A Test of Inventory Models with Permissible Delay in Payment

Journal:	*International Journal of Production Research*
Manuscript ID	TPRS-2015-IJPR-0762.R1
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	18-May-2016
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Keywords:	SUPPLY CHAIN MANAGEMENT, EMPIRICAL STUDY, FINANCIAL MANAGEMENT, MODELLING
Keywords (user):	Permissible Delay in Payment

Response to Reviewers

Overview of the changes implemented

Thank you for the opportunity to revise and resubmit our manuscript titled "A Test of Inventory Models with Permissible Delay in Payment".

The following major changes have been made. We:

- Rewrote and adjusted large parts of the paper to improve readability and flow by adding:
  - more explanations, comments and justifications
  - more elaborate definitions
  - a summary table of main results
- Rewrote and expanded the conclusion section to include subsections on managerial implications, implications for research and future research

Below we have listed each reviewer's comments and our detailed response in italic font. Since we have made substantial revisions to both the presentation and the content of the paper, we sometimes refer to the revised manuscript to improve readability.

Detailed replies:

Reviewer 1

The paper has good findings and the idea is innovative. I think it is publishable after some do-able changes:

Response: Thank you for your comments. We have taken your suggestions to heart and have made subsequent changes to the manuscript.

1. The current writing should be expanded. I suggest the authors add some more elaborated writings after presenting each major analytical result. In particular, some managerial insights should be offered. To enhance the contribution, the author could provide more explanations for the reasons why the conclusions are different with some existing literature.

Response: We agree that are results could be more elaborately explained and that the potential implications should be discussed. We have tried to address this comment all the while balancing the fact that our manuscript exceed the maximum length for IJPR. We have made the following changes:

1. *We have completely rewritten the conclusion section and have added subsections on managerial implications, implications for research and future research. We have chosen to discuss managerial insights here rather than in the results and discussion section*
2. *In addition to point 1) we have provided brief but more elaborate explanations of our results directly in the Results section, in particular by more explicitly referring back to the tables.*

2. The authors had better provide detailed description for the abbreviation in equitation (6) and (7) which will make it easier for the readers to understand.

Response: In relation to equation (6) and (7) we have made direct reference to Table 4 with complete variable definitions. Table 4 has also been expanded to explain all individual variables and their constituents.

Reviewer: 2
It is interesting that this paper investigates the issue of permissible delays in payment from both financial view and the operations management view. Applying three datasets, this empirical study achieved some conclusions that could be useful for researchers and practitioners in this area. This paper actually is suitable for publication under some improvements. For example, Section 6 (econometric specification) could be revised, since the roles of the first five equations and the other two models are not clear. One or more tables could be provided to demonstrate the findings, including the verifications of hypotheses. Not just the descriptions in the text.

Response: Thank you for your positive feedback. As you suggested we have revised Section 6 to better explain the roles of the different equations. In essence, equations 1-5 serve to explain the inconsistencies between the operations management and the finance literature, which we argue are due to omitted variable bias in the empirical finance literature. Using these insights we specify two econometric models (equation 6 and 7), which are used to test our hypotheses using secondary data.

Also according to your suggestions, we have added a table in the reworked conclusion section that summarizes the verification of our hypothesis.

Reviewer: 3
This paper set out to reconcile the finance view with the operations management view of payment delays by applying a secondary data approach to operations management theory. The authors concluded that firm profitability is positively associated with payment delay; payment delay is positively associated with the capital cost difference between buyer and supplier and negatively with the price elasticity of demand and the deterioration rate of inventory, and so on. Overall, I do not find these results providing me with substantially insights into the question of operations management. I would classify it as a minor extension to existing work because it does not open up a new problem area or develop new methodologies for tackling existing problems. So, I believe, the contributions do not justify publication as a full paper. If the journal accepts “Technical Notes” then I would recommend publishing it is as such. If so, then the paper needs to be significantly shortened.

Response: Thank you for your comments and for taking the time to review our paper. In the revised version we have tried to better highlight our contribution to both practice and research. You will find a discussion about the implications of our study in the reworked conclusion section.

We motivate our study with conflicting results in the theoretical operations management and the empirical finance literature (and within the operations management literature). Using a secondary data approach we can shed new light on these discrepancies at the same time as providing novel insights for managers and researchers.

In general, we would like to highlight that it is common practice in many disciplines, such as economics, to test theoretical models using secondary data. Stylistics models inevitably makes assumption but can provide very granular and interesting insights into managerial problems. By testing these insights with data and showing that they actually work we can increase the credibility of such models and maximizing the diffusion of operations management theory to practitioners.

Dear reviewers, thank you for the helpful and constructive comments!

A Test of Inventory Models with Permissible Delay in Payment

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Keywords: Supply Chain Management; Empirical Study; Financial Management; Modelling; Permissible Delay in Payment

May 18, 2016

A Test of Inventory Models with Permissible Delay in Payment

Abstract

Contrary to the long-standing view in the finance literature that firms should maximize payment delays, research in operations management suggests that long payment delays can be suboptimal. In this study, we reconcile these two views by applying a secondary data approach to established operations management theory. Based on a sample of 3,383 groups of public US firms from a novel database we find that our data are consistent with the causal relations and theoretical predictions of the operations management literature. Firm profitability is positively associated with payment delay. Payment delay, in turn, is positively associated with the capital cost difference between buyer and supplier and negatively associated with the price elasticity of demand and the deterioration rate of inventory. However, we do not observe any significant interaction effects between these factors, which raises a number of questions for future research.

Keywords: Supply Chain Management; Empirical Study; Financial Management; Modelling; Permissible Delay in Payment

1 Introduction

Firms commonly rely on supplier credit to purchase inventory. As a result, inventory models with permissible delay in payment determine the optimal order quantity and payment delay simultaneously. Contrary to the long-standing view in the finance literature that firms should maximize payment delays (Soenen, 1993; Jose et al., 1996; Shin and Soenen, 1998; Deloof, 2003; García-Teruel and Martínez-Solano, 2007), these inventory models suggest that long payment delays can be suboptimal (Kim et al., 1995; Jamal et al., 2000; Jaber and Osman, 2006). In fact, in some situations even immediate payment can be optimal (Abad and Jaggi, 2003).

These differing conclusions are the outcome of fundamentally different approaches in theory and methodology. First, while the finance literature examines single firms, the operations management literature analyzes supply chains consisting of firms, suppliers, and customers. Because firms often differ from their suppliers and customers in their operational and financial parameters, joint optimization generates above average profits that can require immediate payment. Second, while the finance literature derives most of its insights from secondary data, the operations management literature draws predominantly on analytical models. Analytical models, however, consider stylized representations that may not necessarily fully reflect business realities in which numerous factors and decisions come into play.

In this study we reconcile these two views by applying a secondary data approach to operations management theory. Thus, we investigate if the empirical reality of firm profitability and payment delays is consistent with the theoretical predictions of inventory models with permissible delay in payment. Consistency would have three major implications. First, it would support the validity of the causal relations presented in the operations management models. Second, it would demonstrate the relevance of such analytical models and position them as an important source of insight for managers. Finally, it would suggest a shift in business practice from acting in isolation towards joint optimization and subsequent benefit allocation among supply chain partners.

As predicted by analytical operations management models, we find that firm profitability is positively associated with payment delay. Payment delay, in turn, is positively associated with the capital cost difference between buyer and supplier and negatively associated with the price elasticity of demand and the deterioration rate of inventory. In contrast to the sensitivity analyses presented in the modeling literature, however, only price elasticity seems to be economically important. Furthermore, we do not observe any significant interaction effects between these factors. Thus, while the modeling literature seems to correctly prescribe how to manage payment delays, firms do not seem to adhere to these models in practice. Potential explanations may be smaller than projected economic benefits, the existence of confounding trade credit motives, and the actual diffusion of such models in practice. These competing explanations motivate future research and hint at a learning opportunity for firms to seize untapped benefits.

The rest of this article is organized as follows. Section 2 reviews the related literature. Section 3 develops the research hypotheses. Section 4 describes the data and Section 5 describes the variables. Section 6 presents the econometric specification and Section 7 discusses the results. Section 8 concludes.

2 Literature review

Three literature streams are directly related to our study. The first is the operations management literature that optimizes inventory and payment delays using mathematical models. The second is the operations management literature that empirically analyzes inventories. The third is the finance literature that empirically links inventory, trade credit, and firm profitability.

The first is central to our study as we directly test its predictions with empirical data. We therefore discuss it in more detail than the other literature streams. In contrast to classical inventory models, this literature optimizes both inventory and payment delays simultaneously. Often, the optimization involves a firm and a supplier with different operational and financial parameters. Thus, these models implicitly provide a number of testable predictions about how these parameters relate to each other (see Table 1). We return to these predictions in the next section when we develop the formal hypotheses.

As part of this first literature stream, Haley and Higgins (1973) develop a deterministic model for calculating the optimal order quantity and payment delay when a supplier offers two-part terms. Kim et al. (1995) develop a deterministic model for optimizing the supplier's credit period if she follows a lot-for-lot policy. Assuming a fixed wholesale price and non-cooperative behavior, they solve her problem based on expected retailer behavior. Jamal et al. (2000) and Sarker et al. (2000) develop a retailer's model for optimal cycle and payment time in a deteriorating-item inventory situation. Abad and Jaggi (2003) present a deterministic, infinite horizon, lot-for-lot model, based on economic order quantity techniques, to calculate an optimal unit price and credit period for a supplier. They assume constant price elasticity and consider both cooperative and non-cooperative behaviors. Jaber and Osman (2006) develop a similar model but do not require the supplier to follow a lot-for-lot policy. Song and Cai (2006) build on Jamal et al. (2000) and show that a single decision variable suffices to solve the optimization problem. Shi and Zhang (2007) and Shi et al. (2007) present models that additionally determine the retailer's optimal payment delay and propose that it should always be shorter than the credit period. More recent studies that show a positive link between trade credit and capital cost differences include Shi and Zhang (2010); Zhou and Zhou (2013); Luo and Zhang (2012). Musa and Sani (2012) investigate delayed deteriorating items and find that the credit term should decrease with the deterioration rate. Many other papers model similar problems without including (or without directly analyzing) capital cost differences, price elasticity, or deterioration rates and we therefore do not present them in detail (e.g. Jaggi et al., 2008; Gupta and Wang, 2009; Ouyang et al., 2009; Charharsoogi and Heydari, 2010; Kouvelis and Zhao, 2012; Wu et al., 2014; Chern et al., 2013; Zhao et al., 2014). We refer to Seifert et al. (2013) for a recent review of the trade credit literature.

The second literature stream investigates inventories empirically. Chen et al. (2005, 2007) analyze inventory trends over 20 years in the manufacturing and retail sector in the US to link inventory levels to financial returns. Lai (2005) documents a reciprocal association between inventory management and stock price performance. Gaur et al. (1999) analyze firm-level inventory data in the retail sector and link it to capital intensity, sales surprise, and gross margin. Fisher and Ittner (1999) link product variety in automotive assembly plants to operational performance. Eroglu and Hofer (2011) and Isaksson and Seifert (2014) focus on leanness, rather than absolute inventory levels, and find an inverted U-shaped association between inventory leanness and financial performance. Methodologically, our study is closely related to Lieberman et al. (1999) and Rumyantsev and Netessine (2007) who test inventory theory propositions by investigating whether classical inventory models explains the levels of inventory held in practice.

Finally, the third literature stream links inventory, trade credit, and firm profitability using secondary data. Early contributions in this area treat working capital as a compound construct and find that firm profitability is negatively associated with working capital intensity (Soenen, 1993; Shin and Soenen, 1998; Jose et al., 1996; Wang, 2001). Deloof (2003) splits the working capital compound into accounts receivable, inventory, and accounts payable and separately links each to firm profitability. He finds that firm profitability is negatively associated with accounts receivable and inventory but, unexpectedly, also with accounts payable and suspects that endogeneity biases the results. García-Teruel and Martínez-Solano (2007) implement an instrumental variable approach to circumvent the endogeneity problem but obtain insignificant results.

This study contributes to the operations management literature in three ways. Most importantly, we provide an empirical test of inventory models with permissible delay in payment, which addresses the question of whether the causal relations and theoretical predictions of these models are consistent with business realities. Second, we provide empirical estimates of parameter sensitivities, addressing the question of economic relevance for practicing managers. Finally, we provide a first discussion of payment delay dynamics and thus long-term implications of working capital improvement programs. We also contribute to the finance literature by demonstrating both theoretically and empirically how to avoid omitted variable bias when regressing firm profitability on days payable.

3 Hypotheses

If production and transportation lead times, stochastic demand, or credit periods cause cash inflows to arrive after raw materials and supplies have to be paid for, firms face a financial gap known as trade working capital requirement. This gap can be bridged with either equity or with debt but in each case the firm incurs financial costs. Therefore, it is in the firm's interest to reduce this gap. One way to do so is to delay cash outflows. Delayed cash outflows essentially transfer part or all of the whole financial burden to the supplier and thus reduce the firm's financial costs. For this reason, all inventory models with permissible delay in payment add avoided interest charges to the firm's profits (see Table 1). Since our goal in this study is to empirically verify these models' propositions and since previous empirical research on this issue remains inconclusive, we test whether

Hypothesis 1 *Firm profitability is positively associated with payment delay.*[1]

The delayed cash outflow causes additional costs at the supplier's end. These additional costs, however, do not necessarily equal the firm's savings. Since the firm and the supplier may finance investments at different rates, the supplier's additional costs may fall below or exceed the firm's savings. Therefore, both the firm and the supplier may exhibit different attitudes towards payment delay during purchase negotiations. If the firm attributes a higher value to a payment delay than the supplier does, the discussion will likely shift from price reductions to payment delays. Therefore, the majority

[1]We state our research hypotheses in alternate form throughout the text.

Table 1: Overview of modeled associations

	Firm profitability	Days payable		
Author(s)	Days payable	Capital cost difference	Price elasticity	Deterioration rate
Haley and Higgins (1973)	+	+	?	?
Kim et al. (1995)	+	?	+	?
Jamal et al. (2000)	+	?	?	−
Sarker et al. (2000)	+	?	?	−
Abad and Jaggi (2003)	+	+	−	?
Jaber and Osman (2006)	+	+	?	?
Song and Cai (2006)	+	?	?	−
Shi and Zhang (2007)	+	+	+	?
Shi et al. (2007)	+	+	+	?
Shi and Zhang (2010)	+	+	?	?
Luo and Zhang (2012)	+	+	?	?
Musa and Sani (2012)	+	?	?	−
Zhou and Zhou (2013)	+	+	?	?

Note. A question mark designates that the study makes no statements about the relationship.

of inventory models with permissible delay in payment (Haley and Higgins, 1973; Abad and Jaggi, 2003; Jaber and Osman, 2006; Shi and Zhang, 2007; Shi et al., 2007; Shi and Zhang, 2010; Luo and Zhang, 2012; Zhou and Zhou, 2013) predict that

Hypothesis 2 *Payment delay is positively associated with the capital cost difference between firm and supplier.*

Next to capital costs, a second factor may influence the length of the payment delay. If the firm faces customers whose demand is highly price elastic, it may not be able to charge high prices and may become price sensitive, too. While this price sensitivity is unlikely to change the firm's trade credit demand, the accompanying price pressure may impact the supplier's revenues. Abad and Jaggi (2003) therefore conclude that it is unprofitable for a supplier to offer low prices in combination with payment delays. Thus, they predict that payment delay is *negatively* associated with the price elasticity of demand. Other models, however, conclude that high price elasticity renders payment delays especially valuable (Kim et al., 1995; Shi and Zhang, 2007; Shi et al., 2007). Because demand reacts more to price changes and because lengthening payment delays is economically equivalent to reducing prices, these models predict that payment delay is *positively* associated with the price elasticity of demand. Since the literature holds opposing views, our two-tailed hypothesis is limited to

Hypothesis 3 *Payment delay has a non-zero association with the price elasticity of demand.*

In many cases, permissible delays in payment consist of an interest-free and a non-interest-free period. Suppliers realize these interest charges either through early payment discounts or through late payment penalties (Howorth and Reber, 2003; Ng et al., 1999; Smith, 1987). Depending on production lead times and permissible delays in payment, firms may begin selling their products before the end of the interest-free period and earn interest on their sales. Then, it may be a profitable strategy to delay payments beyond the interest-free period up to a point where marginal costs equal marginal revenues. A special situation arises when purchased inventories are perishable. If finished goods inventories decrease due to deterioration, e.g., due to specific chemical properties, the deterioration decreases these marginal revenues. Thus, some inventory models with permissible delay in payment (Jamal et al., 2000; Sarker et al., 2000; Song and Cai, 2006; Musa and Sani, 2012) predict that

Hypothesis 4 *Payment delay is negatively associated with the deterioration rate of inventory.*

4 Data

The aforementioned hypotheses contain statements that depend on the firm and its suppliers. We therefore combined two financial databases with a novel database – Revere Relationships – containing information about commercial relations between North American firms. First, we downloaded quarterly financial information from Compustat. We imposed a time window of Q4/2003 through Q3/2008 because of data availability in Revere Relationships. We deleted negative observations for sales; cost of goods sold; sales, general and administrative expenses; depreciation; interest; and all balance sheet items except equity. Second, we downloaded stock price information from the Center for Research in Security Prices (CRSP) but did not treat the data in any way. Third, we downloaded supplier information from Revere Relationships, a recently compiled database containing information on a firm's suppliers, customers, and rivals for approximately 30,000 companies.

We merged the Compustat/CRSP database with the Revere Relationships database using three contingent steps. We first matched firms on CUSIP security identifiers. If a CUSIP match failed, we matched firms on ticker information. If the ticker match failed, too, we matched firms by their names using a sequence matching algorithm. We reviewed all matches manually and tended to be conservative.

To construct our sample we began by selecting all observations where at least one supplier was known (45,106 observations). Next, we excluded all financial institutions (SIC codes 6000-6999) due to the specific nature of their activities. We also dropped all observations with income exceeding sales or with book value of debt exceeding assets. Similar to previous studies (Isaksson and Seifert, 2014; Rumyantsev and Netessine, 2007) we trimmed each variable at 2.5% in each tail to remove outliers. Our results were sensitive to this trimming. However, since we are interested in explaining phenomena pertaining to the majority of firms rather than to outlying firms we retained the trimmed sample. Our final sample consisted of 40,013 observations on 3,383 buyer-supplier groups. The median observation represents a buyer with sales of USD 335.61 million, a book value of debt of USD 540.08 million, and assets of USD 1,405.20 million (Table 2). The sample is fairly evenly distributed across sectors and has buyers from nearly 60 unique two-digit SIC codes (Table 3).

5 Variables

We closely aligned our variables to previous empirical work (Table 4). We introduced two dependent variables, firm profitability and payment delay. Firm profitability was measured as return on assets (Deloof, 2003; García-Teruel and Martínez-Solano, 2007). In contrast to these contributions, however, we included interest expense because we expected interest expense and accounts payable to be interdependent (Chant and Walker, 1988) and excluded accounts payable because we wanted to avoid potential endogeneity issues. When we used the exact definitions in Deloof (2003); García-Teruel and Martínez-Solano (2007) we found no significant difference. We defined

Table 2: Buyer characteristics

Variable (USD million)	n	Mean	S.D.	Minimum	Median	Maximum
Sales	37,212	1,200.03	2,174.99	1.20	335.61	14,741.37
Cost of goods sold	36,890	778.25	1,456.52	1.35	189.79	9,918.50
Sales, general, and admin. expense	33,684	318.92	960.94	0.00	61.27	26,825.73
Depreciation	36,635	106.92	410.55	0.00	13.80	17,978.30
Interest expense	31,286	24.12	41.99	0.00	5.99	253.00
Accounts receivable	36,322	587.68	1,126.90	0.10	146.31	7,626.97
Accounts payable	36,315	421.85	871.71	0.84	83.20	6,384.00
Debt	34,259	2,430.66	4,473.06	3.70	540.08	27,741.00
Assets	36,853	5,350.40	9,442.45	20.00	1,405.20	60,928.00

Table 3: Industry breakdown

Industry	n	%
Agriculture, natural resources	1,820	4.55
Food, textiles, chemicals	7,621	19.05
Rubber, metals, machinery	5,643	14.10
Computers, electronics	5,178	12.94
Automobile, transportation	1,171	2.93
Logistics, supply	6,155	15.38
Wholesale, retail	5,138	12.84
Services	7,287	18.21
Total	40,013	100.00

the second dependent variable – payment delay – as in previous contributions by normalizing accounts payable by cost of goods sold and multiplying by 365.

For independent variables we used the following proxies. To measure capital cost difference we subtracted the suppliers' average cost of capital from the firm's cost of capital. We used a weighted average based on each supplier's share of the firm's cost of goods sold. If information on a supplier was missing, we removed the supplier. If information on the firm's cost of goods sold was missing, we replaced the weighted average with a simple average. The cost of capital was defined as the period-average cost of debt, expressed as interest expense over the book value of short-term and long-term debt. We chose cost of debt capital as our capital cost proxy because (1) inventory models with permissible delay in payment explicitly analyze the impact of short-term capital costs and (2) alternative proxies, especially proxies based on realized equity returns, can be inconsistent and unreliable (Elton, 1999; Botosan and Plumlee, 2005; Fama and French, 1992). Note, however, that our results were sensitive towards this choice. When we used a weighted average cost of capital proxy based on either the capital asset pricing model (CAPM) or historically realized returns for cost of equity capital, the

Table 4: Variable definitions

Variable	Proxy for construct	Compustat definition	Unit	Mean (25%, 50%, 75%)
ROA	Firm profitability	$\frac{SALEQ-COGSQ-XSGAQ-DPQ-XINTQ}{(ATQ-APQ)/4} \cdot 100$	Percent	6.7 (1.19, 7.04, 13.37)
APCOGS	Payment delay	$\frac{APQ/4}{COGSQ} \cdot 365$	Days	54.69 (28.6, 44.04, 65.93)
KdDiff	Capital cost difference	Firm's less suppliers' average cost of debt	Perc. points	2.63 (0.42, 2.59, 4.53)
COGSSales	Price elasticity	$\frac{COGSQ}{SALEQ}$	Ratio	0.68 (0.46, 0.64, 0.78)
Depreciation	Deterioration rate	DPQ	USD	106.92 (3.3, 13.8, 57.27)
ARSales	Days receivable	$\frac{ARQ/4}{SALEQ} \cdot 365$	Days	51.34 (34.04, 50.76, 67.36)
InvCOGS	Days inventory	$\frac{INVQ/4}{COGSQ} \cdot 365$	Days	57.32 (10.06, 43.61, 86.6)
LnSales	Firm size	$\ln(SALEQ)$	USD	5.68 (4.39, 5.83, 7.21)
SalesGrowth	Business opportunities	$\frac{SALEQ_t-SALEQ_{t-1}}{SALEQ_{t-1}} \cdot 100$	Ratio	3.22 (-4.19, 2.62, 9.84)
MarketShare	Market power	Share of sales in primary 3-digit SIC code	Percent	6.24 (0.19, 1.39, 7.34)
Leverage	Level of debt	$\frac{DLCQ+LCOQ+DLTTQ+LOQ}{ATQ} \cdot 100$	USD	39.64 (23.24, 38.91, 53.7)

Note. The variabels are constructed using the following quarterly (Q) Compustat definitions : $SALEQ$= sales
$COGSQ$= cost of goods sold, $XSGAQ$= selling, seneral and administrative expenses, DPQ= depreciation and amortization
$XINTQ$= interest and related expenses, ATQ= assets, APQ= account payable, ARQ= account receivable
$INVQ$= inventory, $DLCQ$= debt in current liabilities, $LCOQ$= current liabilities, $DLTTQ$= long-term debt
$LOQQ$= other liabilities

test of Hypothesis 2 lost statistical significance.

We measured price elasticity using a variant of the Lerner index, as expressed by the ratio of cost of goods sold to sales (Lerner, 1934; Cowling and Waterson, 1976). We also tested this proxy using the analytical results provided in Abad and Jaggi (2003) and found a strong correlation ($r = 0.89$) between the underlying price elasticity and the observed cost-sales ratio.

We measured the deterioration rate using depreciation and amortization as reported in quarterly income statements. The reason for using this proxy is that generally accepted accounting principles (GAAP) include recurring inventory write-offs in the income statement under either depreciation and amortization or cost of goods sold. Both items are readily available in the Compustat database and we employed depreciation and amortization without treating it in any way. When we tested cost of goods sold as an alternative, we obtained similar results. While both depreciation and amortization and cost of goods sold may be crude proxies, there is to our knowledge no commonly accepted way in the operations management literature to estimate deterioration.

For control variables we replicated the variables found in previous studies (e.g., García-Teruel and Martínez-Solano (2007)). We excluded, however, gross domestic product (GDP) growth, which we captured through time dummies, and included market share, which is known to significantly impact firm profitability (Hansen and Wernerfelt, 1989).

6 Econometric specification

To motivate our econometric specification and to explain the inconsistency between theory and econometric results in previous research we first discuss a simple inventory model. The purpose of equations 1-5 is to show that the diametrically different findings in the theoretical operations literature and the emipirical finance literature are, lilkely, due to omitted variable bias in the finance literature. We use these insights to specify a more appropriate economtric model (equations 6-7) that can be tested using secondary data.

Let $D(p)$ be the deterministic demand faced by a monopolistic buyer selling at price p. The buyer's gross profit is thus $D(p)(p-c)$ where c is the purchase price. In order to satisfy demand, the buyer orders Q units and incurs setup cost A and holding cost h. Thus, total inventory-related cost is $\frac{D(p)}{Q}A + \frac{Q}{2}h$. The buyer allows her customers to pay after T_1 days, which entails financial cost $D(p)pkT_1$, where k denotes short-term capital cost. At the same time, she benefits from a payment delay T_2 that reduces her costs by $D(p)ckT_2$. Then, her profit can be expressed as

$$\Pi(p,Q) = D(p)(p-c) - \left(\frac{D(p)}{Q}A + \frac{Q}{2}h\right) - (D(p)pkT_1 - D(p)ckT_2) \quad (1)$$

Contrary to this equation, previous empirical research documents that profits *decrease* as accounts payable increase (Deloof, 2003; García-Teruel and Martínez-Solano, 2007). We argue that the above equation is still correct and that these empirical findings are the result of omitted variable bias. As we will show, both accounts receivable and inventory are negatively associated with profitability and positively associated with accounts payable. Therefore, regressing these three variables separately causes negative bias.

Let $D(p) = Gp^{-e}$ be an annual demand function with constant price elasticity $e > 1$. Then, the buyer's profit can be written as

$$\Pi(p,Q) = Gp^{-e}\left((1-kT_1)p - (1-kT_2)c - \frac{A}{Q}\right) - \frac{Q}{2}h \quad (2)$$

and the optimal price for a given order quantity is

$$p_0 = \frac{e}{e-1}\frac{A + (1-kT_2)cQ}{(1-kT_1)Q} \quad (3)$$

Because the second order derivative is negative for all p_0, Equation 2 is a convex function and reduces to

$$\Pi(Q) = Gp_0^{-e}\left((1-kT_1)p_0 - (1-kT_2)c - \frac{A}{Q}\right) - \frac{Q}{2}h \tag{4}$$

Then, the optimal order quantity satisfies

$$0 = \frac{GA\left(\frac{e}{e-1}\frac{A+(1-kT_2)cQ}{(1-kT_1)Q}\right)^{-e}}{Q^2} - \frac{h}{2} \tag{5}$$

and it is easy to see that $Cov(T_2, T_1) > 0$ and $Cov(T_2, Q) > 0$. Given that T_1 and Q are also negatively related to $\Pi(Q)$, omitting them from the regression will result in downward biased estimates of T_2. Therefore, inventory models with permissible delay in payment correctly specify a *positive* association of firm profitability and payment delay. With fixed effects and robust standard errors we estimate the following specification to test Hypothesis 1 (please refer to Table 4 for variable definitions):

$$\begin{aligned} ROA_{it} =& \beta_0 + \beta_1 APCOGS_{it} + \beta_2 ARSales_{it} + \beta_3 InvCOGS_{it} + \\ & \beta_4 LnSales_{it} + \beta_5 SalesGrowth_{it} + \beta_6 MarketShare_{it} + \\ & \beta_7 Leverage_{it} + a_i + u_{it} \end{aligned} \tag{6}$$

where the subscripts denote period-specific ($t = 1, \ldots, 20$) and firm-specific ($i = 1, \ldots, 3383$) observations; a_i captures all unobserved, time-constant factors that affect ROA_{it}; and u_{it} is the idiosyncratic error. To test the remaining hypotheses (Hypotheses 2, 3, and 4) the dependent variable is days payable and we implement:

$$\begin{aligned}APCOGS_{it} =&\beta_0 + \beta_1 KdDiff_{it} + \beta_2 COGSSales_{it} + \beta_3 Depreciation_{it} + \\ &\beta_4 ARSales_{it} + \beta_5 InvCOGS_{it} + \beta_6 SalesGrowth_{it} + \\ &\beta_7 MarketShare_{it} + \beta_8 Leverage_{it} + a_i + u_{it}\end{aligned} \quad (7)$$

In both cases we also include financial quarter and year dummies, test curvilinear specifications, and mean-center all variables. However, we do not report these results as they do not differ significantly. We also meld the two econometric specifications by interacting $APCOGS_{it}$ with $KdDiff_{it}$, $COGSSales_{it}$, and $Depreciation_{it}$. Furthermore, we test the second econometric model across industries. We define these industries as in Hendricks and Singhal (2003).

7 Results & Discussion

Table 5 provides results for the first econometric model. The data are consistent with Hypothesis 1: Firm profitability is positively associated with payment delay (column I of Table 5). The estimated coefficient (0.01) suggests that 100 additional days increase operating income profitability by one percentage point, which is similar to these firms' average financing costs. As predicted in Equation 1, firm profitability is negatively associated with days receivable and days inventory. When we split the effect of payables on profitability into a short-run and a long-run propensity (column II of Table 5: APCOGS_{t-1}-APCOGS_{t-4}), we find the long-run propensity to be negative. In combination, the long-run propensity coefficients test highly significant (F-value of 12.27) and outweigh the short-run propensity. As a further check, we regress the first difference of all variables, i.e., the change from the previous to the current period, and obtain similar results (column

III of Table 5). Thus, payment delay increases seem to have a positive short-run but a negative long-run propensity. While further study is needed before drawing robust conclusions, these results question the overall value of working capital improvement programs. While such programs may avoid financial costs, they may increase operational costs over a longer horizon, for example, if suppliers retaliate via price increases, lead time increases, or quality decreases.

Table 6 presents the results of the second econometric model. The data are also consistent with Hypothesis 2: Payment delay is positively associated with the capital cost difference between firm and supplier (as can be seen in the positive siginificant coefficients of KdDiff). Thus, days payable seem to be driven by these companies' relative financial situations. We find that a one percentage point increase in capital cost difference is, on average, associated with 0.38 day increase in days payable. Our estimates for individual industries, which range from 0.46 (food, textiles, and chemicals) to 1.51 days (rubber, metals, and machinery),[2] are consistent with the numerical examples provided by Jaber and Osman (2006). Abad and Jaggi's (2003) numerical example, however, which predicts 53 days, seems to overestimate the importance of capital cost differences.

Furthermore, the data are consistent with Hypothesis 3 and suggest that payment delay is negatively associated with the price elasticity of demand (negative siginificant coefficients of COGSSale). Thus, the data lend credibility to Abad and Jaggi's (2003) analytical approach, which suggests that it is unprofitable for a supplier to offer low prices in combination with long payment delays. When we analyze the impact of a one unit change in price elasticity, we find our results to be consistent with their numerical examples. In our results, a one unit increase in price elasticity leads to a 17.75 day decrease in days payable. Our estimates for individual industries range from 8.21 days (food, textiles, and chemicals) to 78.66 days (agriculture and

[2]We only take statistically significant results into account.

Table 5: Results from profitability regression

Variable	Pred. sign	I ROA	II ROA	III ΔROA
$APCOGS_t$ / $\Delta APCOGS_t$	+	0.01**	0.01***	0.01**
		(2.13)	(3.28)	(2.10)
$APCOGS_{t-1}$ / $\Delta APCOGS_{t-1}$	?		−0.01**	−0.01*
			(−2.26)	(−1.76)
$APCOGS_{t-2}$ / $\Delta APCOGS_{t-2}$	?		0.01**	−0.01***
			(2.13)	(−3.33)
$APCOGS_{t-3}$ / $\Delta APCOGS_{t-3}$	?		−0.01***	−0.01***
			(−3.61)	(−3.08)
$APCOGS_{t-4}$ / $\Delta APCOGS_{t-4}$	?		−0.02***	−0.01***
			(−4.74)	(−3.32)
ARSales / ΔARSales	−	−0.03***	−0.03***	0.00
		(−4.32)	(−3.62)	(0.41)
InvCOGS / ΔInvCOGS	−	−0.06***	−0.07***	−0.00
		(−14.82)	(−13.40)	(−0.63)
LnSales	+	6.04***	6.59***	
		(20.73)	(15.57)	
SalesGrowth	+	0.09***	0.09***	0.28***
		(21.68)	(16.82)	(31.23)
MarketShare / ΔMarketShare	+	−0.04*	−0.02	0.03
		(−1.68)	(−0.98)	(1.58)
Leverage / ΔLeverage	−	−0.18***	−0.17***	−0.18***
		(−21.95)	(−17.08)	(−9.50)
Intercept		−16.39***	−19.28***	−0.87***
		(−9.01)	(−7.09)	(−16.25)
Observations		15,986	11,053	8,995
F-value		329.22	147.73	179.81
Adjusted R^2		0.24	0.26	0.39

Note. Significance levels (two-tailed test): *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. t-statistics in parentheses. We drop LnSales in the last specification because its first difference is captured by SalesGrowth.

Table 6: Results from payment delay regression

Variable	Pred. sign	APCOGS								
		Pooled	Agriculture	Food	Machinery	Electronics	Automobile	Supply	Retail	Services
KdDiff	+	0.38***	−0.58	0.46*	1.51***	0.39	0.47***	0.18	0.47***	0.06
		(3.49)	(−1.02)	(1.91)	(4.11)	(1.04)	(3.70)	(0.79)	(4.14)	(0.16)
COGSSales	+/−	−17.75***	−78.66***	−8.21***	−33.51***	−33.10***	−23.81***	−49.61***	−8.99*	−34.57***
		(−5.34)	(−10.73)	(−3.17)	(−4.80)	(−5.75)	(−6.07)	(−4.93)	(−1.69)	(−3.78)
Depreciation	−	−0.01***	−0.04**	−0.03**	−0.12***	−0.01	0.02**	−0.00	0.03**	0.01
		(−2.97)	(−2.24)	(−2.49)	(−3.21)	(−1.61)	(2.35)	(−0.69)	(2.00)	(0.42)
ARSales	+	0.41***	0.80***	0.26***	0.23***	0.39***	0.30***	0.80***	0.37***	0.26***
		(16.60)	(7.52)	(5.01)	(5.41)	(7.09)	(7.47)	(12.44)	(4.87)	(4.64)
InvCOGS	+	0.28***	0.10	0.27***	0.20***	0.28***	0.16***	0.40***	0.45***	0.44***
		(22.27)	(1.47)	(9.99)	(9.12)	(10.40)	(3.22)	(8.69)	(20.25)	(6.14)
SalesGrowth	?	−0.03***	−0.16***	−0.03	−0.01	0.01	0.01	−0.06***	0.04***	−0.02
		(−2.67)	(−2.89)	(−1.32)	(−0.51)	(0.26)	(0.62)	(−2.63)	(2.66)	(−0.43)
MarketShare	?	0.07	−0.11	0.24**	0.06	−0.44	−0.21**	−0.11	0.03	0.10
		(1.38)	(−0.67)	(2.46)	(0.51)	(−0.88)	(−2.12)	(−0.76)	(0.41)	(0.39)
Leverage	?	−0.30***	−0.37***	−0.28***	−0.43***	−0.17***	−0.07***	−0.24***	−0.23***	−0.49***
		(−12.59)	(−2.61)	(−4.50)	(−7.13)	(−2.87)	(−2.59)	(−3.05)	(−7.53)	(−6.59)
Intercept	?	38.34***	103.18***	36.85***	53.44***	41.18***	41.51***	58.75***	12.23***	62.17***
		(14.09)	(12.96)	(8.18)	(9.57)	(7.99)	(8.00)	(7.71)	(2.62)	(9.87)
Observations		18,884	816	3,533	2,990	2,708	520	3,114	2,515	2,688
F-value		157.02	25.69	22.36	33.51	30.56	24.01	50.49	63.50	17.91
Adjusted R^2		0.16	0.25	0.13	0.15	0.21	0.38	0.25	0.49	0.13

Note. Significance levels (two-tailed test): $^{***}\ p < 0.01$, $^{**}\ p < 0.05$, $^{*}\ p < 0.1$. t-statistics in parentheses.

natural resources).

The data are also consistent with Hypothesis 4: Payment delay is negatively associated with the deterioration rate of inventory (Depreciation variable). However, we question the robustness of our finding because deterioration is positively associated with payment delay in three out of eight industries. Moreover, we observe the strongest effect in rubber, metals, and machinery (-0.12 days) and the weakest effect in retail and wholesale (0.03) although the nature of their activities would suggest the opposite. Restricting the sample to food retailers and wholesalers does not change the conclusion. While our results from pooled regression still support Hypothesis 4, it seems that future research should re-visit the issue using a better proxy. Survey data or case study data might be able to shed more light on this issue.

When we compare the economic significance of the three determinants – capital cost difference, price elasticity, and deterioration rate – by computing the effect of a change by one standard deviation, we find price elasticity to be most important (1.08, -13.67, and -4.11 days respectively). This finding, however, differs significantly in the retail and wholesale sector (1.33, -1.53, and 2.92 days respectively). Given that almost all inventory models with permissible delay in payment use this sector as their reference point, it may be less surprising that they consider capital costs to be more important than price elasticity.

We also meld the two econometric specifications (Equations 6 and 7) by interacting $APCOGS_{it}$ with $KdDiff_{it}$, $COGSSales_{it}$, and $Depreciation_{it}$ but do not observe any significant interactions (Table 7). While the interaction with the deterioration rate of inventory is statistically significant, the coefficient is of opposite sign. Moreover, when we use the alternative proxy ($COGS_{it}$), the result becomes insignificant. Thus, while our hypothesis tests suggest that the modeling literature correctly prescribes how to manage payment delays, firms do not seem to adhere to these models in practice.

There may be three potential explanations for this observed discrepancy.

Table 7: Results from interaction regression

Variable	Pred. sign	ROA	ROA	ROA
$APCOGS_t$	+	0.01	−0.02	−0.00
		(1.52)	(−1.60)	(−1.22)
KdDiff	−	−0.18***		
		(−3.30)		
$APCOGS_t \times$KdDiff	+	0.00		
		(0.93)		
COGSSales	−		−58.45***	
			(−12.15)	
$APCOGS_t \times$COGSSales	−		0.01	
			(0.47)	
Depreciation	−			−0.04***
				(−13.00)
$APCOGS_t \times$Depreciation	−			0.00***
				(3.96)
ARSales	−	−0.04***	−0.01*	−0.04***
		(−5.08)	(−1.92)	(−4.89)
InvCOGS	−	−0.06***	−0.08***	−0.05***
		(−14.28)	(−20.05)	(−13.20)
LnSales	+	5.85***	4.94***	7.60***
		(19.65)	(18.42)	(24.05)
SalesGrowth	+	0.09***	0.08***	0.09***
		(21.31)	(20.75)	(21.81)
MarketShare	+	−0.04*	0.00	−0.03
		(−1.69)	(0.22)	(−1.25)
Leverage	−	−0.18***	−0.15***	−0.17***
		(−21.06)	(−20.72)	(−21.72)
Intercept		−14.61***	25.22***	−23.80***
		(−7.85)	(7.36)	(−12.45)
Observations		15,419	15,986	15,986
F-value		249.32	318.95	286.30
Adjusted R^2		0.23	0.41	0.26

Note. Significance levels (two-tailed test): *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. t-statistics in parentheses.

First, the costs of implementing such models may outweigh the benefits. Our analysis of the limited economic significance of the three determinants would support such an explanation. In addition, the operations literature in question does not consider implementation costs. If the implementation costs outweigh the benefits, then the recommendation for practicing managers would be to negotiate payment delays to be as long as possible. Second, payment delays (trade credit) may be more than a purely financial tool: research has determined at least 14 other motives for why firms use trade credit (Schwartz, 1974; Ferris, 1981; Petersen and Rajan, 1997). If this is the case, then the recommendation would be to quantitatively compare foregone financial benefits to other benefits and adjust the policy if necessary. To our knowledge, there are no attempts in the literature to quantify these other benefits. Third, the actual diffusion of such models might be low and thus hard to observe. A recent survey with 213 executives from 55 countries across all major industries, found that only 39% considered their own or their supplier's financial situation in negotiating payment delays (Seifert and Seifert, 2009). If this is the correct explanation for why firms do not adhere to these models, then the recommendation would be to study inventory models with permissible delay in payment in detail, evaluate their benefits, and implement them in collaboration with suppliers.

8 Conclusion

This article set out to reconcile the finance view with the operations management view of payment delays by applying a secondary data approach to operations management theory. To conduct the research, we combined three databases, including a novel database on commercial relations between North American firms. Based on a sample of 3,383 groups of public US firms we find that our data are consistent with the causal relations and theoretical predictions of the operations management literature. As predicted by this literature, firm profitability is positively associated with payment delay. Payment delay, in turn, is positively associated with the capital cost difference between buyer and supplier and negatively with the price elasticity of demand and the deterioration rate of inventory The results from the hypothesis testing are summarized in Table 8.

Table 8: Summary of results

Hypothesis	Pred. sign	Hypothesis validated
I	+	Yes
II	+	Yes
III	+ or -	Yes (-)
IV	-	Yes (partially)

8.1 Managerial insights

The managerial implications of our findings are strong and clear. First, we find that current payment delay is positivly associated with profitability but negatively associated with lagged payment delay. This would suggest that it may be profitable to squeeze suppliers (by imposing long payment delays) in the short run, but that such strategies can backfire in the long run. While further research is needed before drawing any far-reaching conclusions, this highlights the importance of joint supply chain optimization and the need to incorporate factors like capital cost differences when deciding payment delay.

Second, in contrast to the sensitivity analyses presented in the modeling literature, we only find price elasticity to be economically significant. Furthermore, we do not observe any significant interaction effects between payment delay and the three factors (capital cost difference, price elasticity of demand and deterioration rate of inventory). Thus, while the modeling literature seems to correctly prescribe how to manage payment delays, firms do not seem to adhere to these models in practice. Potential explanations may be smaller than projected economic benefits, the existence of confounding trade credit motives, and the actual diffusion of such models in practice. These competing explanations motivate future research and hint at a learning opportunity for firms to seize untapped benefits.

8.2 Implications for Research and Theory

This study set out to reconcile the opposing views on payment delay in the operations management and finance literature. Using a stylistic inventory model we show that the counter-intuitive findings in the empirical finance literature may be the result of omitted variable bias. Taking this into account we specify a more appropriate model, which yields results that are consistent with the theoretical operations manegement literature.

Furthermore, the theoretical operations management literature provide conflicting views on the relationship between payment delay and the price elasticity of demand. By testing this relationship using secondary data we find that payment delay is negatively associated with the price elasticity of demand, as predicted by Abad and Jaggi (2003) but contrary to the conclusion's of Kim et al. (1995); Shi and Zhang (2007); Shi et al. (2007)

8.3 Future Research

There are a number of directions in which future research could prove useful. First, future research should explore payment delay dynamics, i.e., if and how changes in payment delays affect financial costs, operating costs, and service levels. Of particular interest would be to see if firms operating under different time horizons exhibit similar payment delay patterns. Second, a case study of model adoption would complement the present study with further empirical evidence and suggest ways to enhance these models. Such a case study would also be able to examine benefit allocation schemes because they are difficult to evaluate with currently available secondary data. Finally, future research should explore the role of supply network configurations. While there are both topology and dependence questions to be addressed, the most interesting question may revolve around competition. Since suppliers may serve the firm's rivals, too, or may even compete with the firm in some markets, firms may have strategic motives not to subsidize suppliers. In a recent workshop on the interface between operations and finance, one manager fittingly remarked: "I'd rather quit than hand-feed my competitor's suppliers!"

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