 0.122 |
| 36 | 336 | 0.002 | 0.949 | 0.345 | 0.349 | 0.139 |
| 28 | 328 | 0.000 | 0.992 | 0.331 | 0.337 | 0.141 |
| 20 | 280 | 0.011 | 0.946 | 0.248 | 0.262 | 0.115 |
| 38 | 229 | 0.020 | 0.872 | 0.433 | 0.423 | 0.123 |
| 39 | 185 | 0.009 | 0.914 | 0.315 | 0.324 | 0.123 |
| 23 | 155 | 0.000 | 0.960 | 0.297 | 0.305 | 0.105 |
| 37 | 154 | 0.002 | 0.824 | 0.312 | 0.321 | 0.113 |
| 27 | 142 | 0.019 | 0.983 | 0.422 | 0.424 | 0.145 |
| 32 | 142 | 0.048 | 0.736 | 0.364 | 0.374 | 0.097 |
| 34 | 131 | 0.004 | 0.960 | 0.364 | 0.369 | 0.108 |
| 33 | 116 | 0.005 | 0.876 | 0.270 | 0.277 | 0.128 |
| 26 | 111 | 0.012 | 0.950 | 0.291 | 0.287 | 0.098 |
| 30 | 87 | 0.014 | 0.990 | 0.330 | 0.329 | 0.116 |
| Total | 2,787 | 0.000 | 0.992 | 0.333 | 0.339 | 0.131 |

Appendix 2: Time trend of vertical integration for the underlying sample of this study



Note: This figure shows the degree of vertical integration in the manufacturing sector over time for the countries in our sample. The degree of vertical integration in each year is calculated as the median of the value-added to sales ratio across all firms in our sample. The horizontal axes show the year and the vertical axes the degree of vertical integration. The median degree of vertical integration for the country of interest is indicated with a black line. Gray lines show the median degree of vertical integration of all other countries in the sample.

Inventory and Firm Performance: A Material and Financial View of an Interdependent Relationship

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Abstract

The relationship between inventory efficiency and firm performance has spawned a rich body of literature over the last two decades. However, previous research has only partially considered the causal (dynamic) relationship between inventory efficiency and firm performance. To close this research gap, this study investigates empirically the causal logic underlying the relationship between inventory efficiency and firm performance. The data set consists of 332 German manufacturing firms with 3,028 firm-year observations and is based on annual financial data from 1990 to 2016. We use a panel vector autoregressive (PVAR) model, followed by impulse response functions and forecast error variance decompositions, to analyze the dynamic relationship between, on the one hand, the efficiency with which raw materials, work-in-process and finished goods are managed and, on the other hand, firm performance. We find interdependencies both among inventory types themselves and among inventory types and firm performance. Thus, the analysis demonstrates that there is an interdependent relationship between inventory holding and firm performance, which indicates that the inventory-performance link is much more complex than it has been typically assumed.

Keywords: inventory efficiency, inventory types, firm performance, panel vector autoregressive model, Granger causality

1. Introduction

The relationship between inventory holding and firms' financial performance has continued to draw interest from practitioners and scholars alike throughout the last decade, although many empirical studies have investigated the relationship between inventory management and firm performance (e.g. Chen et al. 2005; Cannon 2008; Capkun et al. 2009; Eroglu and Hofer 2011b; Bendig et al. 2018). The theoretical benefits of high inventory efficiency (e.g. lower costs, higher liquidity) are well-established (Modi and Mishra 2011). Thanks to these benefits, prior research finds that firms in major economies like the US or Germany have reduced their inventories throughout the past decades (e.g. Chen et al. 2005; Gaur et al. 2005; Obermaier 2012). However, unduly low inventory levels may cause severe supply chain disruptions (Hendricks and Singhal 2003). Thus, inventories are not bad per se. On the one hand, firms have an incentive to reduce their inventories, and consequently the capital employed. On the other hand inventories contribute significantly to ensuring that the production process runs smoothly and, in addition, allow firms to respond flexibly to changing supply and demand situations. Thus, the trade-off between lower and higher inventory efficiency is a key challenge in operations management (Eroglu and Hofer 2011b), because mismanagement of inventories may result either in a key part being out-of-stock or in a firm holding excess inventories (Hendricks et al. 2009). Regardless of the positive or negative performance outcomes of inventory efficiency, the majority of existing studies assume that inventory efficiency drives firm financial performance. This direction of causality¹ can be interpreted as the material view on the relationship between inventory efficiency and firm performance.

The financial view of the relationship between inventory efficiency and firm performance, i.e. that a firm's financial performance drives inventory efficiency, is plausible as well, but has rarely been investigated (e.g. Rumyantsev and Netessine 2007; Swamidass 2007; Obermaier and Donhauser 2012; Hoberg et al. 2017b).

¹ The terms "causality" or "causal" in this paper are based on the definition used by Granger (1969). Causality in this sense does not mean true causality in a deep sense of the word. Instead, causality refers to the time series nature of the data and measures intertemporal interactions among variables, i.e. Granger causality measures precedence and information content but does not in itself indicate causality in the more common use of the term.

Furthermore, the few studies which have investigated the impact exerted by financial performance on inventory holding, examined this relationship under extreme situations like recessions (Carpenter et al. 1994; Duchin et al. 2010), or individual financial distress periods (Steinker et al. 2016). Under these extreme situations, the reductions of inventories may be a suitable way to free up cash and to boost short-term liquidity.

The aforementioned arguments suggest that both directions of causality should be considered when we look at the inventory-performance link, resulting in complex feedback loops between inventory efficiency and firm performance. While many studies have analyzed either the impact of inventory efficiency on firm performance, and a few studies have analyzed the impact of firm performance on inventory efficiency, empirical knowledge on the interdependent (i.e. dynamic) relationship is scarce. Hoberg et al. (2017, p. 530) conclude that the “[...] effect of inventory holdings on financial performance is well documented, but the reverse relationship is largely unexplored.” In addition, most studies employ simplistic and correlational, rather than causal models. Moreover, the majority of previous studies only investigate the relationship between overall inventory and financial performance, even though recent literature has shown that the relationship between individual inventory components (i.e. raw materials, work-in-process and finished goods) and financial performance substantially differ (e.g. Eroglu and Hofer 2011a). Considering the limited empirical evidence on the dynamic relationship between inventory efficiency and firms’ financial performance, this study aims to answer the following research question:

Is there an interdependent relationship between, on the one hand, the efficiency with which raw materials, work-in-process and finished goods inventories are managed and, on the other, a firm’s financial performance?

One methodological challenge that arises from this simultaneous causality is an endogeneity problem, which has rarely been considered when the inventory-performance link has been investigated (e.g. Isaksson and Seifert 2014; Kroes et al. 2018). However, the problem of endogeneity has to be considered in operations

management research (Ketokivi and Mcintosh 2017), because endogeneity represents a violation of important statistical assumptions and leads to bias in parameter inference. To promote an understanding of the dynamic relationship between inventory efficiency and firm performance, we conduct an empirical study based on a sample of 332 German manufacturing firms from 1990 to 2016. We apply a panel vector autoregressive (PVAR) model (e.g. Love and Zicchino 2006) in order to control for endogeneity, simultaneous causality and complex feedback loops between, on the one hand, the efficiency with which raw materials, work-in-process and finished goods inventories are managed and, on the other, financial performance. Furthermore, we apply impulse-response functions and forecast error variance decompositions to obtain further insights into the inventory-performance link.

Findings from our study suggest that there are bidirectional relationships between inventory efficiency and firm performance. In particular, raw materials efficiency and finished goods efficiency are positively related to firm performance whereas the impact of work-in-process is not significant. Furthermore, the impact of finished goods efficiency is both stronger and more enduring. The impact of firm performance on inventory efficiency is strongest and more enduring for raw materials in the long-run than for work-in-process. The impact of firm performance on finished goods efficiency is not significant. Besides our main analysis, we find interdependent interactions among inventory types themselves. Thus, inventory components not only have direct effects on firm performance, but also indirect effects, as well.

Our study contributes to operations management research in four ways. First, we show that the inventory-performance link is more complex than it has been typically assumed. Second, our analysis sheds more light on the importance of investigating individual inventory components, rather than just total inventory. Third, our method allows us to investigate the longevity of the impact exerted by inventory efficiency on firm performance and that exerted by firm performance on inventory efficiency. Finally, we show that there are significant dynamic interactions among the inventory components themselves.

The remainder of this paper is structured as follows. In the next section, we develop our research hypotheses. Section 3 describes the data set, defining the relevant variables and the estimation method. In Section 4, we present the results of

the empirical analysis. Their implications, limitations and avenues for further research are discussed in Section 5. We conclude with a brief summary of our key findings in Section 6.

2. Theory and Hypotheses

2.1 Effects of Inventory Management on Firm Performance

There is a vast body of theoretical (and empirical) literature that investigates the link between inventory management and financial performance (see Eroglu and Hofer 2011b for an overview). However, previous studies largely concentrate on the impact of inventories on firm performance without taking any potential effects of firm performance on inventories into account. As the literature still reveals a large gap in this research area, the focus of this study lies on the question of interdependent interactions between inventory efficiency and firm performance.

Several arguments justify the idea that inventory holdings may be a driver of firm performance. That said, the relationship between inventory performance and financial performance is inconclusive in empirical literature (Isaksson and Seifert 2014). Furthermore, theoretical arguments on the impact of inventory holding on firm performance are conflicting. Under lean production principles, inventory is seen as a costly waste that needs to be eliminated in order to boost performance (Schonberger 1982; Womack et al. 1990). The analogy of high water (inventory) levels hiding rocks (unsolved operational problems) is often used in this context. However, the pursuit of an extreme, zero-inventory policy (Hall 1983) is widely considered to be a mistake (Hopp and Spearman 1996). Firms implement techniques such as “Just-In-Time” in order to keep up with competitors, improve their results and satisfy their customers (Demeter and Matyusz 2011). Furthermore, researchers agree that inventories are a significant cost driver (Carpenter et al. 1994). High inventory levels are usually associated with higher inventory holding costs, which should be minimized. Among other things, the latter comprise storage costs, insurance, taxes, spoilage, losses and interest (Koumanakos 2008; Hendricks et al. 2009). Greater inventory efficiency (lower inventory levels) also reduces the likelihood of inventory

having to be written off (Hendricks et al. 2009; Modi and Mishra 2011). Furthermore, lower inventories lead, all else being equal, to reduced capital requirements and – a notion supported by the classical DuPont system – should improve financial performance, as measured by ratios such as return on assets. Besides, lower inventories release capital that could be utilized more efficiently for research and development or to make production techniques more efficient.

Supporting these arguments, previous literature often finds a negative relationship between inventory levels and firm performance (e.g. Lieberman and Demeester 1999; Vastag and Whybark 2005; Shah and Shin 2007; Capkun et al. 2009; Hendricks et al. 2009; Eroglu and Hofer 2011b; Modi and Mishra 2011; Alan et al. 2014; Isaksson and Seifert 2014; Kroes et al. 2018) although a number of other studies find little or no relationship between inventory efficiency and firm performance (Cannon 2008; Obermaier and Donhauser 2009). In fact, one study even finds that higher inventories are beneficial to firm performance (Obermaier and Donhauser 2012). Eroglu and Hofer (2011b) was one of the first studies that empirically investigated an inverted U-shaped relationship between inventory leanness and firm performance, as a reaction to the mixed results of previous research. Eroglu and Hofer (2011a) and Eroglu and Hofer (2011b) conclude that there is an optimal level of inventory leanness at which performance is maximized. However, their results are only partly confirmed by Isaksson and Seifert (2014), as the latter find a positive, but diminishing relationship between inventory leanness and financial performance. Analyzing a curvilinear functional form of the inventory-performance link has mainly been justified by pointing out to the trade-offs between lower and higher inventory levels.

Although bulk of previous literature concentrates on positive performance effects through lower inventories, higher inventories do have benefits as well. High inventory holding is often a way to compensate for sloppy and inefficient management, poor forecasting and inadequate attention to efficiently organized processes (Koumanakos 2008). The buffer stock concept sees inventories as a necessary buffer to smooth production levels (e.g. Silver 1981). Furthermore, higher inventory levels are supposed to lead to better levels of service, increase customer satisfaction and reduce the likelihood of stockouts. As Hendricks and Singhal (2005)

show, supply chain glitches (associated with poor inventory performance) have an adverse impact on a firm's reputation and consequently on firm performance. Higher levels of operational slack, especially in the form of inventory slack, reduce the negative impact of supply chain disruption on stock prices (Hendricks et al. 2009). In addition, higher inventories may increase firm performance by offering higher product variety (van Ryzin and Mahajan 1999). In sum, the direction of the impact exerted by inventory efficiency on firm performance cannot be determined a priori. It depends on the relative magnitude of the predicted positive and negative performance implications exercised by inventory levels.

The aforementioned arguments for either lower or higher inventories being beneficial for firm performance could be applied to all types of inventory, i.e. raw materials, work-in-process and finished goods. Although previous research has shown that the performance outcomes of each inventory type could be quite different (Eroglu and Hofer 2011a), only a few studies have investigated the relationship between inventory types and firm performance separately (e.g. Capkun et al. 2009; Eroglu and Hofer 2011a, 2011b; Isaksson and Seifert 2014). Regardless of whether the efficiency with which raw materials, work-in-process and finished goods inventories are managed is assumed to have a positive or negative impact on financial performance, we posit the following:

Hypothesis 1: The efficiency with which raw materials, work-in-process and finished goods inventories are managed drives financial performance.

The impact of the discrete inventory components on firms' financial performance should differ for several reasons. First, their unit values differ substantially. In particular, work-in-process and finished goods include value added from the manufacturing or conversion process (Heizer et al. 2017). Second, finished goods are more directly related to customer service, market share or other value chain activities (Eroglu and Hofer 2011a). On this basis, finished goods efficiency is expected to have the strongest impact on firm performance. We therefore posit the following:

Hypothesis 1a: The impact of inventory efficiency on firms' financial performance is strongest for finished goods, followed by work-in-process and raw materials efficiency.

Furthermore, the bulk of empirical literature solely examines cross-sectional patterns between inventory and firm performance using regression models without taking into account the long-term effects of inventory decisions on firm performance.² Besides our main analysis of interdependent interactions between inventory holdings and firm performance, we are also interested in the long-term effects of inventory efficiency on firm performance. On the basis of the expected varying performance impact of different inventory components (effect of finished goods > effect of work-in-process > effect of raw materials), we hypothesize that the longevity of performance outcomes will substantially vary across these components. Therefore, we hypothesize:

Hypothesis 1b: The impact of inventory efficiency on firm financial performance is most enduring for finished goods, followed by work-in-process and raw materials efficiency.

2.2 Reverse Causality: Effects of Firm Performance on Inventory Holding

As shown above, previous empirical studies show a mixed picture with regard to the inventory-performance link. One possible explanation for these findings might be the dynamic interactions between inventory management and a firm's financial performance. Isaksson and Seifert (2014) conclude in their study that inventory management and firm performance are endogenous. A closer look at the inventory-performance-link literature reinforces this argument, as some studies use performance measures as independent variables or controls when analyzing the determinants of inventory levels (e.g. Gaur et al. 2005; Rumyantsev and Netessine 2007; Tribó 2009). Like Isaksson and Seifert (2014), some studies partially address this question of causality. The study closest to our research question is that done by Sridhar et al.

² A few exceptions are studies that investigate the impact of inventories on long-term stock returns (Chen et al. 2005, Chen et al. 2007, Alan et al. 2014)

(2014). The authors use vector autoregressive models to investigate the dynamic relationships between R&D, advertising, inventory and firm performance. They find a positive and significant long-term impact exerted by inventory holding on sales and a not significant impact exercised by inventory holding on firm value (measured by Tobin's Q). Furthermore, results show that an increase in sales leads to a significant positive impact on inventory holding. An increase in firm value leads to a significant negative impact on inventory holding. In a short post-hoc analysis, Kroes and Manikas (2014) and Kroes et al. (2018) investigate Granger causality between inventories and firm performance. They look at whether lagged values in the measures of inventory changes may help to explain changes in firm performance. Kroes and Manikas (2014) find that lagged values in the days-inventory-outstanding are significantly related to firm performance (measured with Tobin's q) in the current period and vice-versa. Interestingly, Kroes et al. (2018) do not find that inventories are affected by lagged performance when performance is measured by abnormal stock returns. However, the aforementioned studies have some limitations. None of the studies investigate interdependent relationships between different types of inventory, either among each other or between inventory types and firm performance. Furthermore, Kroes and Manikas (2014) and Kroes et al. (2018) investigate the causal relationship (in a post-hoc analysis) when they test "the inverse of the theoretically predicted relationship [...]" (Kroes and Manikas (2014), p. 46) without providing arguments for reverse causality.

The aforementioned literature indicates that financial performance affects inventory efficiency as well. The following section describes arguments for this direction of causality in detail. Lai (2006) hypothesizes that inventory plays a signaling role and that firms may decide to reduce inventories at the fiscal-year end to signal a firm's operational capabilities. According to signaling theory (see Spence 1973), Tribó (2009) identifies a kind of "window dressing" effect, as firms reduce inventories after an IPO in order to signal low capital costs to future investors. Furthermore, after controlling for financial strength, Tribó (2009) finds that firms with financial difficulties display an even larger reduction in inventories after an IPO. Hoberg et al. (2017a) empirically investigate the relationship between a firm's fiscal-year end and inventory holdings. Their results show that firms substantially reduce

their inventories in the fourth fiscal quarter in order to manage earnings and cash flows. Frankel et al. (2017) find similar results while investigating the relationship between working capital (and its components) and the fiscal calendar. Their results also indicate significant inventory reductions towards the fiscal-year end.

Our next argument as to why performance may drive inventory decisions is based on the relationship between sales forecasts and inventory holdings. Inventory levels are largely determined by sales forecasts, something which has been underlined by empirical analysis (Gaur et al. 2005; Romyantsev and Netessine 2007; Koliass et al. 2011). It is not surprising that there will usually be a deviation between forecast and actual sales. It can happen in business practice that firms generate lower (higher) sales than expected, resulting in higher (lower) inventories than expected. In this case, inventory decisions are driven by previous revenues.

A broad stream of literature covers the relationship between financial constraints (distress) and inventory levels. In a financial crisis (be it firm specific or global), the majority of firms face liquidity problems and are forced to reduce their capital requirements. Pecking order theory suggests that firms will exhibit a preference for internal sources of capital over external or equity sources, since these are associated with lower adjustment (transaction) costs (Myers 1984; Myers and Majluf 1984). External finance (e.g. recourse to loans and bonds) is significantly more expensive than internal finance. Furthermore, sources of external finance are scarce in a crisis. Adjustments in inventories, as one element of working capital, are typically characterized by lower adjustment costs than divestments in fixed assets (Fazzari and Petersen 1993; Carpenter et al. 1994). Thus, reducing inventories seems to be a suitable way to increase short term liquidity. Steinker et al. (2016) recently undertook an empirical investigation into inventory management in the presence of firm specific financial distress periods. Their results show that firms significantly reduce inventories during distress periods in order to free-up cash and boost liquidity. Thus, inventory reductions are an essential part of successful turnaround strategies. Furthermore, the authors show that bankrupt firms also reduced inventories, albeit to a lesser extent. However, this argument must be viewed critically. Firms which abruptly shed their inventories during distress periods may not have sufficient liquidity to fill up their inventories again when the distress periods are over. When it

comes to the impact of a global crisis, rather than a firm specific one, Duchin et al. (2010) analyze the impact of the recent financial crisis on different corporate investments and, among other things, on inventory investments. Results show that inventory to assets ratios significantly declined after the onset of the recent financial crisis and that this decline is significantly greater for firms with low cash reserves.

Regarding the impact exerted by the cost of capital and by financial constraints on inventory in general, Hoberg et al. (2017b) find that firms with a higher cost of capital reduce inventory holdings and that lower financial constraints lead to higher inventories. The latter result is in line with another perspective: firms exhibiting a better financial performance can afford to hold more inventory if only because inventory is expensive and needs to be financed. Thus, inventory decisions depend on a firm's financial slack. Larger inventories allow firms to run their processes well, provide better levels of customer service and increase customer satisfaction. Conversely, poorly performing firms are simply not in a position to hold large inventories in order to run their processes well and improve their financial performance. However, this argument could be reversed as well, because lean manufacturing processes also require substantial investments. Financially successful firms can afford to invest in newer and more productive equipment, and in more research and development, leading to lower inventories (Swamidass 2007; Obermaier and Donhauser 2012). Thus, running processes efficiently, while at the same time holding low levels of inventories, can be quite expensive as well. As with the impact of inventory efficiency on firm performance, the direction of the impact of firm performance on inventory efficiency cannot be determined a priori. To be consistent with Hypothesis 1a, we are interested in the effect of financial performance on different types of inventory (raw materials, work-in-process and finished goods). For example, firms experiencing financial distress or resorting to window-dressing measures have various opportunities to boost or to embellish future firm performance. They may stop buying raw materials (lower raw materials levels), reduce production (lower work-in-process and lower finished goods levels) or stop replenishing finished goods: all of these are feasible options. Conversely, higher financial slack can be used to hold, simultaneously, higher inventory levels of raw materials, work-in-process and finished goods. Our next hypothesis is therefore:

Hypothesis 2: A firm's financial performance drives the efficiency with which it manages its raw materials, work-in-process and finished goods inventories.

Taking into account Hypothesis 1 and Hypothesis 2, we expect both directions of causality, i.e. that inventory efficiency drives financial performance and that financial performance drives inventory efficiency. Thus, we expect complex feedback loops among these variables. For example, greater inventory efficiency in period t may increase financial performance in period t and subsequent periods. However, the greater inventory efficiency in period t might be a result of worse or better financial performance in prior periods.

We expect inventory components to be asymmetrically affected by changes in firm performance. Specifically, raw materials and work-in-process efficiency should be more influenced by a firm's financial performance than finished goods, because investments (divestments) in raw materials and work-in-process cause lower adjustment costs than finished goods (Guariglia 1999). In addition, Blinder and Maccini (1991) show that finished goods inventories are the least volatile inventory component. Furthermore, previous literature finds that firms tend to adjust raw materials and work-in-process rather than finished goods. For instance, Tribó (2009) shows that, following an initial public offering, firms reduce raw materials inventories more than for finished goods in order to signal that their capital costs will be. Hoberg et al. (2017a) find that manufacturing firms reduce work-in-process inventories at the end of the fiscal year more than raw materials and finished goods in order to beat cash-flow targets. In line with previous literature, firm performance should have the strongest impact on raw materials and work-in-process followed by finished goods. Based on our arguments above, we formulate the following Hypothesis:

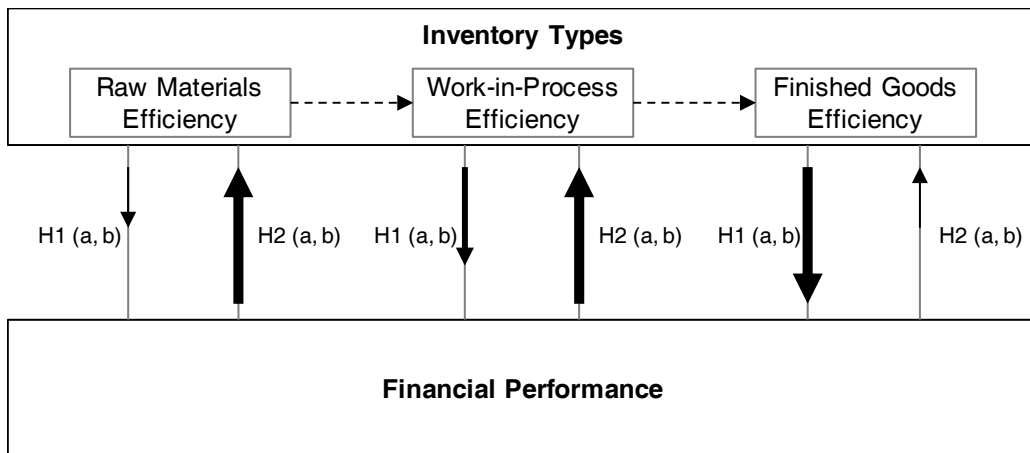
Hypothesis 2a: The impact of firm performance on inventory efficiency is stronger for raw materials and work-in-process than for finished goods efficiency.

If firm performance has the strongest effect on raw materials, followed by work-in-process and finished goods, we expect the impact of firm performance on raw materials and work-in-process to be more enduring than on finished goods. Thus, we hypothesize:

Hypothesis 2b: Firm performance will have a more persistent impact on raw materials and work-in-process than on finished goods.

Beyond the main effects exerted by various inventory types on firm performance and vice-versa that have already been considered, previous research has shown that inventory types are related to each other intertemporally (Eroglu and Hofer 2011a). Thus, inventory types are not only linked directly to firm performance, but indirectly as well. Figure 1 summarizes our model.

Figure 1: Conceptual Framework of the relationship between inventory efficiency and financial performance

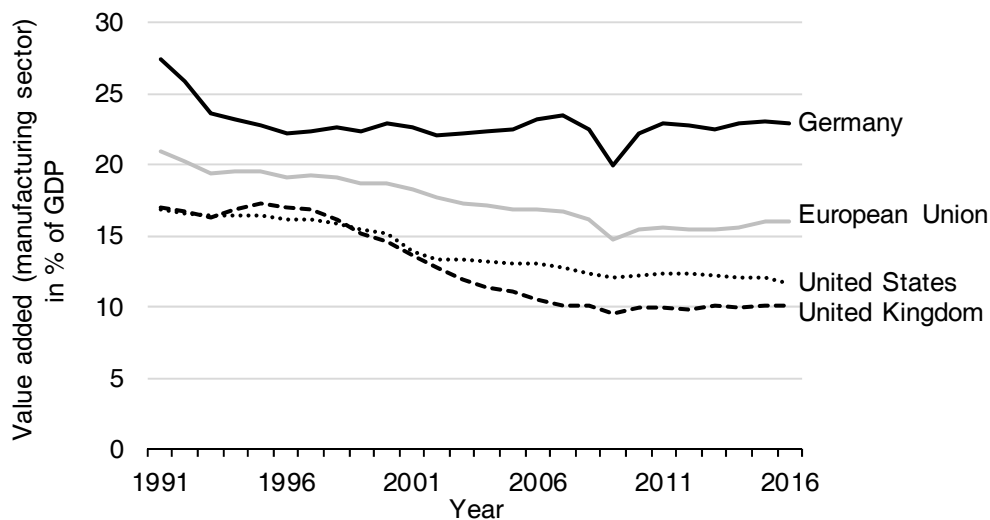


Note: Thicker (thinner) arrows represent bigger / longer (smaller / shorter) effects. Solid arrows represent our main analysis. The corresponding hypotheses are placed beside the arrows. Arrows can be compared among inventory components themselves or in terms of their direction of causality, i.e. the size and length of the effect exerted by inventory components on financial performance can be compared, and the size and length of the effect exerted by financial performance on inventory components can be compared. However, it is not the purpose of this figure to compare differences in size and length between the directions of causality.

3. Data, Measures and Estimation Methods

For the empirical analysis, we use the data from publicly traded German manufacturing companies available in Thomson Reuters Datastream database. Manufacturing firms were identified as those with a two-digit Standard Industrial Classification (SIC) code ranging from 20 to 39. We concentrate on German manufacturing firms due to the important role played by the manufacturing sector in Germany and the importance of inventories in this sector. Supporting this, Figure 2 illustrates the share of value added accounted for by the manufacturing sector as a percentage of GDP in Germany in comparison to the European Union, the United States and the United Kingdom. In contrast to the German manufacturing sector, the share of value added as a percentage of GDP decreased between 1991 and 2016 in other major economies. If the entire manufacturing sector (public and private companies) is taken in Germany, inventory accounts, on average, for 17% of total assets and 30% of current assets (Deutsche Bundesbank 2017). Given the importance of inventories in the manufacturing sector, German manufacturing firms have to manage inventories with the greatest care.

Figure 2: Value added accounted for by the manufacturing sector as a percentage of GDP for selected countries/areas (Source: The World Bank 2017; U.S. Bureau of Economic Analysis 2017)



Our initial dataset consists of 5,410 firm year observations across 478 firms between 1990 and 2016. However, due to the lag structure characterizing our specifications of

the panel vector autoregressive model, we lose some observations. The final dataset contains an unbalanced panel data structure, with 3,028 firm-year observations from 332 firms in the period 1990-2016. The reason why it was decided to begin the time frame was at the point chosen had to do with the availability of data, as the calculation of some of our variables requires lagged data values to be available (e.g. the calculation of demand uncertainty is based on data for the past three years). To mitigate the effect of erroneous data on our results, we delete observations with negative values on inventory data, total assets, sales and debt. We winsorize relative metrics at the 1% level to control for outliers and erroneous data (Hendricks and Singhal 2005; Kroes et al. 2018).

3.1 Measurement of Inventory Efficiency

Several measures of inventory performance have been used in previous literature. The similarity shared by most of these measures is that they are scaled either by sales (e.g. Chen et al. 2005; Swamidass 2007; Capkun et al. 2009; Obermaier and Donhauser 2012), cost of goods sold (e.g. Chen et al. 2005; Alan et al. 2014) or total assets (e.g. Chen et al. 2005; Duchin et al. 2010) with a view to making inventory levels comparable across firms. Since previous research has shown that inventory levels differ by manufacturing sectors (Chen et al. 2005; Eroglu and Hofer 2011b), a growing number of studies use inventory performance measures that adjust for industry effects (e.g. Chen et al. 2005; Eroglu and Hofer 2011b; Modi and Mishra 2011; Mishra et al. 2013). A few studies (e.g. Eroglu and Hofer 2011a; Eroglu and Hofer 2014; Isaksson and Seifert 2014) use the Empirical Leanness Indicator (ELI) developed by Eroglu and Hofer (2011b). The ELI is calculated, in a first step, by regressing the natural logarithm of sales on the natural logarithm of inventory for each industry and year. In a second step, the ELI for each firm-year is obtained by calculating studentized residuals and multiplying them by -1 (see Eroglu and Hofer 2011b for further details). However, using the ELI would not be appropriate in our case because some of our industries contain only a small number of firm observations. Instead, for the purpose of this study we follow the approach taken by Modi and Mishra (2011) and Mishra et al. (2013). In order to measure inventory efficiency for each type of inventory, we use sales scaled by inventory levels and

standardized at the three-digit SIC level. The sales-to-inventory ratio (and its reverse) is one of the most widely used and widely accepted measures of a firm's inventory performance (e.g. Obermaier and Donhauser 2012; Mishra et al. 2013). Furthermore, standardization at industry levels is in line with previous literature. Accordingly, we calculate inventory efficiency at the three-digit SIC level for all three inventory components – raw materials, work-in-process and finished goods for firm i in year t as:

$$RM_Eff_{it} = \frac{\frac{Sales_{it}}{Raw\ Materials_{it}} - \overline{RM_Eff_{jt}}}{\sigma_{RM_Eff_{jt}}} \quad (1)$$

$$WP_Eff_{it} = \frac{\frac{Sales_{it}}{Work\ -In\ -Process_{it}} - \overline{WP_Eff_{jt}}}{\sigma_{WP_Eff_{jt}}} \quad (2)$$

$$FG_Eff_{it} = \frac{\frac{Sales_{it}}{Finished\ Goods_{it}} - \overline{FG_Eff_{jt}}}{\sigma_{FG_Eff_{jt}}} \quad (3)$$

where RM_Eff_{it} , WP_Eff_{it} and FG_Eff_{it} are raw materials efficiency, work-in-process efficiency and finished goods efficiency for firm i in year t . $Raw\ Materials_{it}$, $Work\ -In\ -Process_{it}$ and $Finished\ Goods_{it}$ are the inventory held by firm i in year t . $Sales_{it}$ are the sales of firm i in year t . $\overline{RM_Eff_{jt}}$, $\overline{WP_Eff_{jt}}$ and $\overline{FG_Eff_{jt}}$ are the average sales to raw materials, sales to work-in-process and sales to finished goods ratios for all of the firms in the same three-digit SIC industry j as firm i in year t . $\sigma_{RM_Eff_{jt}}$, $\sigma_{WP_Eff_{jt}}$ and $\sigma_{FG_Eff_{jt}}$ are the corresponding standard deviations of sales to inventory ratios for all of the firms in the same three-digit SIC industry j .

3.2 Measurement of Financial Performance

Existing studies of the inventory-performance relationship employ various measures of firms' financial performance, as financial performance is a multidimensional construct (Venkatraman and Ramanujam 1986). Most studies in operations management measure financial performance by using either an accounting-based measure like return on assets (ROA) or return on sales (ROS) (e.g. Capkun et al. 2009; Eroglu and Hofer 2011a; Eroglu and Hofer 2011b) or a measure of stock market performance such as Tobin's Q or stock market returns (e.g. Chen et al. 2005; Hendricks et al. 2009; Alan et al. 2014; Kroes et al. 2018). Previous literature has shown that inventories have both short- and long-term implications for performance (e.g. Chen et al. 2005). Thus, we require a performance measure to capture short- and long-term performance effects. In order to capture the multidimensional nature of firm performance, we apply Altman's (1968) Z-Score statistic which was originally developed to predict corporate bankruptcy, based on the aggregation of five financial ratios. However, researchers argue that the Z-Score is an appropriate measure of overall financial performance as well (Carton and Hofer 2007). Nowadays, it is also a commonly used measure of financial health in supply chain management literature (e.g. Swamidass 2007, Ellinger et al. 2011, Obermaier and Donhauser 2012, Ha 2013). Altman (1968) applied a discriminant analysis to a sample of 33 bankrupt and 33 surviving firms in order to develop the following function with a view to calculating the Z-Score:

$$Z = 1.2X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + 1.0X_5 \quad (4)$$

with X_1 = Working Capital / Total Assets, X_2 = Retained Earnings / Total Assets, X_3 = Earnings before Interest and Taxes / Total Assets, X_4 = Market Value of Equity / Book Value of Total Liabilities, X_5 = Sales / Total Assets. Thus, the measure combines liquidity (X_1), cumulative profitability (X_2), productivity (X_3), solvency (X_4) and efficiency (X_5) (Altman 1968). As our hypotheses are based on arguments pertaining to liquidity, profitability and solvency, the Z-Score is an appropriate measure of overall financial health in this study, because the Z-Score combines these

aspects. Altman (1968) identified specific cutoff points for bankrupt and non-bankrupt categories. Z-Scores greater than 2.99 were identified as non-bankrupt and firms with scores below 1.81 fell into the bankrupt category. Firms with Z-Score between those values were in the “gray area”. In our study, Z-Score serves as a measure of overall financial performance. Thus, cutoff values are less important. Instead, higher Z-Scores are associated with better firm financial performance in general.

Although the original coefficients of X_1 to X_5 are still used to this day to calculate Z-Scores, previous research has shown that the variable weights are sensitive to the underlying sample (e.g. Altman and Hotchkiss 2006; Obermaier and Donhauser 2012; Steinker et al. 2016). In order to calculate an updated version based on our sample of German manufacturing firms, we re-estimate the original Z-Score function. In a first step, we identified all bankrupt firms in the initial data set between 1990 and 2016 ($n = 57$). Data was obtained from Thomson Reuters Datastream and Nexis. Next, we checked data availability for the variables X_1 to X_5 for those firms. The variables X_1 to X_5 had to be available one or two years prior to bankruptcy. The initial sample size was reduced to 47 firms. One further firm was excluded because it was identified as an extreme outlier, resulting in a final sample comprising 46 bankrupt firms. To conduct the multiple discriminant analysis in line with Altman (1968), we need a corresponding number of non-bankrupt firms. Those firms were randomly chosen. We identify appropriate sample matches by choosing random firms from the same industry (characterized by the same two-digit SIC code) and of a similar firm-size. To ensure the latter, we conducted a t -test in order to compare the mean of total assets held by the bankrupt and non-bankrupt firms. We repeated the random selection of firms thirty times³ and excluded cases where the t -test for equal firm size of bankrupt and non-bankrupt firms was rejected at the 5% significance level. Finally, the multiple discriminant analysis was conducted for 28 random samples. We chose the model which displayed the best fit for the criteria chosen (percentage of correct classification, Wilk’s Lambda) and the following function

³ This number might seem somewhat arbitrary. However, the results of our discriminant analysis based on the random samples have often shown low percentage values of correct classification or high values of Wilk’s lambda. Thus, we extended our analysis to thirty runs.

emerged (see Appendix 1 for standardized coefficients and measure of best fit criteria):

$$Z_{updated} = 1.17X_1 - 0.25X_2 + 3.98X_3 + 0.10X_4 + 0.21X_5 - 0.60 \quad (5)$$

The updated Z-Score was calculated for each firm in each year based on the variables X_1 to X_5 . The higher the resulting score, the better the overall firm's financial performance.

3.3 Control Variables

We include in our model a set of exogenous control variables that have been frequently used in the empirical inventory-performance literature. As previous research has shown (e.g. Chen et al. 2005; Eroglu and Hofer 2011a), firm size (*Size*) may be positively related to financial performance, as large firms generally have more resources than small firms. Firm size is measured by the natural logarithm of total assets. In addition to size, we control for the debt burden (*Leverage*) borne by the firm (Isaksson and Seifert 2014). We measure leverage as the firm's long-term debt scaled by total assets. Leverage could affect firm performance both positively and negatively. On the one hand, firms have incentives to increase their debt ratios, as this is associated with higher tax shields. On the other hand, debt decreases managerial flexibility, as debt obligations have to be met, thereby negatively impacting cash-flows. In addition, we include the year-over-year percentage change in sales (*Sales Growth*), which accounts for the performance implications of positive or negative sales growth (Capon et al. 1990; Eroglu and Hofer 2011b). Eroglu and Hofer (2014) and Han et al. (2013) emphasize the importance of controlling for environmental dynamism when investigating the inventory-performance link. Thus, demand uncertainty (*Demand Uncertainty*) is included in order to control for the market dynamics faced by a firm. Demand uncertainty is calculated as the standard deviation of a firm's sales over the last three years (including the current year) divided by the corresponding mean. This approach is comparable with that used by Hoberg et al. (2017a). As industry competition is also an important driver of firm

performance (Mishra et al. 2013), the Herfindahl-Hirschman index (*HHI*) is included in our model. The index is calculated as the sum of the squared market shares enjoyed by the firms in an industry (defined at the three-digit SIC level), where firm sales are used to compute the respective market share. Firms with a bigger market share (*Market Share*) are expected to achieve better financial performance thanks to positional advantages (Modi and Mishra 2011). Market share is calculated as the sales generated by firm *i* in year *t* divided by the total sales in the three-digit SIC industry during the same year. We further control for positive sales surprises (*PSS*), because previous literature has shown that unexpectedly low or high sales can affect both inventory efficiency and firm performance (Gaur et al. 2005; Capkun et al. 2009). A sales surprise is defined as an indicator variable which equals 1, if actual sales are higher than sales forecast and 0 otherwise. We follow the approach taken by Gaur et al. (2005) and calculate sales forecast with the aid of Holt's linear exponential smoothing. In addition, we include accounts payable (*Accounts Payable*; sales divided by accounts payable) in our analysis in order to control for lead time. Lead time may be positively or negatively related to firm performance (Kroes and Manikas 2014). It should be emphasized that our variables also serve as controls when the impact of firm performance on inventory efficiency is investigated, since *Size*, *Sales Growth*, *Demand Uncertainty*, *PSS*, *Accounts Payable* (Rumyantsev and Netessine 2007), *Leverage* (Kashyap et al. 1994) and *HHI* (Mishra et al. 2013) have all been found to be associated with inventory levels in previous research as well. Table 1 contains a description of the variables and Table 2 presents descriptive statistics.

Table 1: Description of variables

| Variable | Description | Source |
|-------------------------------------|---|-----------------------------------|
| Key variables | | |
| Firm performance (Z-Score) | Updated Altman's (1968) Z-Score statistic | Nexis, Thomson Reuters Datastream |
| Raw materials efficiency (RM_Eff) | Ratio of firm's sales to raw materials inventory, standardized by the industry mean and standard deviation with the industry defined at the three-digit SIC level | Thomson Reuters Datastream |
| Work-in-process efficiency (WP_Eff) | Ratio of firm's sales to work-in-process inventory, standardized by the industry mean and standard deviation, with the industry defined at the three-digit SIC level | Thomson Reuters Datastream |
| Finished goods efficiency (FG_Eff) | Ratio of firm's sales to finished goods inventory, standardized by the industry mean and standard deviation, with the industry defined at the three-digit SIC level | Thomson Reuters Datastream |
| Control variables | | |
| Firm size (Size) | Natural logarithm of total assets of the firm | Thomson Reuters Datastream |
| Leverage | Ratio of firm's long-term debt to total assets | Thomson Reuters Datastream |
| Sales Growth | Year-over-year percentage change in sales | Thomson Reuters Datastream |
| Demand Uncertainty | Standard deviation of a firm's sales over the last three years (including the current year) divided by the corresponding mean | Thomson Reuters Datastream |
| Herfindahl-Hirshman Index (HHI) | Sum of squared market shares enjoyed by firms in an industry (defined at the three-digit SIC level), where firm sales are used to compute market share | Thomson Reuters Datastream |
| Market Share | Firm's sales divided by the industry sales, with the industry defined at the three-digit SIC level | Thomson Reuters Datastream |
| Positive sales surprise (PSS) | Dummy variable; 1 if actual sales of firm <i>i</i> in year <i>t</i> are higher than sales forecast of firm <i>i</i> in year <i>t</i> , 0 otherwise (with forecast obtained using Holt's linear exponential smoothing) | Thomson Reuters Datastream |
| Accounts Payable | Proxy for lead time; sales divided by accounts payables | Thomson Reuters Datastream |

Table 2: Descriptive statistics

| Variable | Min | Max | Mean | Median | SD |
|--------------------|-------|-------|-------|--------|-------|
| Z-Score | -1.72 | 2.92 | 0.37 | 0.29 | 0.70 |
| RM_Eff | -2.07 | 3.59 | 0.00 | -0.30 | 0.87 |
| WP_Eff | -1.87 | 4.00 | 0.00 | -0.30 | 0.87 |
| FG_Eff | -2.09 | 4.14 | 0.00 | -0.32 | 0.87 |
| Size | 7.25 | 19.81 | 12.49 | 12.19 | 1.87 |
| Leverage | 0.00 | 0.46 | 0.11 | 0.09 | 0.11 |
| Sales Growth | -0.54 | 1.59 | 0.08 | 0.04 | 0.28 |
| Demand Uncertainty | 0.02 | 1.03 | 0.18 | 0.12 | 0.17 |
| HHI | 0.14 | 1.00 | 0.56 | 0.51 | 0.29 |
| Market Share | 0.00 | 1.00 | 0.37 | 0.17 | 0.39 |
| PSS | 0.00 | 1.00 | 0.49 | 0.00 | 0.50 |
| Accounts Payable | 3.15 | 76.34 | 16.93 | 14.00 | 11.66 |

3.4 Estimation Method

To capture the underlying dynamics and expected feedback effects among our key variables, we apply a panel data vector-autoregressive (PVAR) methodology (Holtz-Eakin et al. 1988; Love and Zicchino 2006). A VAR model enables us to control for potential endogeneity, reverse causality and complex feedback loops (Luo 2009). That is, this approach captures not only the direct impact exercised by inventory efficiency on firm performance, but also the impact of firm performance on future inventory efficiency. The PVAR approach combines the traditional VAR approach, which allows us to treat all of the key variables (raw materials efficiency, work-in-process efficiency, finished goods efficiency, financial performance) as jointly endogenous within a system of equations without worrying about the direction of causality, with the panel data approach, which allows for individual heterogeneity (Love and Zicchino 2006). For this purpose, we have included firm-fixed effects in our model. We specify the following PVAR model with exogenous variables:

$$Y_{it} = \Gamma_0 + \sum_{l=1}^L \Gamma_{1l} \cdot Y_{i,t-l} + B \cdot X_{it} + \mu_i + \varepsilon_{it} \quad (6)$$

The vectors Y_{it} and $Y_{i,t-l}$ contain all the endogenous variables (*RM_Eff*, *WP_Eff*, *FG_Eff*, *Z-Score*) for firm i in year t . We ran Granger causality tests to check whether the variables were indeed endogenous (Granger 1969). In general, Granger causality tests compare the forecast for variable y , based on its own history, with that of the forecast for variable y , including the past performance displayed by variable x . If adding the past of the x -variable significantly adds to the forecast fit, then the test concludes that x Granger causes y . It is possible that Granger causality runs in the opposite direction, i.e., the causation may run from y to x . Note that it is possible for Granger causality to run in both directions, i.e. x Granger causes y and y Granger causes x . In this case, the results would suggest feedback effects, as we expect based on our hypotheses. X_{it} contains the control variables (*Size*, *Leverage*, *Sales Growth*, *Demand Uncertainty*, *HHI*, *Market Share*, *PSS*, *Accounts Payable*). The matrices Γ_0 , Γ_{1l} and B contain the regression coefficients. l is the order of the model and has

to be determined before model estimation, using Akaike's information criterion, as suggested by the PVAR literature (Holtz-Eakin et al. 1988; Love and Zicchino 2006). To eliminate time-specific effects, each variable is time-demeaned (Love and Zicchino 2006), i.e., by subtracting the corresponding mean of each variable across all firm-year observations. μ_i captures the firm-fixed effects. On account of the lagged dependent variable, the "within" transformation, which is usually used to eliminate the fixed effects, would result in the coefficients being biased. Thus, we use the forward mean-differencing procedure suggested by Arellano and Bover (1995). This transformation subtracts the mean of all future observations available for each firm-year. Also referred to as the "Helmert procedure", forward mean-differencing ensures the orthogonality between transformed variables and regressors. Therefore, we can use lagged regressors as instruments and estimate coefficients with system GMM (Love and Zicchino 2006).

Since the coefficients of the estimated PVAR model are rarely interpreted because of severe multicollinearity (Sims 1980), we follow the standard procedure used in the (P)VAR literature and calculate both impulse response functions (IRFs) and forward error variance decompositions (FEVDs) (Pauwels et al. 2004). IRFs allow us to capture the complete perspective on the dynamic interactions between inventory holding and financial performance and to analyze long-term effects. IRFs describe the reaction of one variable to an exogenous shock to another variable in the system, while holding all other shocks equal to zero. Cholesky decomposition of the variance-covariance matrix of the residuals is applied to impose a recursive structure to the VAR model (Love and Zicchino 2006). However, the results depend on the causal ordering of endogenous variables. We use the following ordering: raw materials \rightarrow work-in-process \rightarrow finished goods \rightarrow financial performance. The identifying assumption is that every variable in the system affects the subsequent variables both contemporaneously and with a lag, while variables that come later in the ordering affect the previous ones only with a lag (Love and Zicchino 2006). That is, financial performance reacts immediately to shocks involving different types of inventory, but inventory types react only after a lag following shocks to financial performance. To complement our analyses, we also present FEVDs, which determine

the relative contribution of one variable to the prediction of another variable (i.e., variance explained).

4. Results

4.1 Model-free Analysis

Table 3 reports the average Z-Score grouped by quartiles (low 25% and high 25%) for raw materials efficiency, work-in-process efficiency and finished goods efficiency, and, in addition, the mean of raw materials efficiency, work-in-process efficiency and finished goods efficiency grouped by quartiles of Z-Score. Firms were ranked by one variable (*RM_Eff*, *WP_Eff*, *FG_Eff*, *Z-Score*), and divided into four quartiles for each year of our time frame. Then, the corresponding average Z-Score or the average inventory efficiency was calculated for quartile one (low 25%) and quartile four (high 25%).

Table 3: Model-free analysis for the relationship between inventory and financial performance

| | quartile | | Δ high-low |
|--|----------|----------|-------------------|
| | low 25% | high 25% | |
| <i>Mean Z-Score grouped by Inventory types</i> | | | |
| Mean Z-Score grouped by <i>RM_Eff</i> | 0.282 | 0.427 | 0.15 |
| Mean Z-Score grouped by <i>WP_Eff</i> | 0.257 | 0.425 | 0.17 |
| Mean Z-Score grouped by <i>FG_Eff</i> | 0.285 | 0.351 | 0.07 |
| <i>Mean inventories grouped by Z-Score</i> | | | |
| Mean <i>RM_Eff</i> grouped by Z-Score | -0.062 | 0.098 | 0.16 |
| Mean <i>WP_Eff</i> grouped by Z-Score | -0.063 | 0.192 | 0.26 |
| Mean <i>FG_Eff</i> grouped by Z-Score | 0.006 | 0.083 | 0.08 |

Our results show, that firms with higher (lower) inventory efficiency are characterized by better (worse) financial performance over all inventory types. The largest performance difference occurs when firms are grouped by work-in-process efficiency (0.17), followed by raw materials efficiency and finished goods efficiency. The average of the inventory types grouped by Z-Score show that firms that perform poorly (well) carry higher (lower) inventories. In sum, the analysis of mean values of Z-Score (inventory efficiency) grouped by inventory efficiency (Z-Score) suggests

that there are substantial differences among each group. This indicates that inventory efficiency could drive firm performance, but that firm performance could drive inventory efficiency as well.

In addition, Table 4 reports the pairwise correlations between our key variables. To measure intertemporal correlations among variables, we included the one-year lag of the variables the analysis.

Table 4: Pairwise correlations (contemporaneously and one-year lag)

| Variable | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. |
|---------------------------|---------|---------|---------|---------|---------|---------|---------|------|
| 1. Z-Score _t | 1.00 | | | | | | | |
| 2. Z-Score _{t-1} | 0.69*** | 1.00 | | | | | | |
| 3. RM_Eff _t | 0.09*** | 0.06*** | 1.00 | | | | | |
| 4. RM_Eff _{t-1} | 0.09*** | 0.09*** | 0.82*** | 1.00 | | | | |
| 5. WP_Eff _t | 0.12*** | 0.11*** | 0.24*** | 0.23*** | 1.00 | | | |
| 6. WP_Eff _{t-1} | 0.14*** | 0.14*** | 0.23*** | 0.26*** | 0.82*** | 1.00 | | |
| 7. FG_Eff _t | 0.03** | 0.00 | 0.10*** | 0.07*** | 0.04** | 0.02 | 1.00 | |
| 8. FG_Eff _{t-1} | 0.01 | 0.03*** | 0.06*** | 0.09*** | 0.07 | 0.04*** | 0.80*** | 1.00 |

*, **, and *** denote statistical significance at 10%, 5%, and 1% levels, respectively.

There is a significantly positive correlation between $Z\text{-Score}_t$ and the inventory efficiency of raw materials (0.09) and work-in-process (0.12; 0.14) both in t and in $t-1$. The correlation between finished goods efficiency and financial performance in t is not significant. However, overall these results indicate that firms with higher inventory efficiency achieve better financial performance in the same and next period and provide initial evidence for Hypothesis 1, i.e. that inventory efficiency drives firm performance. Furthermore, the correlation is strongest for work-in-process efficiency, followed by raw materials and finished goods. According to Hypothesis 1a, we should find stronger correlation between finished goods efficiency and firm performance, followed by work-in-process and raw materials. $Z\text{-Score}_{t-1}$ is positively correlated with the inventory efficiency of raw materials (0.06; 0.09) and work-in-process (0.11; 0.14) in $t-1$ and t , but not for finished goods in t . These results partly suggest that firm performance in $t-1$ drives inventory holding in t (Hypothesis 2). The correlation between $Z\text{-Score}_{t-1}$ and inventory efficiency is strongest with work-in-process efficiency, followed by raw materials and finished goods. This result provides initial evidence for Hypothesis 2a. Besides the analyses of the relationship between different types of inventory and firm

performance, we find a high correlation between inventory types themselves, providing initial evidence for intertemporal relationships between inventory types. All in all, the results of the correlation analysis indicate that inventory efficiency of both raw materials and work-in-process in $t-1$ drive financial performance in t , but that financial performance in $t-1$ drives raw materials and work-in-process efficiency in t as well.

But, of course, such model-free analysis is only a preliminary indication. For a more rigorous analysis, we need to account for sufficient lags, reverse causality, complex feedback loops and other exogenous control variables, which we do in our PVAR model. The PVAR analysis, specifically the analysis of impulse response functions, also enables us to investigate the long term impacts of inventory efficiency on firm performance and vice versa.

4.2 Stationarity and Granger Causality

Before we proceed with the PVAR approach, an important prerequisite is that all the variables entering the model be stationary so that both Granger causality and a PVAR analysis can be undertaken. All unit root tests include trend and drift. Panel unit root test results (augmented Dickey-Fuller test with first order lag) indicate that this stationarity prerequisite is fulfilled for all endogenous variables, i.e. the absence of unit roots. All unit root tests are reported in Table 5.

Table 5: Unit root tests of the variables

| Variable | Inverse normal Z^4 | p-value | Conclusion |
|----------|----------------------|---------|------------|
| RM_Eff | -9.654 | 0.000 | Stationary |
| WP_Eff | -9.750 | 0.000 | Stationary |
| FG_Eff | -9.683 | 0.000 | Stationary |
| Z-Score | -8.921 | 0.000 | Stationary |

Note: We used one lag in the augmented Dickey-Fuller unit root test. All unit root tests include trend and drift. The null hypothesis for all tests is that all the panels contain unit roots.

Z-Score: Financial performance measured by Altman's (1968) Z-Score. RM_Eff: raw materials efficiency. WP_Eff: work-in-process efficiency. FG_Eff: finished goods efficiency.

⁴ According to Choi's (2001) simulation results, this statistic offers the best trade-off between size and power. Hence, he recommends using inverse normal Z test for empirical applications.

Next, we conducted Granger causality tests (Granger 1969), which examine whether one variable is temporally causing a second variable, after the lagged values of the second variable have been accounted for. These tests help us to detect feedback effects in our data and to identify endogenous variables. A variable is identified as endogenous (and enters the PVAR model as endogenous) only when a key variable Granger causes at least one other variable and is Granger caused by other variables. The results of pairwise Granger causality tests in Table 6 show that raw materials cause finished goods ($X^2 = 10.86$). Firm performance (Z-Score) is Granger-caused by work-in-process ($X^2 = 5.32$) and finished goods ($X^2 = 12.65$) but in turn causes raw materials ($X^2 = 6.68$) and work-in-process ($X^2 = 11.26$). Overall, we conclude that all variables of interest are indeed endogenous and we confirm complex feedback loops among inventory types and firm performance. Furthermore, this result highlights the need for a PVAR model.

Table 6: Panel Granger non-causality tests

| X^2 | RM_Eff | WP_Eff | FG_Eff | Z-Score |
|---------|--------|----------|----------|----------|
| RM_Eff | -- | 0.36 | 10.86*** | 0.08 |
| WP_Eff | 1.32 | -- | 1.98 | 5.32* |
| FG_Eff | 0.06 | 5.18* | -- | 12.65*** |
| Z-Score | 6.68** | 11.26*** | 0.18 | -- |

Notes: The null hypotheses assume that the variables shown in the first column do not Granger-cause the variables shown in the first row.

Z-Score: Financial performance measured by Altman's (1968) Z-Score. RM_Eff: raw materials efficiency. WP_Eff: work-in-process efficiency. FG_Eff: finished goods efficiency.

*, **, and *** denote statistical significance at 10%, 5%, and 1% levels, respectively.

4.3 Main Results

We assess the Panel VAR analysis in line with the optimal lag order estimated by the Akaike's information criterion (AIC), as suggested by the panel VAR literature (Holtz-Eakin et al. 1988; Love and Zicchino 2006; Dewan and Ramaprasad 2014; Price and Sun 2017). The results indicate that the optimal lag structure is two. As we use six prior lags as instruments, we have to check Hansen's J statistic of over-identifying restrictions (Arellano and Bond 1991). The p -value of 0.15 suggests that the instruments used are valid. We also checked the stability condition of the

estimated PVAR model. According to Hamilton (1994), a PVAR model is stable, if the modulus of each eigenvalue is strictly less than 1, which is the case in our model (see third column in Table 7). Thus, the PVAR model is stable.

Table 7: Eigenvalue stability condition

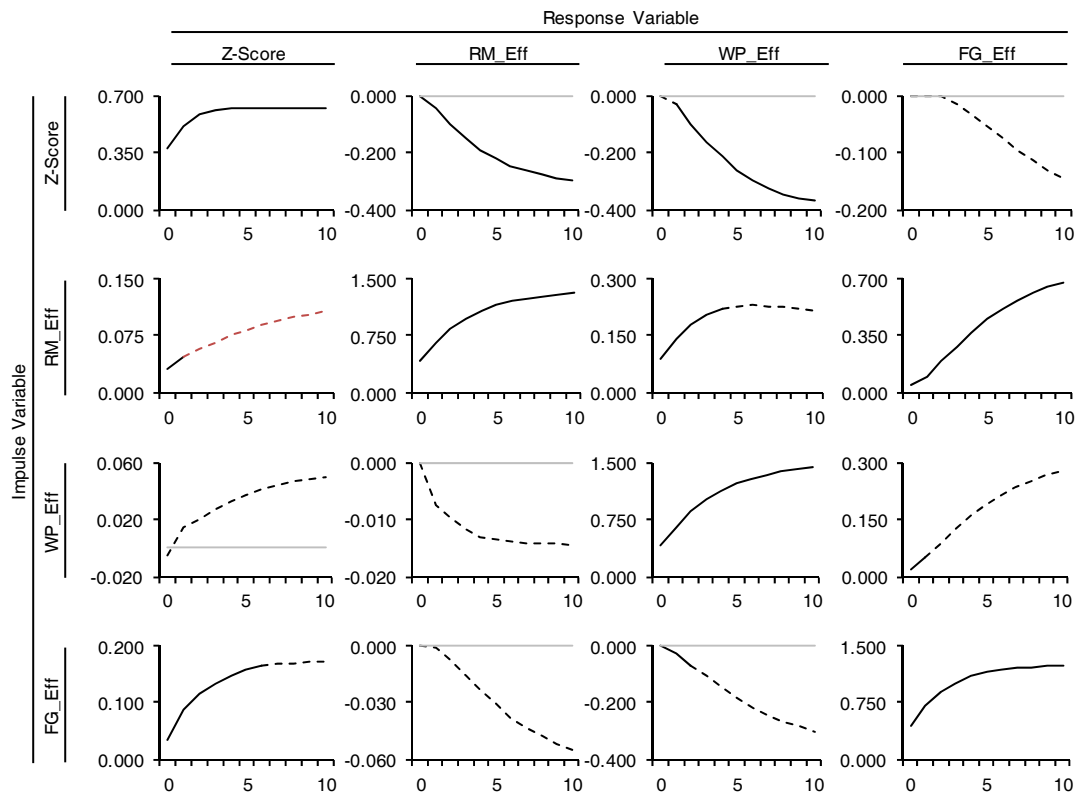
| Eigenvalue | | |
|------------|-----------|---------|
| Real | Imaginary | Modulus |
| 0.773 | 0.000 | 0.773 |
| 0.720 | 0.047 | 0.722 |
| 0.720 | -0.047 | 0.722 |
| 0.389 | 0.000 | 0.389 |
| -0.238 | 0.000 | 0.238 |
| -0.162 | 0.042 | 0.167 |
| -0.162 | -0.042 | 0.167 |
| -0.026 | 0.000 | 0.026 |

Because of severe multicollinearity issues, it is not feasible to interpret the coefficients of the estimated PVAR models (Sims 1980). For the sake of completeness, the results of the PVAR model are shown in Appendix 2.

The interdependencies in the relationships can be derived from the estimated coefficients through the impulse response functions. The results of the cumulative effects are reported in Figure 3.⁵ We calculate standard errors for the impulse response functions and generate confidence intervals with 1,000 Monte-Carlo simulations (Love and Zicchino 2006). The solid lines in Figure 3 represent significant effects of impulses exerted by one variable on another variable while dotted lines represent insignificant effects.

⁵ See Appendix 3 for non-cumulative impulse response functions.

Figure 3: Long-term (cumulative) effects of the Impulse Response Functions from the PVAR model



Note: This figure illustrates the long-term effects of each endogenous variable with respect to one standard deviation shock in other variables. Horizontal axes show the number of periods. The solid parts of the lines are significant impulse responses at the 5% level based on 1,000 times Monte-Carlo simulation. The dotted parts are impulse responses that are no longer significant. Z-Score: Financial performance measured by Altman's (1968) Z-Score. RM_Eff: raw materials efficiency. WP_Eff: work-in-process efficiency. FG_Eff: finished goods efficiency.

The first column of Figure 3 shows the effect of raw materials efficiency, work-in-process efficiency and finished goods efficiency on financial performance. The results provide empirical support for Hypothesis 1, which postulates that inventory efficiency drives firm performance. The second diagram in the first column of Figure 3 indicates performance improvements generated by greater raw materials efficiency, i.e. lower (higher) raw materials lead to better (worse) financial performance. The last diagram in the first column of Figure 3 shows the effect of one standard deviation shock to finished goods efficiency on financial performance. The effect of finished goods efficiency on financial performance is also positive. The effect of shocks to work-in-process efficiency on financial performance is not significantly different from zero. In order to compare the longevity and the magnitude of the responses

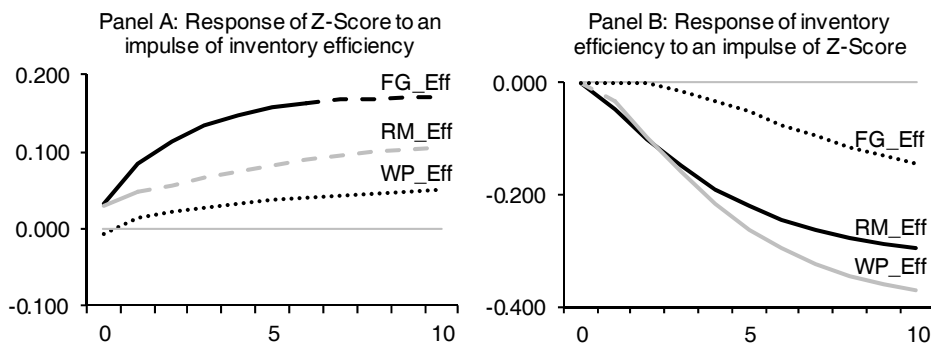
displayed by financial performance to a one standard deviation shock to inventory efficiency, we plot the responses of Z-Score to innovations in inventory efficiency in Panel A of Figure 4. The immediate effect of raw materials efficiency and finished goods efficiency on financial performance is similar. However, the magnitude of the response of Z-Score to a shock in finished goods efficiency is much larger than the magnitude of the response of raw materials efficiency in the long run. Furthermore, the results show that finished goods have a more persistent effect (6 years) on financial performance than do raw materials (1 year). Thus, our results partly support Hypothesis 1a and Hypothesis 1b. The impact of inventory efficiency on firm performance is strongest and most enduring for finished goods, but is followed by raw materials rather than work-in-process efficiency.

The first row of Figure 3 provides evidence for a reverse causal relationship between inventory holding and a firm's financial performance (Hypothesis 2), i.e. that financial performance drives inventory efficiency. The response of raw materials efficiency to a one standard deviation shock in financial performance is negative, indicating that better (worse) financial performance leads to lower raw materials efficiency, i.e. higher (lower) raw materials. We observe a comparable, but slightly different response for work-in-process efficiency: A one standard deviation shock to financial performance will lower work-in-process efficiency and thus raise work-in-process levels. This effect is not significant in the short run, but comes to be significant after two years. The response of finished goods efficiency to a shock in financial performance is not significant, either in the short or long run. Figure 4 shows that the magnitude of the response displayed by work-in-process to a shock in financial performance is larger than the response of raw materials in the short run, but is subsequently reversed, starting after two years. Overall, we find support for Hypothesis 2a and Hypothesis 2b, since the impact of firm performance is stronger and more enduring for raw materials and work-in-process than for finished goods efficiency.

Besides our main analysis, we find dynamic interactions among inventory types themselves. The third and fourth diagrams in the second row of Figure 3 reveal a positive response displayed by work-in-process efficiency and finished goods efficiency to a shock in raw materials efficiency. In the short run, the magnitude of

the response of work-in-process efficiency is larger than the response of finished goods efficiency. The response displayed by finished goods efficiency is larger after two years. Furthermore, the response of finished goods efficiency is more persistent than the response of work-in-process efficiency. The last diagram in row three shows a positive response displayed by finished goods efficiency to a one standard deviation shock in work-in-process efficiency which disappears after one year. Interestingly, a one standard deviation shock to finished goods efficiency will lower work-in-process efficiency indicating reverse causality between these inventory types.

Figure 4: Impulse-Response-Functions of inventory efficiency and financial performance

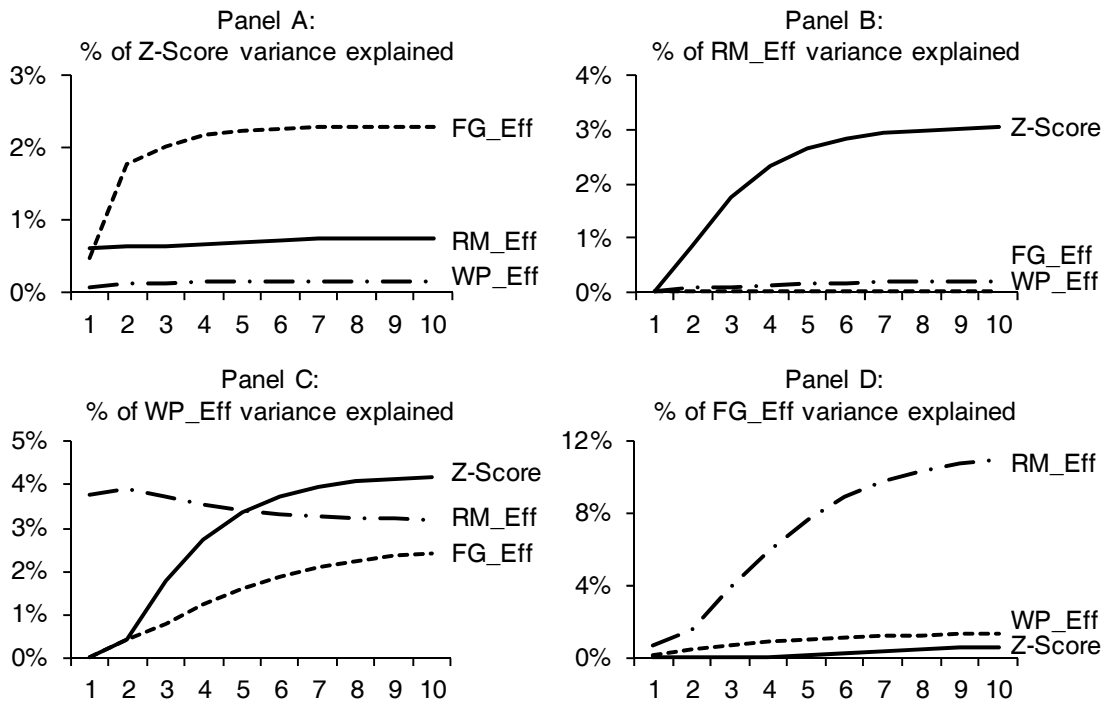


Note: This figure illustrates the long-term effects of inventory efficiency and financial performance with respect to one standard deviation shock in other variables. Horizontal axes show the number of periods. The solid parts of the lines are significant impulse responses at 5% level based on 1,000 times Monte-Carlo simulation. The dotted parts are impulse responses that are no longer significant. The left-hand part shows the response displayed financial performance (Z-Score) to a shock in inventory efficiency. The right-hand side shows the response displayed by inventory efficiency to a shock in financial performance (Z-Score).

Z-Score: Financial performance measured by Altman's (1968) Z-Score. RM_Eff: raw materials efficiency. WP_Eff: work-in-process efficiency. FG_Eff: finished goods efficiency.

Our analysis is complemented by the forecast error variance decomposition (FEVD) analysis. The results of the FEVDs in Figure 5 provide information pertaining to the relative importance of previous inventory efficiency and financial performance in explaining the variance in the other endogenous variables. Thus, FEVD analysis allows us to determine the relative strength of each endogenous variable's predictive power vis-à-vis other variables. We report the total effect over 10 periods ahead, but longer time horizons produced equivalent results.

Figure 5: Explained variance of performance and inventory types



Notes: This figure reports the variance decompositions for the PVAR model over 10 periods. Variance decompositions show the percentage of the variation in one variable that is explained by the shock to another variable, accumulated over time.

Z-Score: Financial performance measured by Altman's (1968) Z-Score. RM_Eff: raw materials efficiency. WP_Eff: work-in-process efficiency. FG_Eff: finished goods efficiency.

The results for the variance in financial performance are shown in Panel A of Figure 5. After ten periods, the results suggest that to predict financial performance the inventories should be used in the following order: finished goods efficiency (2.3%), raw materials efficiency (0.76%) and then work-in-process efficiency (0.14%). Interestingly, the ability of finished goods efficiency to explain financial performance deviations in the short run is smaller than that of raw materials efficiency. After two periods, an increasing percentage of the variance in financial performance is attributable to finished goods efficiency (more than 2.8 times larger than raw materials efficiency). Furthermore, the financial performance forecast error variance explained by finished goods is approximately 4 times larger after 10 periods than it is after 1 period. Panel B of Figure 5 reports the results for FEVDs of raw materials efficiency. Z-Score is found to explain 3.0% of the forecast error variance. The percentage of the forecast deviation variance explained by finished goods and work-

in-process is negligible (0.02% and 0.20%, respectively). Panel C of Figure 5 shows the work-in-process efficiency forecast error variance explained by other variables. Although raw materials are initially more important (3.8%), an increasing percentage of the forecast error variance is attributable to financial performance and finished goods. After 2 periods, financial performance becomes more prominent in explaining up to 4.2% after 10 periods. Furthermore, financial performance has the strongest predictive value after 5 periods. In Panel D of Figure 5, raw materials efficiency is found to explain 11% of the forecast error variance for finished goods efficiency, followed by work-in-process efficiency (1.3%) and financial performance (0.6%). Overall, the results of the FEVD analysis are consistent with the results obtained from the impulse response functions, i.e. the more important one variable is in explaining the forecast error variance of another variable, the higher is the impact and the longer is the longevity of the variable shown by the impulse response functions.

We extend the FEVD analysis with a so-called spillover table in line with Diebold and Yilmaz (2009) in Table 8. Spillover tables allow us to aggregate spillover effects across our endogenous variables.

Table 8: Spillover table

| To | From | | | | Contribution from others |
|------------------------|---------|--------|--------|--------|--------------------------|
| | Z-Score | RM_Eff | WP_Eff | FG_Eff | |
| Z-Score | 0.968 | 0.008 | 0.001 | 0.023 | 0.032 |
| RM_Eff | 0.030 | 0.967 | 0.002 | 0.000 | 0.033 |
| WP_Eff | 0.042 | 0.032 | 0.902 | 0.024 | 0.098 |
| FG_Eff | 0.006 | 0.110 | 0.013 | 0.871 | 0.129 |
| Contribution to others | 0.078 | 0.150 | 0.017 | 0.047 | 0.292 |
| Net | 0.046 | 0.117 | -0.081 | -0.082 | 0.000 |

Notes: This table reports the variance decompositions for the PVAR model after 10 periods. Variance decompositions show the percentage of the variation in one variable that is explained by the shock to another variable, accumulated over time. In the last column we have the aggregated impact received (contribution from others). Contribution to others is the aggregated impact sent by each row variable. The “Net” row shows the net spillover for each variable (difference between contribution to others and contribution from others).

Z-Score: Financial performance measured by Altman’s (1968) Z-Score. RM_Eff: raw materials efficiency. WP_Eff: work-in-process efficiency. FG_Eff: finished goods efficiency.

The column “Contribution to others” shows the aggregate impact of shocks sent to the other variables in the system while the row “Contribution from others” reports the aggregate impact of shocks received from other variables. The number of shocks sent

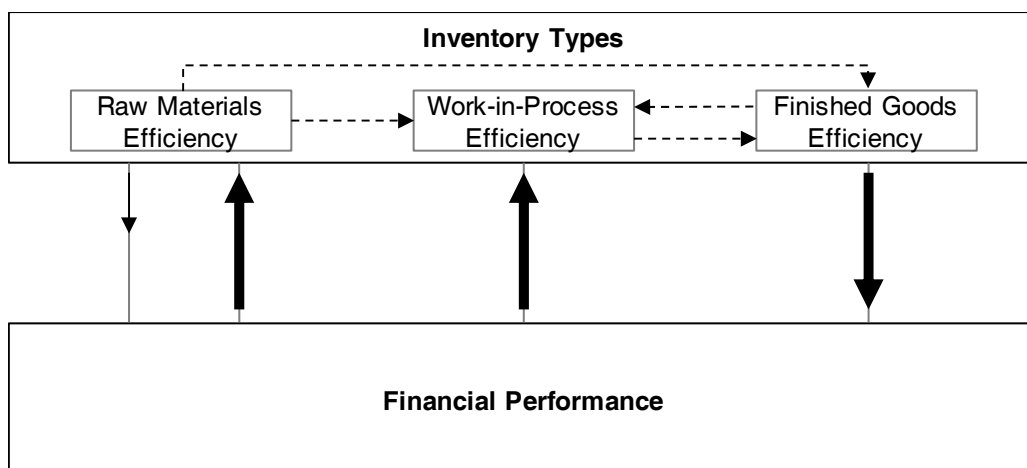
to all other variables in the system is highest for raw materials efficiency (15%), followed by financial performance (7.8%), finished goods (4.7%) and work-in-process efficiency (1.7%). The number of shocks received from other variables is highest for finished goods efficiency (12.9%), followed by work-in-process efficiency (9.8%), financial performance (3.2%) and raw materials efficiency (3.3%).

The “Net” row shows the net spillover for each variable (the difference between contribution to others and contribution from others). Since the net values of financial performance (4.6%) and raw materials efficiency (11.7%) are positive, these variables are net senders of shocks, i.e. the shocks sent to other variables is higher than the shocks received from other variables. By contrast, work-in-process (−8.1%) and finished goods efficiency (−8.2%) are net recipients, i.e. the number of shocks received is greater than the number of shocks sent. The results indicate that financial performance and raw materials efficiency are significant contributors to the outcomes for other inventory types and that work-in-process and finished goods are most sensitive to shocks from other variables.

5. Discussion

Our work has been inspired by previous studies that partially address the question of reverse causality when the inventory-performance link is investigated (e.g. Lieberman and Demeester 1999; Swamidass 2007; Obermaier and Donhauser 2012; Isaksson and Seifert 2014; Kroes et al. 2018) and by studies that found interdependencies among inventory types themselves (Eroglu and Hofer 2011a). With respect to our conceptual framework (see Figure 1), Figure 6 summarizes our findings and shows the complex interdependencies among inventory efficiency and financial performance. In contrast to the underlying conceptual framework of this study, Figure 6 only depicts significant results.

Figure 6: Overview of the interdependencies among inventory types and financial performance



Note: Thicker (thinner) arrows represent bigger / longer (smaller / shorter) effects. Solid arrows represent our main analysis. The corresponding hypotheses are placed beside the arrows. Arrows can be compared among inventory components themselves or in terms of their direction of causality, i.e. the size and length of the effect exerted by inventory components on financial performance can be compared, and the size and length of the effect exerted by financial performance on inventory components can be compared. However, it is not the purpose of this figure to compare differences in size and length between the directions of causality.

Theoretical implications

This study contributes in several ways to the research on inventory efficiency and financial performance. Our results show that the inventory-performance link is more complex than has been typically assumed. Thus, this study contributes a more comprehensive view of inventories to the empirical inventory management literature. Indeed, we find both directions of causality, i.e. inventory efficiency drives financial performance, but financial performance drives inventory efficiency as well. The question in previous literature has either been whether inventory efficiency affects financial performance or whether financial performance affects inventory efficiency. However, our results indicate that the question underlying the inventory-performance link should not be “either...or...” but rather how these variables affect each other simultaneously when their interdependencies are considered.

Our results show that raw materials and finished goods efficiency are significantly positively related to financial performance. The impact of finished goods efficiency is stronger in magnitude and lasts longer than that exerted by raw materials efficiency. The impact of firm performance on inventory efficiency is significantly negative for raw materials and work-in-process efficiency. No significant relationship

was found for finished goods. Our results show that the positive impact exercised by raw materials and finished goods efficiency on firm performance is overall in line with the findings of Capkun et al. (2009), Eroglu and Hofer (2011a) and Isaksson and Seifert (2014): leaner inventories have a positive effect on firm performance and the magnitude of the impact of inventory types on firm performance differs. But unlike to some previous studies (Capkun et al. 2009, Eroglu and Hofer 2011a), we find the strongest impact for finished goods efficiency, rather than for raw materials. Eroglu and Hofer (2011a) explain their results with possible intertemporal interactions between inventory types. Raw materials have both a direct and indirect effect (through finished goods) on firm performance. However, these interactions are not included in their baseline regression model. Furthermore, their post-hoc analysis of intertemporal interactions is based on a completely different data set than their initial regression model. Finally, because insufficient data is available to them, Eroglu and Hofer (2011a) do not consider work-in-process in their analysis of intertemporal interactions. It should be emphasized that Eroglu and Hofer (2011a) expected finished goods to have the strongest impact on firm performance, because finished goods include the value added from the manufacturing process, resulting in a higher unit value than work-in-process or raw materials. Furthermore, finished goods are directly linked to customer service, market share and pricing considerations. Thus, our results are in line with their hypothesized relationship but not with their empirical result. Using a broader set of control variables, Isaksson and Seifert (2014) also find the strongest effect for finished goods. Using a structural equation model, Andreou et al. (2016) only find an impact for finished goods on overhead costs. Their analysis is close to our study as they consider interdependencies among inventory types. However, their approach does not control for reverse causality or complex feedback loops. In contrast to previous research (Capkun et al. 2009; Eroglu and Hofer 2011a; Isaksson and Seifert 2014) we do not find that a significant impact is exerted by work-in-process efficiency on firm performance. However, previous research (Capkun et al. 2009; Eroglu and Hofer 2011a; Isaksson and Seifert 2014) detects the weakest performance effect for work-in-process inventory. One possible explanation for this result is that work-in-process inventory is characterized by a lower unit value than the other inventory components in our data. Furthermore, raw materials and

finished goods are more directly linked to monetary outcomes (e.g. purchases or sales) than is work-in-process inventory. In contrast, improvements in work-in-process efficiency primarily affect operational efficiency measures such as cycle times, and thus are not directly linked to financial performance. The results indicate that managers put more effort into improving relations with customers and suppliers (Chen et al. 2005), which manifests itself in better performance outcomes.

Investigating the impact of firm performance on each inventory component, our results reveal that the impact differs across inventory types. Better (worse) firm performance leads to lower (higher) inventory efficiency in the case of raw materials and work-in-process. These results are consistent, overall, with Gaur et al. (2005) and Rumyantsev and Netessine (2007). Their results indicate that higher gross margins (as a measure for firm performance) lead to higher inventory levels. Thus, better firm performance could serve as financial slack that offers a firm the opportunity to hold higher inventory levels in order to run its processes well and help boost product variety, service levels and customer satisfaction (Obermaier and Donhauser 2012). Interestingly, Swamidass (2007) find that US manufacturing firms with better financial performance are characterized by lower inventories, which is explained by their having made investments in modern manufacturing technologies that allow them to hold lower inventories. However, we are unable to observe this relationship in our sample of German manufacturing firms. Furthermore, the negative impact exercised by firm performance on raw materials and work-in-process efficiency indicates that firms reduce their inventories when they experience financial distress in order to free up liquidity (e.g. Carpenter et al. (1994); Guariglia (1999); Steinker et al. (2016)). In general, the impact exercised by firm performance on inventory holding can be explained by the relatively low cost of adjusting inventories (Fazzari and Petersen 1993; Carpenter et al. 1994). Therefore, adjustments to inventory efficiency allow a firm to react quickly to improvements or deteriorations in financial variables. The fact that our results do not show a significant impact being exercised by financial performance on finished goods efficiency can be explained by higher costs involved in adjusting this type of inventory (Guariglia 1999), as it requires adjustments in employment and negotiations with customers. Raw materials can easily be reduced by simply delaying reordering, and adjustments to work-in-process require less

coordination with external partners (Balakrishnan et al. 1996). This is also in line with the results obtained by Blinder and Maccini (1991), who show that the finished goods inventory is the least volatile inventory component. Besides, Tribó (2009) finds that, following an initial public offering, firms tend to reduce raw materials inventories more than their stocks of finished goods with a view to signaling low costs of capital. Hoberg et al. (2017a) find that manufacturing firms reduce total inventories at the end of the fiscal year in order to beat cash-flow targets. The inventory reduction is stronger for work-in-process and raw materials than for finished goods. Overall, our results confirm previous studies which show that inventory adjustments triggered by changes in financial variables are more common for raw materials and work-in-process than for finished goods.

In addition, our analysis sheds more light on the importance of investigating inventory components, rather than total inventory. When our PVAR model methodology is applied to total inventories and financial performance, our results only show causality moving in only one direction, from inventory holding to financial performance, rather than in the opposite direction (see Appendix 4 for the results). Specifically, when the relationship between total inventory and firm performance is investigated, our results confirm the well-known pattern that greater inventory efficiency leads to better firm performance (e.g. Capkun et al. 2009; Modi and Mishra 2011). Furthermore, the Granger causality test, impulse response functions and variance decompositions show that total inventory does indeed drive financial performance, but that financial performance does not drive inventory holding. The direction of causality is in line with Kroes et al. (2018), who show that lagged changes in firm performance do not Granger-cause inventory slack (measured for total inventories) in subsequent periods. It seems as if our results for the inventory components are mainly driven by finished goods efficiency. Thus, without investigating the impact of each inventory component (financial performance) on financial performance (each inventory component), we were unable to observe the differing outcomes. Breaking down total inventory into its components - raw materials, work-in-process and finished goods - reveals that both the effects of inventory types on firm performance and the impact of firm performance on each inventory component differ significantly. The use of total inventory rather than

inventory components might be one reason why our results differ from those of Sridhar et al. (2014). The latter find a positive and significant long-term impact being exerted by inventory holding on sales and a non-significant impact being exerted by inventory holding on firm value (measured by Tobin's Q). Furthermore, results show that an increase in sales leads to a positive and significant impact on inventory holding. An increase in firm value leads to a negative and significant impact on inventory holding.

The long-term patterns displayed by raw materials, work-in-process, finished goods efficiency and financial performance have further implications for the inventory-performance link. To the best of our knowledge, previous research has not investigated the longevity of the impacts exercised by inventory efficiency on firm performance. We find that shocks to finished goods efficiency have a more persistent impact on financial performance than raw materials. Therefore, finished goods efficiency not only yields a much stronger effect than other inventory components on financial performance, but also has a more persistent impact. The reasons are similar to what holds for the magnitude of the impact exerted by finished goods efficiency: Finished goods have the highest unit value among all inventory components and are directly linked to customer service and pricing considerations (Eroglu and Hofer 2011a). In this sense, identifying the differing longevity of the performance outcomes exercised by inventory components is necessary if the effects of these supply chain performance resources are to be fully captured.

Finally, by investigating the impact exerted by each inventory component (financial performance) on financial performance (each inventory component) with a PVAR model, we are able to detect interdependent interactions among inventory types themselves, because the PVAR model makes it possible for all endogenous variables to affect one another in a fully interactive modeling system. Our results suggest that raw materials efficiency has a positive impact on work-in-process and finished goods efficiency. Furthermore, we observe feedback loops between work-in-process and finished goods efficiency, i.e. not only does work-in-process affect finished goods, but finished goods affect work-in-process as well. Thus, our results not only show direct effects, but indirect effects through other variables, too. Our results enhance the analysis of intertemporal interactions undertaken by Eroglu and

Hofer (2011a), who find an asymmetric relationship between raw materials and finished goods. Specifically, they observe that raw materials affect finished goods more than vice versa and conclude that raw materials have both a direct and an indirect effect, via finished goods, on financial performance. We show that raw materials efficiency has a direct and indirect impact on firm performance via finished goods. The latter is also true for work-in-process efficiency. Thus, although we do not find a significant direct impact being exerted by work-in-process efficiency on firm performance, this inventory component may have an indirect effect through finished goods.

Managerial implications

The study's findings also generate useful implications for managerial practice. First, managers should consider the differing performance outcomes generated by different inventory types, not only in terms of magnitude, but also in terms of longevity. As our analysis shows, the impact of inventory components (financial performance) on financial performance (inventory components) differs substantially. While our results show a positive response being exerted by financial performance to shocks associated with both raw materials and finished goods efficiency, managers should first and foremost focus their efforts on increasing finished goods efficiency (followed by raw materials). The magnitude of the response exhibited by financial performance to a shock in finished goods efficiency is much stronger than the magnitude of the response triggered by raw materials efficiency. Furthermore, the impact exerted by finished goods on firm performance is more enduring. We conduct an analysis of inventory-to-sales ratios over time with panel data regression models in a manner comparable to Chen et al. (2005) and Gaur et al. (2005) (see Appendix 5 for further details). Our trend analysis of inventory holding reveals that German manufacturing firms have significantly reduced work-in-process inventory over time, while raw materials and finished goods inventories still stand at a high level. It seems as if firms have reduced inefficiencies in their internal processes, on the one hand, but continue to hold larger stocks of raw materials that are readily available for production and that ensure better customer service levels by providing a buffer of finished goods, on the other hand. Thus, managers should think about reducing raw materials and finished

goods inventories in order to boost financial performance in subsequent periods, because these inventory components provide the largest potential to improve firm performance. But managers should not expect to improve their firm's performance by (further) reducing their work-in-process inventories.

Second, managers could use additional financial slack as a means to hold larger raw materials and work-in-process inventories as a buffer against uncertain supply and to ensure that they can run their manufacturing processes efficiently even if there is a breakdown. In contrast, our results suggest that a negative shock triggered by financial performance leads to lower stocks of raw materials and lower stocks of work-in-process being held, indicating that managers of less financially successful firms may use inventory reductions as a way of boosting liquidity.

Third, based on our analysis of variance decompositions, managers should analyze immediately changes in both inventory components and firm performance, as they contain helpful information about the long-run fluctuations in each respectively. Finished goods explain the largest amount of the variance in financial performance among the inventory components. Financial performance is a more powerful indicator of long-run changes in raw materials and work-in-process efficiency than in the other inventory components.

Fourth, managers should consider dynamic interactions among inventory components that lead to indirect effects on firm performance. Inventory levels of one particular inventory type should not be planned without taking into account potential interactions with the other two components. Given that performance impacts inventory decisions as well, managers should be aware of the dynamic relationships between inventory types and firm performance.

Limitations and avenues for further research

Despite the importance of our findings, there are limitations to our study that provide avenues for further research. First, by focusing on German manufacturing firms, we provide interesting insights for a major European economy. However, country-specific and industry-specific conditions may differ and affect the inventory-performance relationship differently. Thus, it may not be possible to generalize the results beyond the German manufacturing sector. Future research could look at

whether the results for other countries and/or other industries (e.g. retail) remain the same.

Second, we had to aggregate the data to a yearly level because quarterly data coverage for Germany manufacturing firms in Thomson Reuters Datastream is very poor. Studies which are able to analyze data on a quarterly or monthly data might provide more in-depth insights into the inventory-performance link.

Third, our data is pooled at firm level. However, the relationship between inventory efficiency and firm performance may differ at the plant or product level as a result of differing demand or supply characteristics. Thus, disaggregating data at manufacturing plant or product level could help guard against an aggregation bias. In summary, further research is necessary to gain a better understanding of the dynamic relationships between inventory efficiency and firm performance.

6. Conclusion

This study provides a more comprehensive view of inventories to the empirical inventory management literature. To address the question of whether and how raw materials, work-in-process and finished goods are related to firm performance, we analyzed interdependent interactions among those individual inventory components (themselves) and a firm's financial performance. Our results show that the inventory performance link is more complex than typically assumed as there are interdependent relationships between inventory efficiency and firm financial performance, and complex interactions among inventory components themselves. Regarding the impact of inventory efficiency on firm performance, our results suggest that higher inventory efficiency leads to higher financial performance in the case of raw materials and finished goods efficiency. The impact of work-in-process efficiency is not significant. Furthermore, our analysis enables to investigate the longevity of performance outcomes of different inventory components. Finished goods efficiency not only more strongly influence firm performance but also has a longer lasting impact. The impact of financial performance on inventory components shows that higher (lower) financial slack leads to higher (lower) raw materials and work-in-process inventories.

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Appendix

Appendix 1: Standardized coefficients and goodness of fit criteria of the multiple discriminant analysis

| Run | X_1 | X_2 | X_3 | X_4 | X_5 | % correct | Wilk's Lambda | p |
|-----|-------|-------|-------|-------|-------|-----------|---------------|-------|
| 1 | 0.15 | 0.30 | -1.01 | -0.54 | 0.08 | 67.4 | 0.84 | 0.010 |
| 2 | 0.32 | 0.60 | 0.21 | 0.25 | -0.02 | 79.3 | 0.80 | 0.001 |
| 3 | 0.43 | -0.27 | 0.65 | 0.46 | 0.29 | 68.5 | 0.83 | 0.005 |
| 4 | -0.21 | -0.25 | -0.51 | -0.52 | -0.11 | 78.3 | 0.76 | 0.000 |
| 5 | 0.49 | -0.53 | 0.69 | 0.36 | 0.19 | 70.7 | 0.80 | 0.001 |
| 6 | 0.45 | -0.40 | 0.84 | -0.25 | -0.24 | 77.2 | 0.87 | 0.029 |
| 7 | 0.50 | -0.26 | 0.65 | 0.21 | -0.05 | 76.1 | 0.83 | 0.007 |
| 8 | 0.65 | -0.71 | 0.72 | 0.33 | 0.18 | 73.9 | 0.79 | 0.001 |
| 9 | 0.46 | -0.48 | 0.75 | 0.36 | 0.27 | 73.9 | 0.86 | 0.026 |
| 10 | -0.22 | 0.26 | -0.85 | -0.43 | -0.18 | 72.8 | 0.82 | 0.005 |
| 11 | 0.20 | -0.32 | 0.72 | 0.57 | 0.42 | 71.7 | 0.81 | 0.003 |
| 12 | -0.31 | -0.10 | -0.68 | -0.43 | -0.05 | 77.2 | 0.75 | 0.000 |
| 13 | -0.34 | 0.33 | -0.80 | -0.30 | -0.28 | 73.9 | 0.77 | 0.000 |
| 14 | 0.94 | -0.79 | 0.70 | -0.31 | 0.24 | 76.1 | 0.76 | 0.000 |
| 15 | 0.68 | -0.73 | 0.66 | 0.39 | 0.19 | 76.1 | 0.78 | 0.001 |
| 16 | 0.16 | -0.09 | 0.65 | 0.64 | 0.36 | 77.2 | 0.74 | 0.000 |
| 17 | 0.40 | -0.16 | 0.63 | 0.44 | -0.05 | 73.9 | 0.83 | 0.007 |
| 18 | 0.12 | -0.31 | 0.79 | 0.61 | 0.22 | 72.8 | 0.83 | 0.005 |
| 19 | 0.54 | -0.34 | 0.73 | 0.42 | 0.50 | 73.9 | 0.79 | 0.001 |
| 20 | -0.37 | -0.08 | -0.69 | -0.23 | -0.11 | 77.2 | 0.82 | 0.004 |
| 21 | -0.32 | 0.07 | -0.74 | -0.31 | 0.12 | 78.3 | 0.85 | 0.014 |
| 22 | 0.58 | -0.66 | 0.75 | 0.56 | 0.15 | 73.9 | 0.82 | 0.004 |
| 23 | 0.44 | -0.38 | 0.76 | 0.37 | 0.16 | 73.9 | 0.81 | 0.003 |
| 24 | 0.11 | -0.13 | 0.87 | 0.34 | 0.14 | 77.2 | 0.78 | 0.000 |
| 25 | 0.25 | -0.29 | 0.85 | 0.35 | 0.25 | 78.3 | 0.78 | 0.001 |
| 26 | 0.14 | -0.16 | 0.83 | 0.36 | 0.15 | 76.1 | 0.79 | 0.001 |
| 27 | 0.60 | -0.66 | 0.78 | 0.25 | 0.09 | 71.7 | 0.85 | 0.012 |
| 28 | 0.50 | -0.44 | 0.79 | 0.34 | 0.14 | 79.3 | 0.76 | 0.000 |

Note: Note: Significance of coefficients not reported here. X_1 = Working capital/total assets; X_2 = retained earnings/total assets; X_3 = earnings before interest and tax/total assets; X_4 = market value of capital/total liabilities; X_5 = sales / total assets.

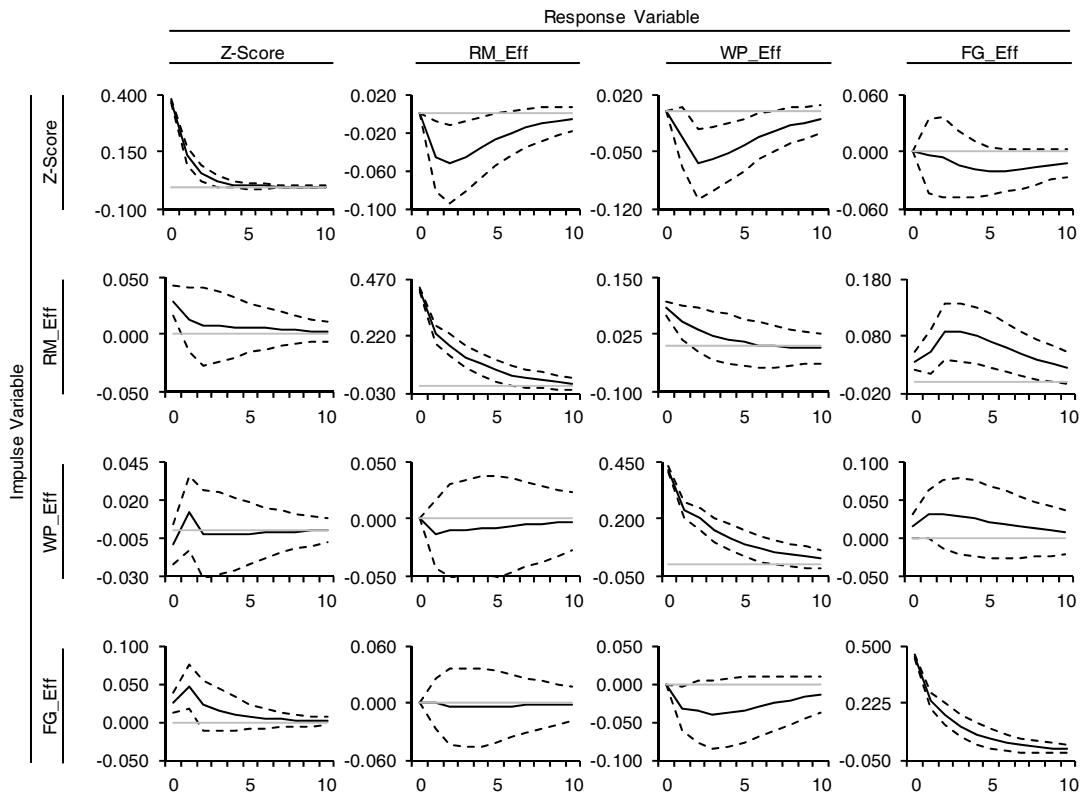
Appendix 2: PVAR estimation results

| Independent | Dependent Variable | | | |
|------------------------|--------------------|----------------------|----------------------|---------------------|
| | Z-Score | RMS | WIPS | FIGS |
| RM_Eff(t-1) | -0.007 (-0.22) | 0.547*** (11.95) | 0.020 (0.49) | 0.067* (1.67) |
| RM_Eff(t-2) | 0.004 (0.16) | 0.140*** (4.31) | -0.009 (-0.33) | 0.088*** (2.99) |
| WP_Eff(t-1) | 0.032 (1.11) | -0.035 (-1.00) | 0.577*** (13.97) | 0.054 (1.40) |
| WP_Eff(t-2) | -0.040* (-1.93) | 0.016 (0.58) | 0.156*** (4.48) | 0.000 (0.00) |
| FG_Eff(t-1) | 0.084*** (2.76) | 0.007 (0.24) | -0.068** (-2.06) | 0.538*** (11.84) |
| FG_Eff(t-2) | -0.032 (-1.53) | 0.000 (0.00) | 0.013 (0.53) | 0.103*** (2.67) |
| Z-Score(t-1) | 0.354*** (7.22) | -0.120** (-2.43) | -0.084* (-1.66) | -0.011 (-0.21) |
| Z-Score(t-2) | 0.028 (0.81) | -0.036 (-1.34) | -0.093*** (-3.21) | 0.009 (0.33) |
| Size | -0.061 (-0.49) | -0.203 (-1.21) | -0.067 (-0.39) | 0.148 (0.86) |
| Leverage | -0.214 (-0.79) | -0.962*** (-3.11) | -0.138 (-0.42) | 0.156 (0.52) |
| Sales Growth | 0.368*** (3.78) | 0.080 (0.76) | 0.021 (0.22) | 0.236** (2.11) |
| Demand Uncertainty | 0.104 (0.55) | 0.132 (0.78) | 0.063 (0.35) | -0.291 (-1.42) |
| HHI | -0.127 (-0.53) | -0.236 (-0.85) | 0.157 (0.52) | 0.051 (0.18) |
| Market Share | -0.62 (-1.32) | 0.32 (0.60) | -0.07 (-0.12) | 0.41 (0.73) |
| PSS | 0.05** (2.12) | 0.00 (0.11) | -0.05* (-1.90) | -0.03 (-0.99) |
| Accounts Payable | (0.01)*** 4.09 | 0.01** (2.15) | (0.00) 0.55 | (0.00) 1.08 |
| Number of firms | | 332 | | |
| Number of observations | | 3,028 | | |

Notes: The PVAR model is estimated by GMM, time fixed effects are removed prior to estimation. z-values are reported in parentheses. Z-Score: Financial performance measured by Altman's (1968) Z-Score. RM_Eff: raw materials efficiency. WP_Eff: work-in-process efficiency. FG_Eff: finished goods efficiency. HHI: Herfindahl-Hirshman Index. PSS: Positive sales surprise.

*, **, and *** denote statistical significance at 10%, 5%, and 1% levels, respectively.

Appendix 3: Impulse response functions with 95% confidence intervals for firm performance and inventory types



Note: This figure illustrates the impulse response functions (IRFs) of each endogenous variable with respect to one standard deviation shock in other variables. Horizontal axes show the number of periods. Dotted lines are the 95% confidence intervals and are generated by Monte-Carlo simulation.

Z-Score: Financial performance measured by Altman's (1968) Z-Score. RM_Eff: raw materials efficiency. WP_Eff: work-in-process efficiency. FG_Eff: finished goods efficiency.

Appendix 4: Relationship between total inventories and financial performance

(1) Unit root test of inventory efficiency

Inverse normal Z: -9.683; $p = 0.0000 \Rightarrow$ stationary

(2) Panel Granger non-causality tests for inventory efficiency and Z-Score

| χ^2 | Inv_Eff | Z-Score |
|----------|---------|-----------|
| Inv_Eff | -- | 13.613*** |
| Z-Score | 6.213 | -- |

(3) Stability condition

| Eigenvalue | | |
|------------|-----------|---------|
| Real | Imaginary | Modulus |
| 0.877 | 0.000 | 0.877 |
| 0.450 | 0.266 | 0.523 |
| 0.450 | -0.266 | 0.523 |
| -0.002 | -0.425 | 0.425 |
| -0.002 | 0.425 | 0.425 |
| -0.267 | 0.319 | 0.416 |
| -0.267 | -0.319 | 0.416 |
| -0.296 | 0.000 | 0.296 |

(4) PVAR estimation results for inventory efficiency and Z-Score

Optimal lag order: 4

| Independent | Dependent variable | |
|------------------------|---------------------|---------------------|
| | Z-Score | Inv_Eff |
| Inv_Eff _{t-1} | -0.008 (-0.23) | 0.601*** (12.87) |
| Inv_Eff _{t-2} | -0.057** (-2.25) | 0.062* (1.78) |
| Inv_Eff _{t-3} | -0.033 (-1.32) | 0.069** (2.09) |
| Inv_Eff _{t-4} | -0.044** (-2.22) | 0.024 (0.87) |
| Z-Score _{t-1} | 0.341*** (4.95) | -0.073 (-0.89) |
| Z-Score _{t-2} | 0.048 (1.24) | 0.009 (0.21) |
| Z-Score _{t-3} | 0.043 (1.22) | -0.063** (-2.00) |
| Z-Score _{t-4} | -0.022 (-0.62) | -0.039 (-1.26) |
| Size | -0.062 (-0.37) | 0.146 (0.55) |
| Leverage | 0.273 (0.70) | -0.057 (-0.12) |

Table continued

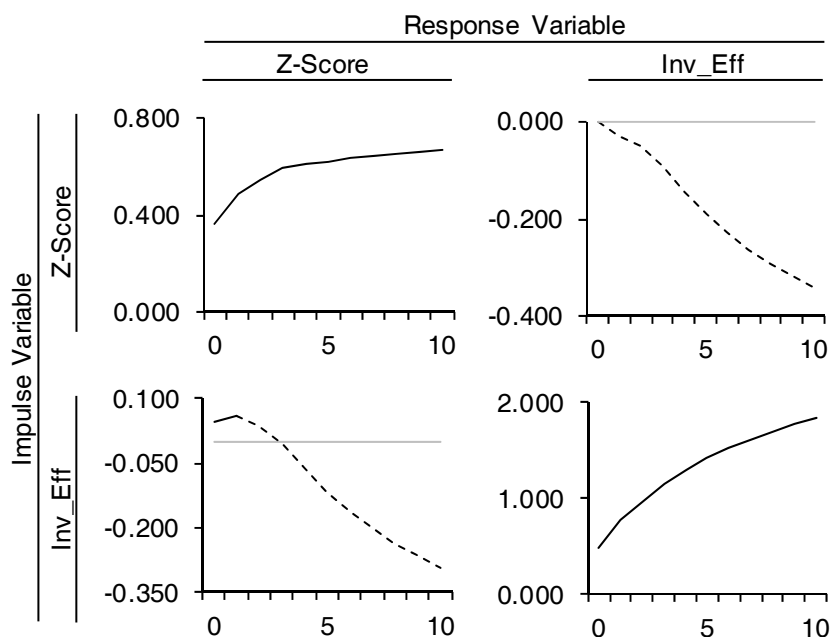
| | | |
|--------------------|----------|----------|
| Sales Growth | 0.218* | 0.126 |
| | (1.68) | (0.84) |
| Demand Uncertainty | 0.056 | 0.030 |
| | (0.19) | (0.11) |
| HHI | 0.197 | -0.016 |
| | (0.57) | (-0.03) |
| Market Share | -0.887 | -1.812** |
| | (-1.47) | (-2.29) |
| PSS | 0.069** | 0.004 |
| | (2.37) | (0.12) |
| Accounts Payable | 0.012*** | 0.015*** |
| | (3.11) | (2.86) |
| No. firms | 332 | |
| No. obs. | 3,028 | |

Notes: The PVAR model is estimated by GMM, time fixed effects are removed prior to estimation. Z values are reported in parentheses.

Z-Score: Financial performance measured by Altman's (1968) Z-Score. Inv_Eff: inventory efficiency. HHI: Herfindahl-Hirshman Index. PSS: Positive sales surprise.

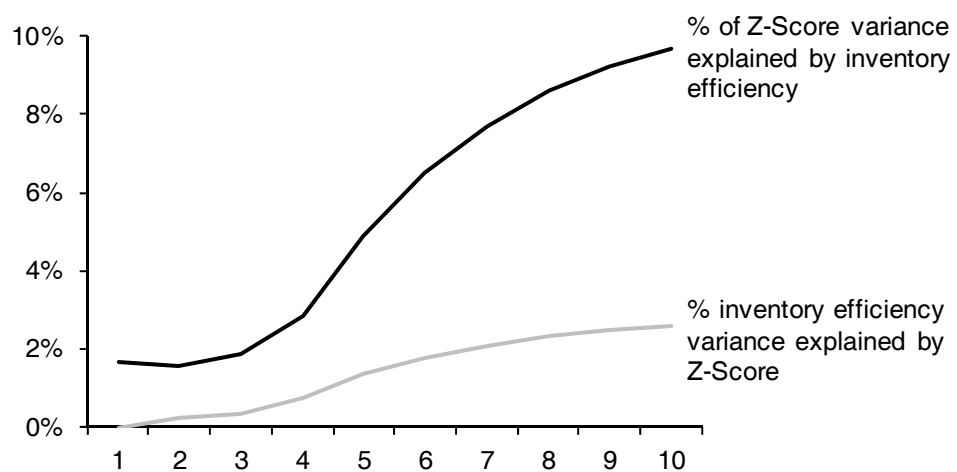
*, **, and *** denote statistical significance at 10%, 5%, and 1% levels, respectively.

(5) Long-term (cumulative) effects of the Impulse Response Functions from the PVAR model for total inventory efficiency and financial performance



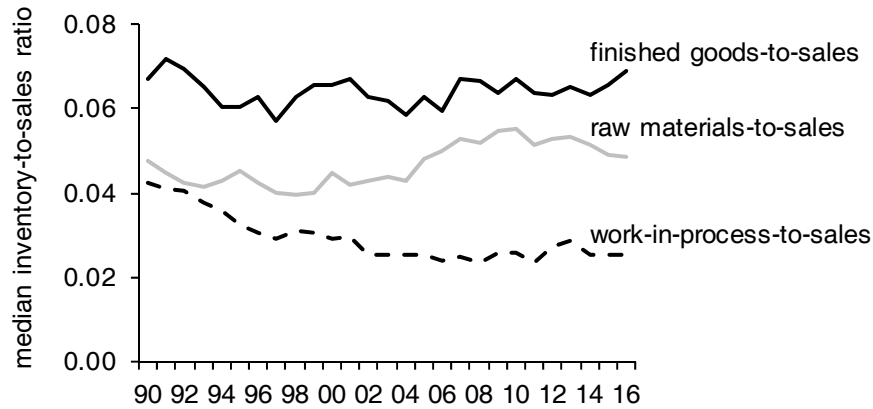
Note: The solid parts of the lines are significant impulse responses at the 5% level based on 1,000 times Monte-Carlo simulation.

(6) Explained variance of performance and inventory types



Appendix 5: Trend analysis

(1) Median inventory-to-sales ratios for raw materials, work-in-process and finished goods



(2) Time trend of inventory-to-sales ratios

| | Raw materials | Work-in-process | Finished goods |
|--------------------|----------------------|----------------------|----------------------|
| Time trend | -0.003 (-0.83) | -0.031*** (-5.46) | 0.000 (-0.06) |
| Size | -0.043 (-1.08) | 0.123* (1.77) | 0.09** (2.40) |
| PSS | -0.019 (-1.23) | -0.051** (-2.54) | -0.06*** (-3.23) |
| Gross Margin | -0.03 (-0.55) | -0.048 (-0.96) | 0.058 (1.21) |
| Sales Growth | -0.004 (-0.99) | -0.016** (-2.03) | -0.005 (-0.78) |
| Demand Uncertainty | -0.017 (-1.17) | 0.001 (0.06) | -0.023 (-1.21) |
| Accounts Payables | 0.152*** (3.96) | 0.115** (2.29) | 0.108*** (3.04) |
| Constant | -2.276*** (-4.22) | -4.533*** (-5.41) | -3.702*** (-7.53) |
| N | 4,851 | 4,851 | 4,851 |
| R ² | 0.023 | 0.077 | 0.023 |

Notes: All models contain firm fixed effects. T-values are reported in parentheses. We estimate the following regression model (comparable to Chen et al. 2005; Rummyantsev and Netessine 2007):

$$\log\left(\frac{inv}{sales}\right)_{it} = \alpha + \beta_1 (year - 1990) + \sum_{k=1}^6 \beta_k \log(CV)_{k,it} + u_i + \varepsilon_{it},$$

where $\frac{inv}{sales}$ is the inventory-to-sales ratio (raw materials, work-in-process or finished

goods) of firm i in year t and $CV_{k,it}$ is a vector of control variables (Size, PSS, Gross margin, Sales Growth, Demand Uncertainty, Accounts Payables). We use robust standard errors clustered at the firm level.

Z-Score: Financial performance measured by Altman's (1968) Z-Score. PSS: Positive sales surprise. Accounts payable is the calculated as accounts payables divided by sales.

*, **, and *** denote statistical significance at 10%, 5%, and 1% levels, respectively