
International Journal of Systems Science: Operations & Logistics

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tsyb20

# Measuring inventory turnover efficiency using stochastic frontier analysis: building materials and hardware retail chains in Norway

**Jørgen Breivik, Nils Magne Larsen, Sverre Braathen Thyholdt & Øystein Myrland**

INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE: OPERATIONS & LOGISTICS
https://doi.org/10.1080/23302674.2021.1964635



# Measuring inventory turnover efficiency using stochastic frontier analysis: building materials and hardware retail chains in Norway

Jørgen Breivik [a], Nils Magne Larsen [a], Sverre Braathen Thyholdt [b] and Øystein Myrland [b]

[a]School of Business and Economics, UiT The Arctic University of Norway, Harstad, Norway; [b]School of Business and Economics, UiT The Arctic University of Norway, Tromsø, Norway

**ABSTRACT**

Operational efficiency in the retail business is vital in order to be profitable in a competitive environment. This paper investigates how environmental factors, firm size and time trends are linked to inventory performance. We use location data, demographic data and 16 years of financial accounting data from small and medium-sized home improvement retailers to explain inventory performance at a chain and a regional level. Traditionally a regression model could be used to assess the impact of the explanatory variables on inventory performance. We choose to use a stochastic frontier model since inventory turnover is linked to efficiency and productivity. Furthermore, we allow the model to control for key financial figures such as gross margin, capital intensity and sales growth. We find that efficiency in inventory performance varies depending on local market conditions and store location. Moreover, increased firm size tends to increase inventory efficiency, while time trend in inventory efficiency varies by retail chain affiliation. This paper provides new insights into the literature on operations- and inventory management, and suggests that retail managers should consider including environmental factors as part of their analysis when using inventory turnover as an efficiency benchmark.

**ARTICLE HISTORY**
Received 5 February 2021
Accepted 2 August 2021

**KEYWORDS**
Inventory turnover; logistics management; efficiency; market conditions; retail

## Introduction

Inventory is a critical asset in the retail sector and associated with considerable costs (Azzi et al., 2014). In 2016, inventory costs were estimated at $409.8 billion for US businesses alone, representing nearly 30% of the total logistics costs and accounting for as much as 2.2% of US GDP (Monahan et al., 2017). Inventory is further considered the asset that is most difficult to manage (Kolias et al., 2011). Inventory represents what the business can offer its customers and determines the firm's service level. There are costs related to both over- and understocking inventories. While excessive inventories lead to higher storage costs, increased capital tie up, and risks of spoilage and obsolescence, a shortage of inventory may lead to unsatisfied customers and reduced sales. Inventory levels must therefore be balanced with the associated costs of holding inventory (Salam et al., 2016).

The most frequently used measure to evaluate inventory efficiency is the inventory turnover ratio (Gaur et al., 2005). The inventory turnover ratio is calculated as the cost of goods sold divided by the average inventory level, and can be used as a comparative measure across firms. Since research shows that inventory efficiency is linked positively to financial performance (Eroglu & Hofer, 2014; Isaksson & Seifert, 2014; Shockley & Turner, 2015), most firms will gain financial benefits by increasing their efforts to enhance inventory efficiency.

Surprisingly little research has been done on the effect of environmental factors on inventory efficiency in retail businesses. We find this interesting because geographical store location due to topography and transportation distance can result in differences in replenishment lead times between stores located in different regions and consequently affect the need for more or less safety stock (Ballou, 2005). Furthermore, geographical presence, market concentration, demand density, density of economic activity, competitive environment, urbanisation and centrality have all been shown to be associated with firm-level efficiency in the more general literature on productivity (e.g. Aiello & Bonanno, 2016; Assaf et al., 2011; Bos & Kool, 2006; Carlino & Voith, 1992; Ciccone & Hall, 1996; Ko et al., 2017). Thus, it is likely that environmental factors affect inventory efficiency in retail businesses.

To address these shortcomings, we estimate the effects of geographic store location, degree of rurality, and

**CONTACT** Jørgen Breivik jorgen.breivik@uit.no School of Business and Economics, UiT The Arctic University of Norway, Postboks 1063, Harstad 9480, Norway

market conditions on inventory turnover efficiency. We further decompose retail inventory efficiency at the chain and store levels using firm size and time trends. While the main novelty of this paper is related to the effects of environmental factors on inventory turnover efficiency, we are also the first to estimate inventory efficiency by empirically applying stochastic frontier analysis (SFA). The benefit of SFA is that it computes a relative measure of performance. Specifically, a frontier is estimated which allows comparison of each firm to the best-practice companies. This deviation gives an efficiency score and, consequently, this efficiency score measure how close a firm's inventory turnover is to what a firm's optimal turnover would be (Weill, 2008).

The results show that market conditions in the area surrounding the location of the store affect inventory efficiency. The most rural locations and the most central locations are the most efficient. However, relative to municipal population size, inventory efficiency at the store level increases as the population size rises. These findings contribute to theory by bridging an important theoretical gap in the literature on operations- and inventory management concerning environmental factors affecting inventory efficiency. Since the results suggest that retail managers should consider including environmental factors as part of their analysis when using inventory turnover as an efficiency benchmark, the findings also have important managerial implications. We also find firm size to be positively associated with inventory efficiency. The estimates indicate that increasing firm size from five to 25 employees improves inventory efficiency by approximately 12 percentage points. Moreover, no firms with more than 40 employees display inventory efficiency scores below 80% of the best performing firms. Further, although inventory efficiency varies widely both at the store and retail chain levels, we find that stores affiliated with one of the retail chains have increased their inventory efficiency over time while the stores affiliated with the other two chains have become less efficient. The stores affiliated with the outperforming retail chain advanced their efficiency on inventory by 10.5 percentage points in the 1998–2013 period relative to the lesser performing chain.

The rest of the paper is organised as follows. In the next section, we discuss relevant literature and present our analytical framework. This is followed by a description of the data, the variables, and the foundation of the applied method and models. We then present and discuss the results. Finally, as part of the conclusion section, we present and discuss possible implications, suggest further research and discuss the limitations of the current study.

## Literature review

From a theoretical point of view, it is evident that inventory management is of significant importance to minimise costs in holding inventory. The early findings of these relations date back to Harris (1913/1990) through the construction of the economic order quantity model, which states that there is an optimum number of items to replenish. Even though the assumptions for this model are rather restrictive, the contribution from these insights and subsequent inventory control models have had a prominent impact on operations management in industries carrying inventory. Thus, the early focus of research on inventory management was on inventory systems and practices (Williams & Tokar, 2008).

However, research during the past two decades shows a shift in research focus on inventory management. For instance, the interest towards factors related to inventory performance across firms and industry segments has increased. In this section, we first look into the literature on inventory and financial performance. Although this topic is not directly related to the scope of this article, these research projects provide useful insights into what has been done in the broad field of inventory research. Then, we look at firm characteristics relevant for the current research, followed by research on environmental factors that can affect inventory levels. This section concludes with a figure presenting our analytical framework.

### *Inventory and financial performance*

Most studies have examined manufacturing firms and similar industries with discrete inventory components as raw materials inventory (RMI), work-in-progress inventory (WIPI) and finished-goods inventory (FGI). The attention paid to retail and wholesale businesses has been scarcer. To some extent and depending on context, there are similarities between inventories of retail companies and FGI of manufacturing companies. However, there are also visible differences. Transportation, direct labour, and inventory holdings represent 11-20% of the total costs for process industries, while similar numbers for retail are 5% (Moser et al., 2017).

A large part of the literature on inventory performance focuses on the effect efficient inventory management has on financial performance. The association between inventory and financial performance was for some time inconclusive and examined initially only for manufacturing firms. Rumyantsev and Netessine (2007b) examined listed manufacturing businesses across eight different OECD countries and found a negative relationship between days of FGI and profitability in half of the sample. Further, Rumyantsev and Netessine (2007c) and Cannon (2008) found no relationship between inventory and financial performance. However, Capkun et al. (2009) found a negative relationship between levels of RMI, WIPI, and FGI scaled on sales, and concluded, contrary to Rumyantsev and Netessine (2007b), that FGI was the most important inventory. Still, as pointed out by Eroglu and Hofer (2011a), these findings may be subject to poor modelling and data issues. First, scaling the dependent and explanatory variables with the same variable, i.e. sales as done by Capkun et al. (2009), would introduce a significant bias in estimates. Second, the use of large samples and broad segments would also lead to incorrect benchmarking results. Correcting for these issues, they find that RMI have the greatest effect of financial performance.

There has also been a discussion about the shape of the relationship between inventory levels and financial performance, and some of the aforementioned research in the previous paragraph support a linear association. However, there seem to exist a non-linear relation between inventory and profitability. Thus, there is an optimum level of inventory and beyond this level profitability suffers, and most companies will gain financial benefits by increasing inventory efficiency (Eroglu & Hofer, 2011a; Isaksson & Seifert, 2014).

In the retail sector, there is a positive relationship between inventory turnover, return on sales and assets (Shockley & Turner, 2015). Retail firms with high inventory turnover respond better to demand changes than do firms with low inventory turnover (Kesavan et al., 2016). Furthermore, inventory performance predicts future stock returns for U.S. retailers (Alan et al., 2014), and inventory level is negatively associated with cost efficiency for medium-sized companies operating in seven European countries (Weill, 2008).

From an overall corporate perspective, inventories have been analysed in several different research directions, such as their association with financial performance, scale effects, and other firm-specific drivers that are associated with inventory performance. These factors are, to some degree, possible for the management to adjust. However, exploring the relationship between inventory performance and environmental factors that are harder to control by management, has not caught the same attention in research of inventory performance. Still, some studies have investigated how inventory levels evolve over time. Others have highlighted the importance of varying lead-time to explain differences in inventory performance due to various distances between retailers and central warehouses. This and other environmental factors, such as local market conditions, could also affect inventory performances for firms. In the following section, we discuss the relationship between firm characteristics and environmental factors on inventory performance in more detail.

### Firm characteristics

When analysing inventory performance metrics such as inventory turnover or inventory in days, these should be controlled for financial metrics such as gross margin, capital intensity, and sales surprise (Gaur et al., 2005). There seem to be a negative relationship between gross margin and inventory turnover, and a positive relationship between capital intensity and sales growth (Gaur et al., 2005; Kolias et al., 2011). This implies that firms with better margins on their sales have higher relative inventory levels, while firms with high investment in assets relative to inventory return better inventory performance.

As several authors have identified, and Eroglu and Hofer (2011a, 2011b, 2014) and Isaksson and Seifert (2014) in particular, there are considerable differences between firms in broadly defined industrial sectors, and failure to adjust for that may lead to incorrect benchmarking results. Thus, it is important to control for different industry segments when modelling inventory performance. Table 1 presents an overview of selected studies in the context of firm characteristics, which are relevant for the current research.

The interest in how firm size affects firm specific measures is evident throughout the management and operations literature. Within the productivity literature, Diaz and Sanchez (2008) found in their analysis of Spanish manufacturing firms in the 1995–2001 period that firm size negatively affects value added. However, related to inventories, the number of studies is limited. Kesavan et al. (2016) and Breivik (2019) found that firm size measured in term of sales is positively correlated with inventory turnover.

In addition to firm size, chain affiliation is also recognised for possessing scope-and-scale economies in sales and purchasing. Retail chains utilise more sophisticated distribution and inventory control systems and tend to offer lower prices and more standardised products (Dinlersoz, 2004). Chain stores are an important part of the economy in developed economies, and this is especially the case for the retail sector (Kosová & Lafontaine, 2012; Perrigot, 2006). Studies show that national chains in the U.S. have contributed to productivity gains in the retail sector (Doms et al., 2004; Foster et al., 2006) and that national chains have experienced faster growth (Jarmin et al., 2009).

**Table 1.** Selected studies on firm characteristics.

| Scope of study | Dataset/sample | Dependent var. (output) | Independent var. (input) | Key findings | Authors |
|---|---|---|---|---|---|
| Examines the structure of retail markets by type of organisation: stand-alone stores and chain stores. | 1995-1998. U.S. | Fraction of total establishments. | Store type, population, income, non-white, age, wage, rent, metropolitan statistical area. | Chain stores are larger than stand-alone stores. Chain store expand their scales when market size increases, while stand-alone stores increase in numbers. | Dinlersoz (2004) |
| Examines the relationship between investments in information technology and firm performance. | U.S. retail. 1992-1997. (N = 6,036) | Sales per worker. | Employment, industry segment, investment in information technology, total capital investment. | Positive relationship between investments in information technology and sales. | Doms et al. (2004) |
| Develop a model to evaluate inventory turnover while controlling for key financial figures. | U.S. retailers. 1985-2000. (N = 3,407) | Inventory turnover. | Gross margin, capital intensity, sales surprise, sales, industry segment, time trend. | Inventory turnover negatively correlated with gross margin and positively associated with capital intensity and sales surprise. Negative time trends in inventory turnover. | Gaur et al. (2005) |
| Explores the relationship between retail restructuring and labour productivity. | U.S retail. 1987, 1992, and 1997. | Labour productivity at industry level. | Labour productivity at establishment level, | The entry of establishments of national chains on displacement of single-unit establishments contribute to overall productivity growth. | Foster et al. (2006) |
| Review differences between franchise chains; retail and service. | 228 services chains, 302 retail chains. France. 2005. | | Chain and store specific measures on age, fees, investment, sales and others. | Identify differences between retail and services, such as: age, fees, royalties and length of contract. | Perrigot (2006) |
| Examines determinants of technical efficiency. | 1,898 Spanish manufacturing, 20 industry segments. 1995-2001. | Value added. | Capital stock, employment, time, industry segment, share of temporary workers, foreign shareholders, gross investment/capital, public limited company, size – number of employees. | SMEs more efficient than larger firms. Firms with a lower ratio of temporary workers are more efficient. | Diaz and Sanchez (2008) |
| Study the effects of inventory leanness on financial performance. | U.S. manufacturing. 2003-2008. 1,600 firms. (N = 7,804) | Inventory scaled by industry segment, return on assets, return on sales. | Sale, assets, growth in sales, time effects, inventory scaled by industry segment. | Inventory leanness effects financial performance. Argue in general that results point towards a positive relationship. | Eroglu and Hofer (2011a) |
| Examines effects of the three discrete components of inventory on financial performance. | U.S. manufacturing. 2003-2008. (N = 4.121) | Return on sales. | Assets, total inventories, raw material inventories, work in progress inventories, finished goods inventories, industry segment, time. | Discrete components of inventory have different effects on firm financial performance. | Eroglu and Hofer (2011b) |
| Study determinants of inventory turnover. | 566 Greek retail firms, 2000-2005. (N = 3,336) | Inventory, inventory turnover. | Gross margin, capital intensity, sales growth, sales surprise, time trend. | Inventory turnover heterogeneity caused by industry segment effects. That changes in sales is affected by sales decline in the location region. | Kolias et al. (2011) |
| Examines effects of demand shocks on retailers with high/low inventory turnover. | 460 U.S. public retailers. 1985-2009.(N = 11,905) | Return on assets. | Cost of goods sold (COGS), delta COGS, abnormal inventory growth, gross margin, delta gross margin, return on assets lagged. | Low (LIT) and high (HIT) inventory turnover retailers respond differently to demand shocks. HIT retailers adjust shortages and excesses by adjusting quantity, LIT retailers rely on price changes. | Kesavan et al. (2016) |
| Study inventory turnover performance and its association with retail chain affiliation and time trends. | 184 Norwegian retail firms. 1998-2013. (N = 2,107) | Inventory turnover. | Gross margin, capital intensity, sales, growth in sales, industry segment, retail chain affiliation, time trend. | Retail chain affiliation explain some of the variance in inventory turnover. Inventory turnover decline with 2.3 % annually, and by 5.2 % when controlling for key financial ratios. | Breivik (2019) |

Various measures of capital turnover is frequently used to identify a firms' ability to operate efficiently by being able to utilise invested capital in an optimal way. Delen et al. (2013) classify the asset turnover rate as asset utilisation and that this ratio indicate a firms' ability to generate sales, hence operating efficiently. Shockley and Turner (2015) find in analysing financial performance that firm level deviations from segment levels on asset ratios affected firm financial performance in a positive manner.

### Environmental factors

The variation in inventory performance is affected by factors over which the managers have little control, due to circumstances present in the firm's environment. Empirical studies have shown that environmental factors have moderating effects from organizational- and ownership structure to strategic decisions (Eroglu & Hofer, 2014). In the productivity literature, geographical presence, market concentration, demand density, density of economic activity, competitive environment, urbanisation and centrality have all been shown to be associated with firm-level efficiency (e.g. Aiello & Bonanno, 2016; Assaf et al., 2011; Bos & Kool, 2006; Carlino & Voith, 1992; Ciccone & Hall, 1996; Ko et al., 2017). Hence, environmental factors could help explain why some firms are more efficient in their inventory management compared to other firms. Table 2 gives an overview of relevant studies.

When assessing relative inventory levels in multiple firms, it is essential to control for geographic store location. This is because the distance between retail stores and the warehouses of producers, importers and wholesalers, as well as the centralised retail chain inventory, vary and affect lead times. Ballou (2005) showed by simulations for various inventory models that aggregated inventory levels increased when lead-time increases. This is due to an added need for safety stock to countermeasure the demand uncertainty associated with an increase in lead-time (Baker, 2007). Research on how regional factors affect retailers is limited, but earlier examinations have shown that total factor productivity across U.S. states increased with urbanisation (Carlino & Voith, 1992).

Several studies show that local market conditions affect company performance. Eroglu and Hofer (2014) show that reduction in inventory levels may lead to negative financial performance in markets with lower degrees of competition. In the retail sector, Ko et al. (2017) examined sales revenue and number of customers and found a positive association between efficiency and competitive environment, measured as similar stores within a radius of 500 metres. In the bank sector, however, there has been contrary results. Aiello and Bonanno (2016) found that cost- and profit efficiency dropped when the competitive environment increases, measured as an increase in number of local bank branches.

Further, Bos and Kool (2006) found environmental factors to be less important than managerial performance using urban versus rural location and population size as proxies for market conditions. However, using other measures of local market conditions could lead to other results. Ciccone and Hall (1996) are using density, measured as intensity of humans, labour, and physical capital relative to physical space, and state that density is a better measure than size (of the municipality) in the regard of explaining productivity. Otsuka (2017) found that population agglomeration, investments in infrastructure, and density of firm clusters increased regional productivity.

Several studies aim to measure time trends in inventory, and time trends are in general used to capture time effects not otherwise captured in a model (Hill et al., 2011). Rajagopalan and Malhotra (2001) investigated manufacturing firms using industry-level data and concluded that finished-goods inventories vary among industries in both directions, but they identified no significant time trend for half of the industries. Chen et al. (2007) found that the median number of inventory days decreased from 73 to 49 using firm-level data from both retail and wholesale firms, but that the inventory for the retail segment only started to decline in the mid-1990s. Contradictory to these, Gaur et al. (2005) found for the 1987–2000 period that unadjusted inventory turnover declined by 0.45% annually, which demonstrates an increase in relative inventory levels. For Norwegian home improvement stores for the 1998–2013 period, Breivik (2019) found inventory turnover to decline by 2.3% annually. Although research at the present time does not clearly indicate the direction of the time trends for inventory in retail firms, several findings point towards some firm specifics that are closely associated with relative levels of inventory (Gaur et al., 2005; Kolias et al., 2011).

Figure 1 illustrates the proposed model for analysing the effects of firm characteristics and environmental factors on inventory performance. The first component analyses the factors explaining inventory turnover, while the second component analyses the factors explaining the differences in inventory efficiency.

## Methodology

### Data

The data used in this study are annual financial statements for firms affiliated with three different Norwegian

**Table 2.** Overview of studies on environmental effects.

| Scope of study | Dataset/sample | Dependent var. (output) | Independent var. (input) | Key findings | Authors |
|---|---|---|---|---|---|
| Examines determinants of aggregate productivity at state level. | 48 U.S. states. 1967-1986. (N = 960) | Aggregate annual real wage/no. employees. | Education level, union membership, total highway system, time, energy shocks, population in metropolitan area, real gross state product, the real output share per industry segment, aggregate employment, state dummy. | Productivity is affected by the state's industrial mix, infrastructure, education level and metropolitan structure. | Carlino and Voith (1992) |
| Study labour productivity across U.S states. | Gross state output on. 1998. (N = 50) | Output on state level. | Data on labour input on county level, area data on county level, education level. | Employment density increases labour productivity. | Ciccone and Hall (1996) |
| Estimate time trends in inventory ratios. | U.S. manufacturing. 1961-1994. 20 industry segments. | Inventory ratio. | Time trend parameters. | No statistical time trend for finished goods inventories. | Rajagopalan and Malhotra (2001) |
| Evaluate aggregate inventory level effects of different inventory control policies. | Monte Carlo simulation. | Inventory/Inventory turnover. | Item characteristics, inventory policy. | Aggregate inventory levels can be estimated based on product characteristics and inventory policy. | Ballou (2005) |
| Examines the role of environmental factors in bank efficiency. | Micro- and macroeconomic data. 401 Dutch banks. 1998-1999. | Profit before tax, total costs. | Bank specific factors, market factors, macro factors | Environmental factors to some degree to affect efficiency. | Bos and Kool (2006) |
| Examines inventory holding periods for retail and wholesale. | 1,254 U.S. retail & wholesale firms. 1981-2004. (N = 10,000+) | Inventory days, inventory to sales, inventory to assets. | Industry segment, macro-economic control variables. | Wholesale reduced median holding period from 73 to 49 days. Retail inventories to decline from about 1995. | Chen et al. (2007) |
| Exploratory study on inventory levels and inventory control models. | 722 public U.S. companies. 1992-2002. | Inventory. | Cost of goods sold, fixed assets, gross margin, sales, positive sales surprise, time trend. | Firms operating with increased lead time and demand uncertainty have elevated inventories. | Rumyantsev and Netessine (2007a) |
| Examines quantitative measures of lead time and perceptions of supply chain risk. | Case studies of 13 supply chains within six firms. | Lead time. | Lead time. | Supplier lead time exceed customer lead time. Inventory mitigates risks associated with variability in demand and transportation. | Baker (2007) |
| Study factors to impact cost efficiency in supermarkets. | 77 Spanish supermarket retail chains. 2001-2007. | Total cost/price of capital. | Price on labour, price on capital, vertical integration, low price retailer, age of firm, geographic expansion. | Efficiency is associated with age of firm, geographic presence and if chain is low price retailer. | Assaf et al. (2011) |
| Examines effects of environmental factors in the relationship between inventory leanness and firm financial performance. | 123 U.S. manufacturing firms. 1997, 2002 and 2007. 108 industries segments (N = 5,749) | Return on sales | Size, growth, inventory leanness, innovative intensity, demand uncertainty, competitive intensity. | Innovative and competitive intensity affect the effects lean inventories have on firm financial performance. | Eroglu and Hofer (2014) |
| Examines effects from local market conditions on cost and profit efficiency. | Italian banks. 2006-2011. (N = 3,766). | Total costs, total profits. | No. of employees, gross banking product, debt, labour costs, cost of capital, cost of deposits, bank density, market concentration. | Bank efficiency increase with increased market concentration and demand density. Negative time trend. | Aiello and Bonanno (2016) |
| Study efficiency in Korean individual retail chain stores. | Korean retailer. 32 outlets. | Sales revenue, number of customers. | Store size, number of items, number of employees, rental cost, trade area index, no. of competitive stores, trade area index. | Competitive environment and number of items per employer affect store efficiency. | Ko et al. (2017) |

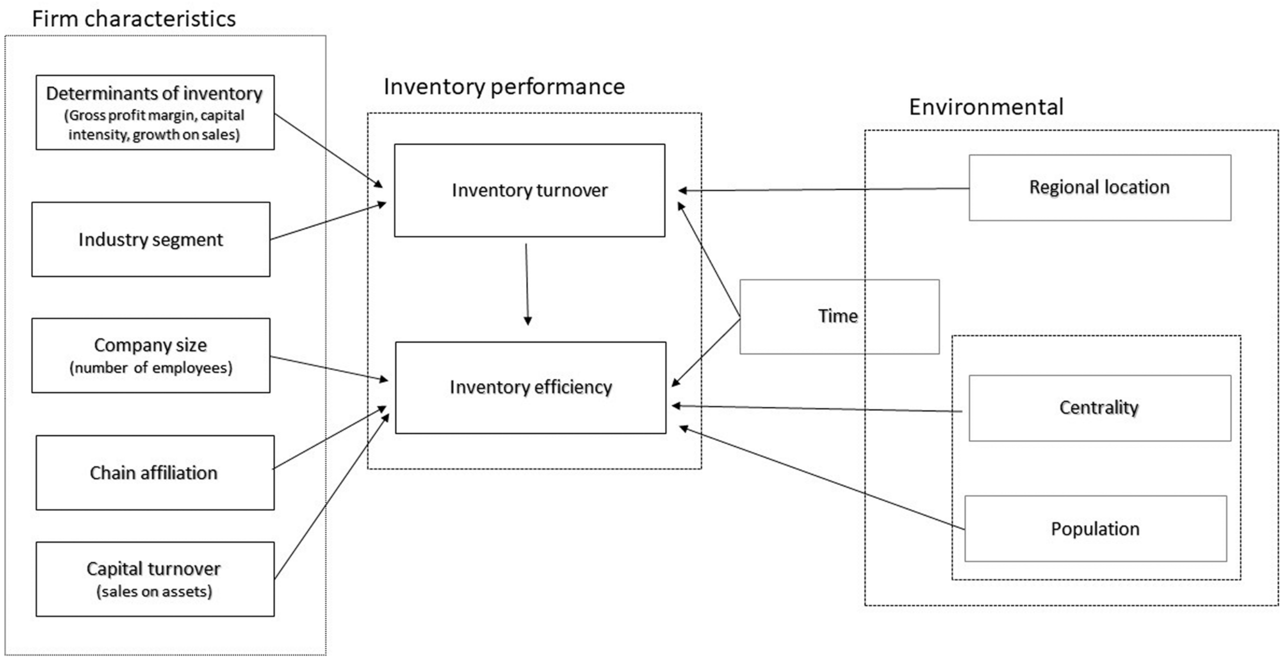



**Figure 1.** Analytical framework.

retail chains. The firms are operating as home improvement retailers selling construction products and tools to end users in Norway. The original dataset consists of all the firms affiliated with the chains, but some firms were excluded in the final dataset due to the following criteria: (1) The data are limited to include only private limited companies, thus leaving out firms organised as sole proprietorships since those firms are not legally bound to report accounting records according to the Norwegian Accounting Act. (2) Missing observations on inventory turnover or growth in sales are removed. (3) Observations with an inventory turnover $> 80$ and growth in sales $> 10$ are removed since these values are considered extreme values and are mainly related to enterprises in a start-up phase. (4) Firms with turnover of more than 50 million Euro (approximately 500 million NOK[1]) are removed since such firms are not considered small- and medium sized enterprises based on EU recommendation 2003/361.

Approximately 10.6% of the observations were removed from the original dataset due to these criteria, and the final dataset comprises of 2,189 observations from 187 firms for the period of 1998-2013. Not all firms are represented every year in our study period, making our panel unbalanced. Moreover, there may exist gaps in the observations of the firm. All the firms present in our dataset report financial statements according to Norwegian General Accepted Accounting Principles (N-GAAP). According to N-GAAP, transactions enter in the accounts when risk and control of the good is transferred from seller to buyer, meaning that goods in transit would not be present in the accounts either as sales and COGS (for the seller) or as inventory (for the buyer). The study period of 1998–2013 was chosen since there have been substantial structural changes in the marketplace post 2013, with several mergers and acquisitions taking place.

The three retail chains present in our study represented approximately 30% of the industry revenue in 2014. These chains were chosen since the local stores are registered as limited companies with independent accounts. Other players in the market are either part of conglomerates that operate in several different sectors of the economy, e.g. groceries and real estate, and do not present stand-alone accounting data for their activity in the sector for building materials and hardware, or where the local stores are not registered as a limited company. Thus, these actors only provide accounting data for their total activity in Norway as a whole. The retail chains present in our study consists of Byggtorget, Xl-bygg, and Byggmakker. The latter is owned by a foreign building and construction material company, while the other two are owned by their members. According to statistics from Virke (Byggeindustrien, 2018), total turnover for the building materials and hardware retail industry in Norway was in 2017 approximately 4.58 billion Euro (45.8 billion NOK[2]).

In addition to store level accounting data, we include in the analysis records on annual municipal population reported by Statistics Norway (2018) and a classification

**Table 3.** Description of variables (the panel data indicative of firm i at time t).

| Variable | Description | Measure |
|---|---|---|
| $IT_{it}$ | Inventory turnover | Measured as: $\frac{\text{COGS}_{it}}{\overline{\text{Inventory}_{it}}}$, whereas $\overline{\text{Inventory}_{it}} = \frac{\text{Inventory}_{it} - \text{Inventory}_{it-1}}{2}$ |
| $GM_{it}$ | Gross profit margin | Measured as: $1 - \frac{\text{COGS}_{it}}{\text{Sales}_{it}}$ |
| $CI_{it}$ | Capital intensity | Measured as: $\frac{\text{Fixed assets}_{it}}{\text{Fixed assets}_{it} - \text{Inventory}_{it}}$ |
| $G_{it}$ | Growth in sales | Measured as: $\frac{\text{Sales}_{it}}{\text{Sales}_{it-1}}$ |
| $IndC_i$ | Sector code based on SIC 2007 | Dichotomous variable: 1 if firm operates in a specific industrial sector; 0 if not. Based on the firm's sector code in 2013. Included sector codes (2-digit): 16, 41, 43, 46, 47, 52, 68 and 71. |
| $REG_i$ | Geographical region where the firm is located | See map for details. Based on the firm's post code in 2013. |
| $SOA_{it}$ | Sales on assets | Measured as: $\frac{\text{Sales}_{it}}{\text{Total assets}_{it} - \text{Inventory}_{it}}$ |
| $MC_i$ | Measure of municipal centrality as defined by Statistics Norway (1999) | Factor variable: 3 if it is a central municipality, 2 if it is a fairy central municipality, 1 if it is a fairly remote municipality, and 0 if it is a remote municipality |
| $POP_{it}$ | Population of municipality | Population of municipality of which the store is located |
| $CHN_{it}$ | Retail chain affiliation of the firm | Based on the chain affiliation the firm has in 2013. The retail chain affiliations are Byggmakker. Xl-Bygg and Byggtorget. |
| $NoE_{it}$ | Company size | Number of employees in firm |
| $Time_{it}$ | Time trend | Discrete variable: 1 for the first year of observation for the firm |

Note: The EU NACE rev.2 and UN ISIC standards are basis for the Norwegian Standard Industrial Classification - SIC 2007 (Statistics Norway, 2008).

**Table 4.** Summary statistics.

| | Mean | Std.Err. | Min. | Max. |
|---|---|---|---|---|
| Inventory turnover (IT) | 5.81 | 4.36 | 1.60 | 37.55 |
| Gross profit margin (GM) | 0.30 | 0.07 | 0.16 | 0.62 |
| Capital intensity (CI) | 0.25 | 0.19 | 0.00 | 0.85 |
| Growth in sales (G) | 1.11 | 0.22 | 0.84 | 3.61 |
| Employees (NoE) | 15.81 | 23.49 | 1.20 | 196.67 |
| Sales over fixed assets (SOA) | 5.01 | 2.42 | 0.92 | 18.47 |
| Population (POP) | 18.351 | 48.757 | 618 | 549.807 |

on centrality on municipal level as defined by Statistics Norway (1999).

## Variables

A full description of the variables used in this study is presented in Table 3, and summary statistics is given in Table 4.

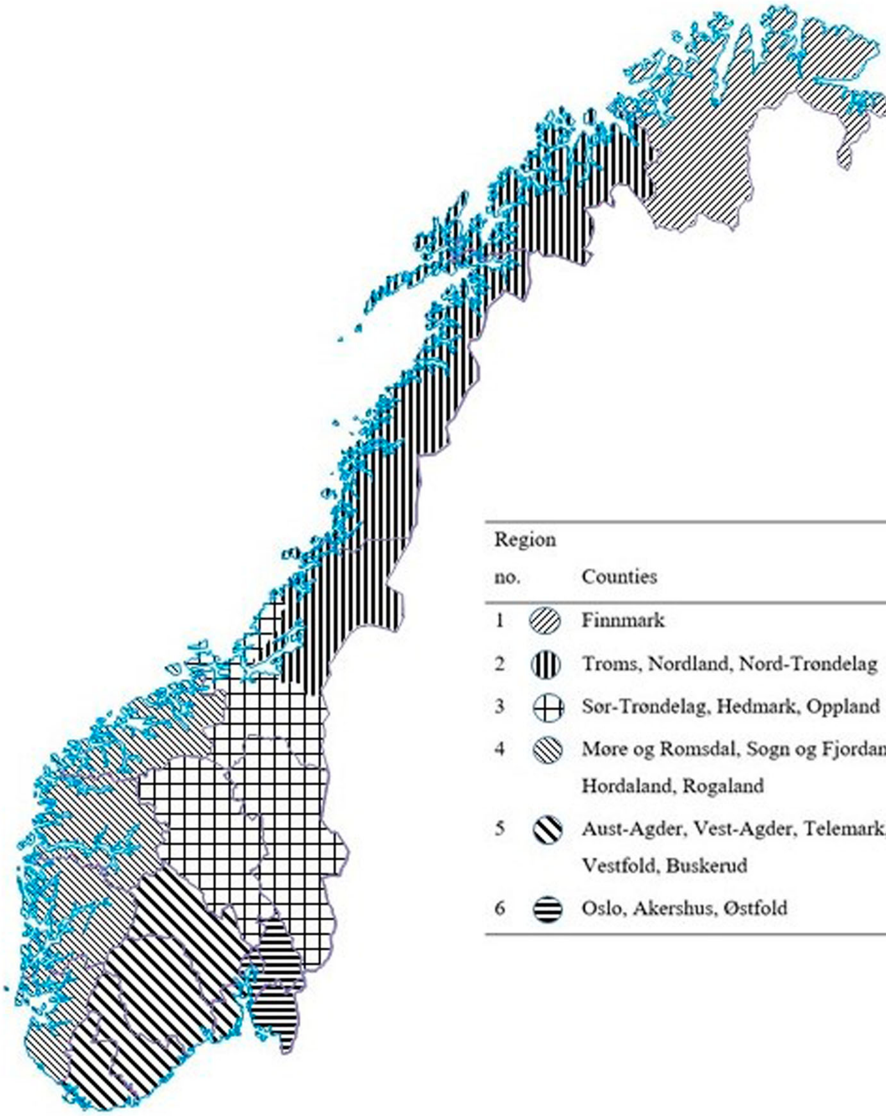
Some of the variables in Table 3 need a more thorough description. The dependent variable is inventory turnover, represented by $IT_{it}$, and this variable is commonly used as measuring efficiency in the retail sector (Gaur et al., 2005). Since the inventory turnover is calculated using both the opening and closing balance of the accounting year, the analysis starts from the year 1999.

Norway is a long and narrow country which consists of 323,752 $\text{km}^2$ (CIA, 2020), and the driving distance from the southernmost point (Lindesnes) to the northernmost point (Nordkapp) is about 2,350 km. In addition, approximately 3/10 of the area is situated above the Arctic Circle, and these factors are causing logistical challenges that may not be present in other countries. In Norway, as in most countries, there are present regional differences in terms of population and population density. Thus, geographical locations may influence replenishment lead times and consequently affect the need to increase or decrease safety stock (Ballou, 2005). To capture the spatial dependence and regional differences in our data, we include a regions variable, represented as $REG_i$, using the structure of nomenclature territorial units, NUTS, defined by Statistics Norway (1999). Figure 2 presents the six different regions including population and population density of those regions.

Further, we are using the population of the municipality, represented by $POP_{it}$, as a proxy of the size of the local market. But, since there is a difference of being situated in a small municipality in terms of population nearby Oslo, the capital of Norway, than being situated in a similarly small municipality in a more sparsely populated part of the country, we include a measure of municipal centrality, represented by $MC_i$, to control for a more competitive environment in nearby areas.

## Measuring efficiency

To determine the inventory efficiency, the stochastic function analysis (SFA) of Aigner et al. (1977) and Meeusen and van Den Broeck (1977) is used as a methodological starting point. The frontier methodology is based on a frontier function that gives limit (i.e. minimal or maximal) output values for any given level of inputs (Baltas, 2005). This approach presents the advantage of disentangling the efficiency and statistical noise taking exogenous events into the distance from the efficiency frontier. Hence, the error term consists of two components, one to account for purely random statistical noise, and another error-term to account for the deviation from



| Region no. | Counties | Area ($km^2$) | Population | Population density |
|---|---|---|---|---|
| 1 | Finnmark | 48,618 | 76,149 | 1.56 |
| 2 | Troms, Nordland, Nord-Trøndelag | 86,745 | 545,731 | 6.29 |
| 3 | Sør-Trøndelag, Hedmark, Oppland | 71,437 | 703,032 | 9.84 |
| 4 | Møre og Romsdal, Sogn og Fjordane, Hordaland, Rogaland | 58,532 | 1,368,527 | 23.38 |
| 5 | Aust-Agder, Vest-Agder, Telemark, Vestfold, Buskerud | 48,867 | 1,000,858 | 20.48 |
| 6 | Oslo, Akershus, Østfold | 9,553 | 1,564,020 | 163.72 |

**Figure 2.** Geographic regions, population and population density in Norway.

the frontier. Thus, the frontier is specified as:

$$y_{it} = \beta' x_{it} + \epsilon_{it} \tag{1}$$

$$\epsilon_{it} = v_{it} \pm u_{it} \tag{2}$$

in which $y_{it}$ is the dependent variable, inventory turnover in our case, $x_{it}$ is a vector of explanatory variables. The error term, $\epsilon_{it}$, is asymmetric and consists of two components. The first term,$v_{it}$, of the composite error term is the white-noise stochastic term as in a standard regression disturbance which is normally distributed with zero mean and constant variance, i.e. $v_{it} \sim N(0, \sigma^2)$. The second term, $u_{it}$, is the firm inefficiency as a non-negative measure with assumption on distributional properties as $N(u_{it}, \sigma_u^2)$. Further, the inefficiency term, $u_{it}$, could incorporate exogenous variables, $Z_{it}$, that explain inefficiency characterising the environment in which the firm operate, such as competitive conditions, network characteristics, and so on (Kumbhakar & Lovell, 2000). The two terms, $v_{it}$ and $u_{it}$, are distributed independently. Hence, in addition $u_{it}$ have the following specifications:

$$u_{it} = \delta Z_{it} + \mu_{it} \tag{3}$$

The advantages of using a SFA approach is that it computes a relative measure of performance which allows comparison of each firm to the best-practice companies in the frontier. Further, this deviation gives an efficiency score that measures how close a firm's inventory turnover is to what the optimal inventory would be for that specific firm (Weill, 2008).

Traditionally, SFA was estimated by a two-stage procedure, where the frontier, Equation (1), was estimated in the first-stage, and the obtained efficiency, Equation (3), was regressed on a set of explanatory variables in the second-stage (Weill, 2008). However, as pointed out by Kumbhakar and Lovell (2000), this leads to some econometric issues. The explanatory variables, in Equation (3), must be assumed as uncorrelated to the frontier, in Equation (1), or else the maximum likelihood estimates of the frontier would be biased due to omission of explanatory variables. Further, it assumes that the efficiency terms are identically distributed in the first step, while this assumption is contradicted in the second step since the regression on explanatory variables assumes that the efficiency term is not identically distributed (Weill, 2008).

For that reason, we are using the one-stage procedure proposed by Battese and Coelli (1995). Based on their proposition, we are using panel data in which the non-negative inefficiency term, $u_{it}$, has the truncated distribution as $N(u_{it}, \sigma_u^2)$ with different means for each firm. As a result, the distributions of the inefficiency terms are then independently but not identically distributed, since it is expressed as a function of explanatory variables.

The analysis of inventory turnover consists of two components. The first component, Equation (4), is to estimate the stochastic frontier that serves as a benchmark of differences in efficiency between the firms. The second component, Equation (5), concerns the incorporation of exogenous variables that exert an influence on the performance of the firms.

The model is then specified as followed:

$$\log(IT_{it}) = \alpha_0 + \sum^{j} \beta_j \log\mathbf{X}_{jit} + \frac{1}{2}\sum^{j}\sum^{k} \beta_{jk}\log\mathbf{X}_{jit}\log\mathbf{X}_{kit} + \sum_{j=1}^{7} \zeta_j IndC_i + \sum_{j=1}^{5} \eta_j REG_i + \iota Time_{it} + v_{it} - u_{it} \tag{4}$$

where the dependent variable is the inventory turnover for firm $i$ at time $t$. The X-vector is represented by the variables $GM_{it}, CI_{it}$, and $G_{it}$. $IndC_i$ are industry sectors, $REG_i$ are regions, and $Time_{it}$ is a time trend. $\alpha$, $\beta$, $\zeta$, $\eta$ and $\iota$ are the estimated parameters, $v_{it}$ is the random noise component, and $u_{it}$ is the inefficiency term.

$$u_{it} = \kappa_0 + \sum_{j=1}^{4} \nu_j MC_i + \sum_{j=1}^{4} \pi_j MC_i{*}\log(POP_{it}) + \sum_{j=1}^{3} \tau_j CHN_i{*}\log(NoE_{it}) + \sum_{j=1}^{3} \upsilon_j CHN_i{*}Time_{it} + \sum_{j=1}^{3} \psi_j CHN_i{*}\log(SOA_{it}) + \mathrm{e_{it}} \tag{5}$$

in which $MC_i$ is the centrality of the municipality, $POP_{it}$ is the population in the municipality, $CHN_i$ is the affiliated retail chain, $NoE_{it}$ is the number of employees, $SOA_{it}$ is the ratio of sales to fixed assets, and $Time_{it}$ is a time trend. $\kappa$, $\nu$, $\pi$, $\tau$, $\upsilon$ and $\psi$ are estimated parameters and $e_{it}$ is a truncated zero-mean residual.

**Table 5.** Estimates of the translog response function.

| Variable | Estimate | Std. Err. | z value | Pr( > \|z\|) | |
|---|---|---|---|---|---|
| (Intercept) | 2.309 | 0.207 | 11.158 | 0.000 | *** |
| log(GM) | −0.041 | 0.262 | −0.156 | 0.876 | |
| log(CI) | 0.641 | 0.058 | 11.147 | 0.000 | *** |
| log(G) | 0.670 | 0.223 | 3.010 | 0.003 | ** |
| I(0.5 ∗ log(GM)$^2$) | 0.208 | 0.200 | 1.039 | 0.299 | |
| I(0.5 ∗ log(CI)$^2$) | 0.067 | 0.012 | 5.415 | 0.000 | *** |
| I(0.5 ∗ log(G)$^2$) | 0.148 | 0.169 | 0.874 | 0.382 | |
| I(log(GM) ∗ log(CI)) | 0.280 | 0.043 | 6.594 | 0.000 | *** |
| I(log(GM) ∗ log(G)) | 0.317 | 0.178 | 1.778 | 0.075 | . |
| I(log(CI) ∗ log(G)) | −0.013 | 0.049 | −0.264 | 0.791 | |
| IndC41 | 0.004 | 0.055 | 0.068 | 0.946 | |
| IndC43 | −0.054 | 0.098 | −0.553 | 0.580 | |
| IndC46 | −0.031 | 0.050 | −0.613 | 0.540 | |
| IndC47 | −0.094 | 0.045 | −2.093 | 0.036 | * |
| IndC52 | 0.252 | 0.232 | 1.087 | 0.277 | |
| IndC68 | −0.584 | 0.101 | −5.793 | 0.000 | *** |
| IndC71 | 0.743 | 0.143 | 5.201 | 0.000 | *** |
| REG1 | −0.409 | 0.063 | −6.461 | 0.000 | *** |
| REG2 | −0.352 | 0.058 | −6.107 | 0.000 | *** |
| REG3 | −0.249 | 0.064 | −3.867 | 0.000 | *** |
| REG4 | −0.253 | 0.058 | −4.362 | 0.000 | *** |
| REG5 | −0.259 | 0.058 | −4.482 | 0.000 | *** |
| Time | −0.006 | 0.004 | −1.733 | 0.083 | . |

Notes: ∗ ∗ ∗, ∗∗, ∗, ., – significant at the 0.1%, 1%, 5%, 10% levels, respectively (two-sided).

## Results and discussion

### Estimation of the translog response function

Through the estimation of the translog response function, we obtained estimates of the frontier defined by observations of the best firms. Inefficiency relative to the frontier is then estimated simultaneously for each store. Estimates are provided by use of maximum likelihood on the translog response function defined in Equation (3) and the specification of inefficiency effects as defined in Equation (4). For this analysis, we use R (R core team, 2020) and the Frontier package (Coelli & Henningsen, 2017) with the specifications formulated by Battese and Coelli (1995). The estimates of the translog response function are presented in Table 5.

We find estimates of the response function for log$CI$ (0.641) and log$G$ (0.670) to be significantly different from zero at the $p < 0.001$ and $p < 0.01$ levels, respectively. These estimates imply that both investment in fixed assets and growth in sales are associated with an increase in

**Table 6.** Elasticities from the translog response function.

| | Mean | Std.Err. | Min | Max |
|---|---|---|---|---|
| Gross profit margin (GM) | −0.78 | 0.34 | −2.43 | 0.10 |
| Capital intensity (CI) | 0.18 | 0.11 | −0.27 | 0.70 |
| Growth in sales (G) | 0.32 | 0.08 | −0.13 | 0.66 |

**Table 7.** Estimates of inventory turnover inefficiency determinants.

| Variable | Estimate | Std. Err. | z value | Pr(> \|z\|) | |
|---|---|---|---|---|---|
| Z_(Intercept) | 5.641 | 2.045 | 2.758 | 0.006 | ** |
| Z_MC0 | −5.461 | 2.081 | −2.624 | 0.009 | ** |
| Z_MC1 | 14.734 | 7.412 | 1.988 | 0.047 | * |
| Z_MC2 | 0.365 | 1.981 | 0.184 | 0.854 | |
| Z_MC3 | −3.998 | 2.021 | −1.978 | 0.048 | * |
| Z_I(MC0 * log(POP)) | 0.038 | 0.031 | 1.198 | 0.231 | |
| Z_I(MC1 * log(POP)) | −2.393 | 1.128 | −2.121 | 0.034 | * |
| Z_I(MC2 * log(POP)) | −0.632 | 0.187 | −3.390 | 0.001 | *** |
| Z_I(MC3 * log(POP)) | −0.155 | 0.057 | −2.724 | 0.006 | ** |
| Z_I(CHN_BM * log(NoE)) | −0.015 | 0.052 | −0.298 | 0.765 | |
| Z_I(CHN_XL * log(NoE)) | −0.291 | 0.054 | −5.407 | 0.000 | *** |
| Z_I(CHN_BT * log(NoE)) | −0.368 | 0.056 | −6.576 | 0.000 | *** |
| Z_I(CHN_BM * Time) | 0.019 | 0.013 | 1.457 | 0.145 | |
| Z_I(CHN_XL * Time) | −0.002 | 0.009 | −0.160 | 0.873 | |
| Z_I(CHN_BT * Time) | 0.029 | 0.008 | 3.723 | 0.000 | *** |
| Z_I(CHN_BM * log(SOA)) | −0.290 | 0.112 | −2.601 | 0.009 | ** |
| Z_I(CHN_XL * log(SOA)) | 0.160 | 0.070 | 2.281 | 0.023 | * |
| Z_I(CHN_BT * log(SOA)) | 0.046 | 0.045 | 1.017 | 0.309 | |
| sigmaSq | 0.205 | 0.014 | 15.121 | 0.000 | *** |
| Gamma | 0.219 | 0.066 | 3.318 | 0.001 | *** |

Notes: * * *, **, *, ., – significant at 0.1%, 1%, 5%, and 10%, respectively (two-sided).

inventory turnover. The squared coefficient estimates are significant for the $\log CI^2$ variable (0.067, $p < 0.001$) and represent the nonlinear elasticity to scale. Furthermore, the estimates of the interaction variables return significant values for $\log(GM) * \log(CI)$ (.280, $p < 0.001$) and for $\log(GM) * \log(G)$ (.317, $p < 0.1$). In addition, Table 5 reports three estimates of the industry segment that return significant values at the $p < 0.05$ level or higher. This indicates that inventory turnover varies between different industries and verifies the necessity to control for such firm characteristics.

To simplify the interpretation of the translog response function, we calculate the composite elasticities. These estimates of $\log(GM)$, $\log(CI)$ and $\log(G)$ are presented in Table 6 and based on Equation (3). The estimates of these coefficients represent elasticities, which are evaluated at the mean level. We find that a one percent increase in the gross profit margin is associated with a 0.78% lower inventory turnover ratio. Furthermore, this table reports that a one percent increase in capital intensity is associated with a rise in inventory turnover by 0.18%. Finally, we identify that a one percent expansion in sales growth is associated with a 0.32% increase in inventory turnover.

### The effects of regional variables on inventory performance and time trend

When we estimated the translog response function in Table 5, we controlled for regional differences. The argument for this approach rests on topography and logistic challenges that cause large differences in the transportation distance between stores located in different regions and hence are likely to influence the lead time at the store level. As Table 5 shows, all of the estimates of the regional variables (*REG*) are significant at the $p < 0.001$ level, which implies that geographic location affects inventory turnover. This is in line with research on retail store productivity, which measures regional effects on sales per square foot of the selling area (Kumar & Karande, 2000). As the estimates in Table 5 show, the lowest inventory turnover ratios reported are for those stores located in the most northern regions (REG1 and REG2). One possible explanation is the varying but generally increasing lead times for those regions located to the north and further away from the capital of Oslo, as the latter in many cases serves as a logistic centre in Norway. The relationship between lead time and inventory levels is recognised in the literature (Ballou, 2005; Ben-daya & Raouf, 1994; Rumyantsev & Netessine, 2007a).

The estimates reported in Table 5 also indicate that a linear time trend is present in the frontier of inventory performance ($p < 0.1$). The estimate of the time coefficient indicates that the frontier of inventory performance represented by the best performing firms is decreasing annually by 0.6%. This is in line with previous findings in the literature (Gaur et al., 2005; Kolias et al., 2011) and may stem from general industry characteristics where product assortment and variety have increased to meet customer demands, which leads to increased levels of inventory and lower turnover.

### Inventory efficiency and environmental factors

Table 7 presents the estimates of the inventory inefficiency determinants. The model explains 21.8% of the detected inefficiency and 20.5% of the variation within the observed data.

Related to the main emphasis in this paper, Table 7 shows that the environment in which the store is located (*MC*) has an effect on inventory turnover. MC is a categorical variable representing how close or remote the municipal, in which the store is located, is to another larger urban area. Based on the more general literature on efficiency, which for instance suggests improved bank efficiency when demand density and market concentration increase (Aiello & Bonanno, 2016), we expected that inventory turnover efficiency generally improves when stores are located in more urban areas. However, the estimate for $MC0$ is significant ($p < 0.01$) and points to reduced inefficiency for the most rural areas. In contrast, locations in more central areas $MC1$ indicate lower levels of efficiency. For the $MC3$ variable, which represents the most central municipalities, the estimate again indicates better efficiency ($p < 0.05$). Hence, the most remote municipalities deviate from the general trend. There may be several reasons for this deviancy. First, all of the municipalities embedded in this group represent small communities, and retailers in some of these locations operate as monopolists with the accompanied consequence of reduced service level and product variety (Hernant et al., 2007), thereby improving inventory turnover. Second, several of the municipalities embedded in this group have suffered depopulation over recent decades and simply need to operate effectively to be able to run a sustainable business, avoid bankruptcy and survive, particularly with regard to inventory management, as it is important to keep costs down and achieve financial results (Isaksson & Seifert, 2014; Weill, 2008).

The estimates reported in Table 7 further indicate that an increase in population ($POP$) in the $MC1$ through $MC3$ variables reduces inefficiency at significant levels,

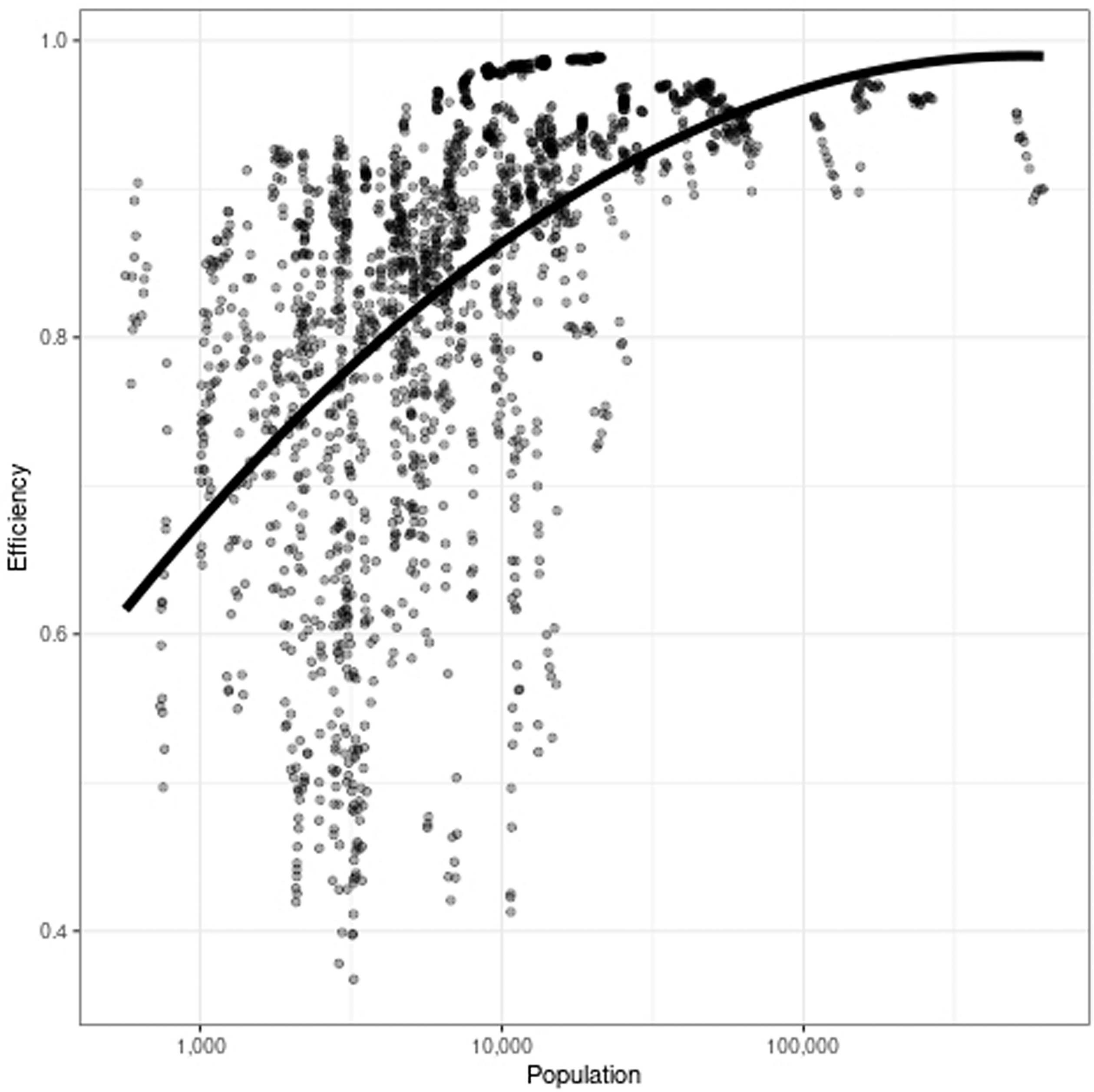



**Figure 3.** Inventory turnover efficiency by population.

but at a diminishing rate. This is in accordance with the existing literature, which has identified that store productivity increases with growth in population density (Kumar & Karande, 2000).

As illustrated in Figure 3, we find that inventory efficiency in general increases with an increase in the municipal population. The figure also reveals a high variation in the data at the point of approximately 3.000 inhabitants.

In Figure 4, we plot inventory turnover efficiency by geographical region (*REG*). As portrayed, inventory efficiency differs significantly among the six regions. Region 6 represents the most efficient firms, while region 3 contains the stores that are the least efficient. The most northern region of Norway (region 1), which is the most sparsely populated, demonstrates an inventory efficiency that is below average. In contrast, the firms located in region 6, which consists of the area surrounding the capital of Norway and the area that is the most densely populated, are the most efficient. Figure 1 further implies that the stores located in less population dense areas are less efficient. Regions 1 through 3 have less than 10 inhabitants per square km and the stores in these regions have all suffered the greatest decline in inventory inefficiency.

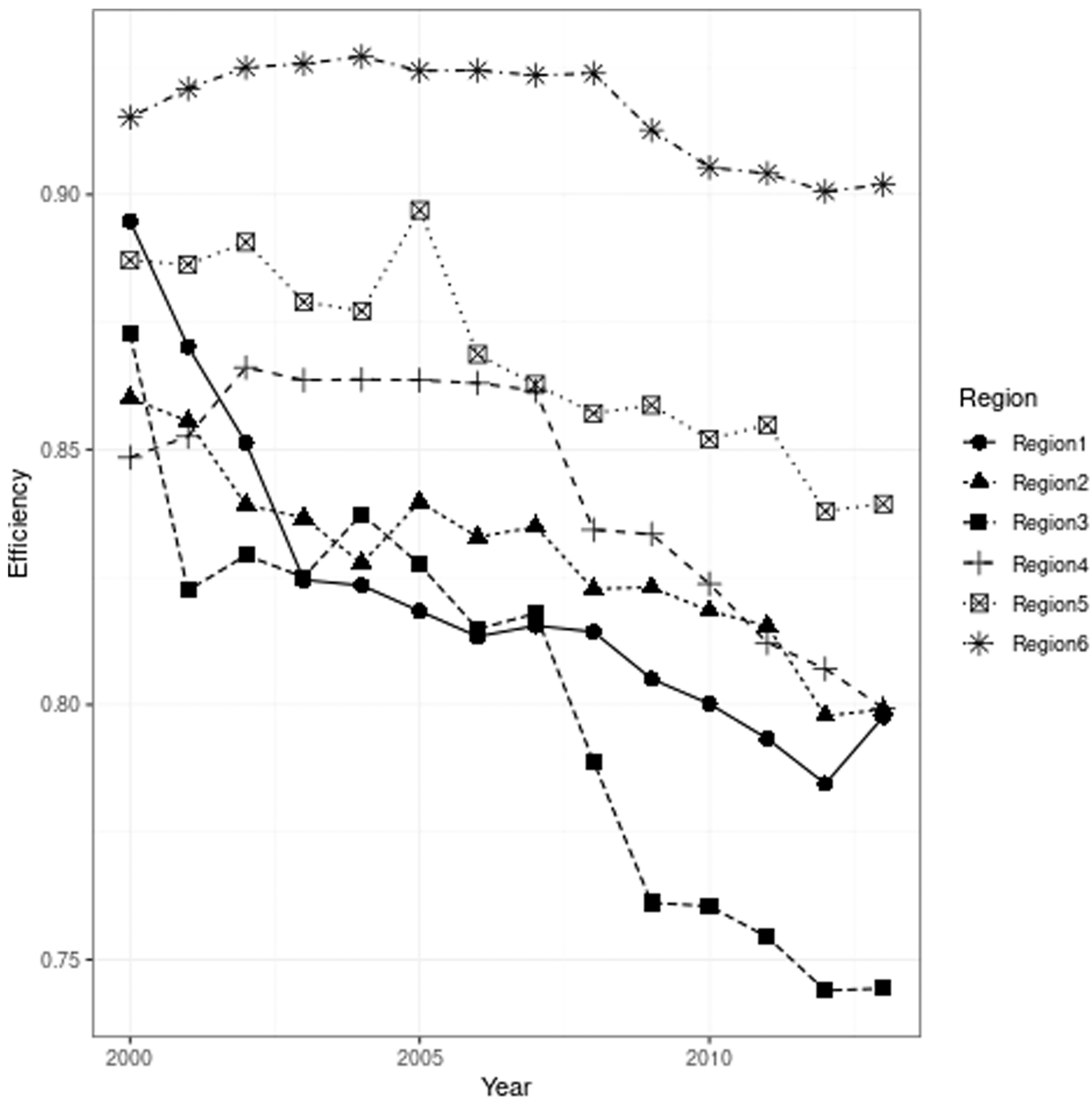



**Figure 4.** Inventory turnover efficiency by region.

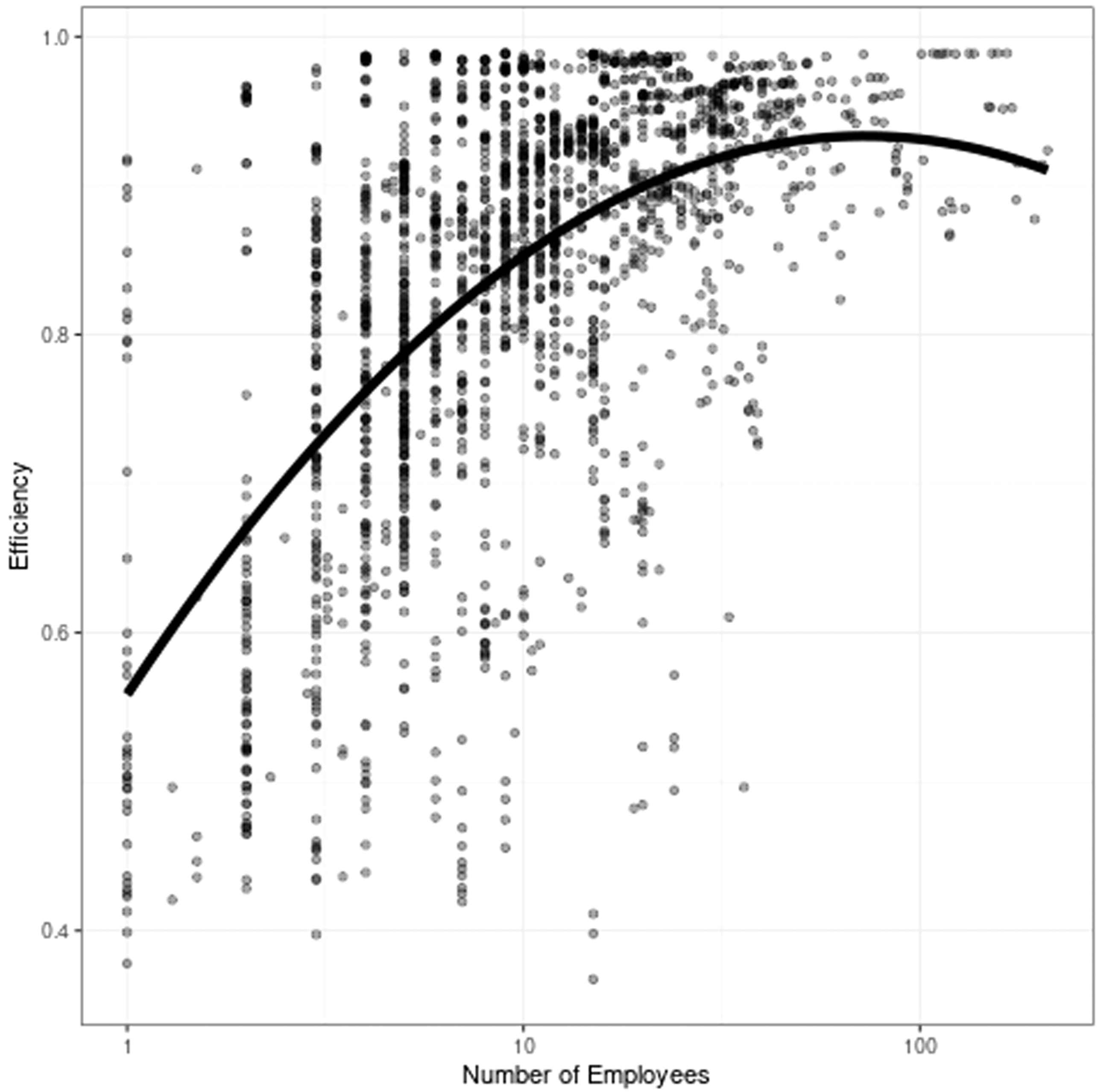



**Figure 5.** Inventory turnover efficiency by firm size.

The estimates reported in Table 7 further show that retail chain affiliation plays an important role in explaining firm inefficiency. First, the effects of firm size (*NoE*) on inventory turnover are significant at the $p < 0.001$ level for both XL-bygg and Byggtorget. Both estimates indicate that an increase in firm size reduces inefficiency. These findings extend and elaborate on previous findings in the literature (Gaur & Kesavan, 2009; Rumyantsev & Netessine, 2007a) and suggest that scale effects apply for efficiencies and vary among chains of retailers. Effective inventory management depends on updated transaction information (Yao & Carlson, 1999), such as the number of units sold and in stock, at the SKU level, and it requires high operating standards. In addition, inventory record inaccuracy is a substantial problem in retail operations that can be prevented by good auditing practices (DeHoratius & Raman, 2008). On average, high operating standards are more likely to be present in larger firms with staff trained and dedicated to monitor, follow-up and fine-tune inventory decisions.

Figure 5 displays the effects of firm size on efficiency, regardless of chain affiliation. The figure suggests that efficiency rises as firm size increases but at a diminishing rate. The figure further illustrates a great variance for

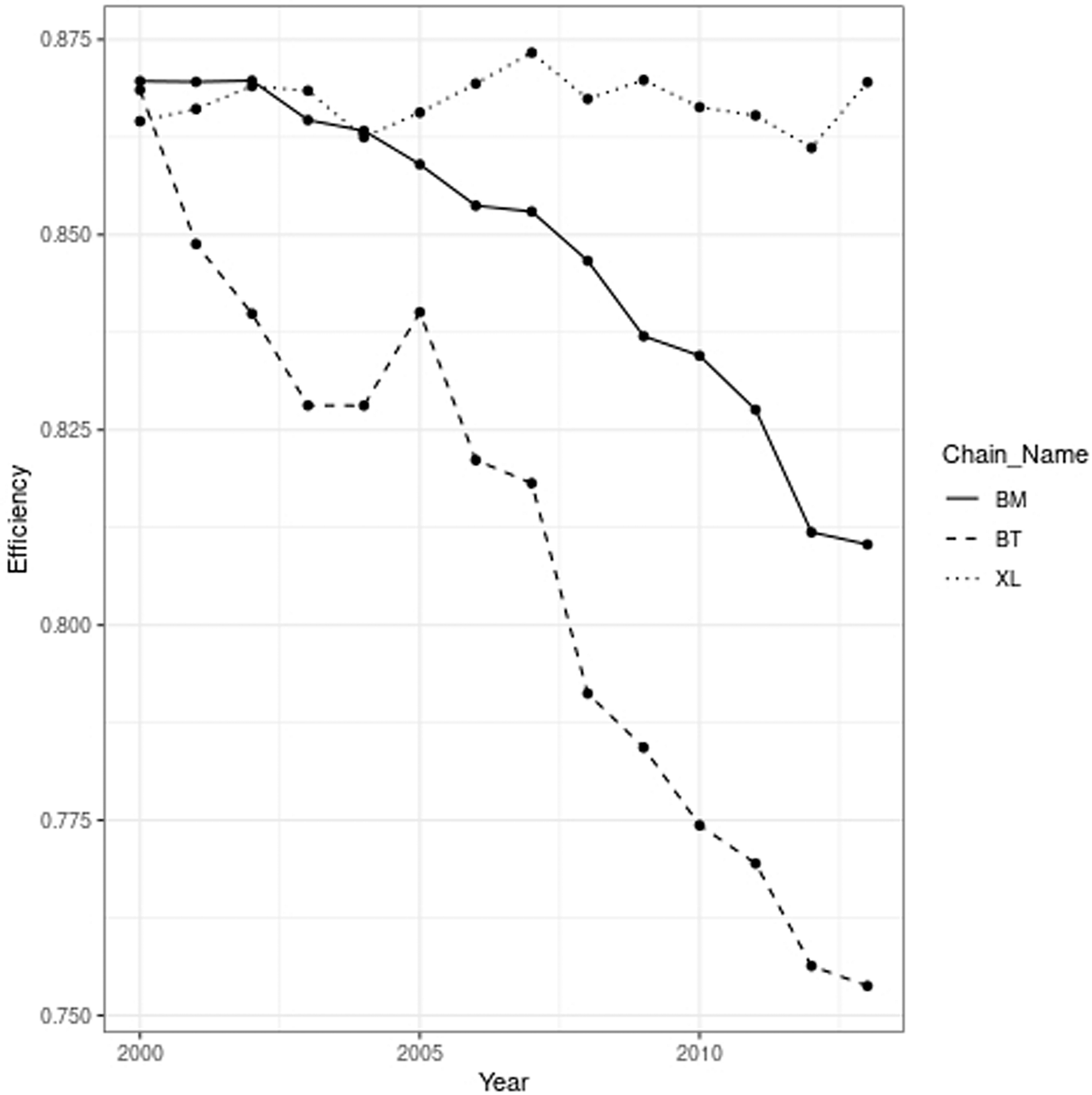



**Figure 6.** Inventory turnover efficiency by retail chain.

firms with fewer than approximately 20 employees and that beyond this point, all firms have efficiency scores better than and above 80% of the best performing firms. In assessing efficiency for firms that employ five workers, we find it on average to be 78.7% of the best performing firms, whereas for those employing 25 employees, it is estimated to be approximately 90.8% of the best performing firms.

Second, the coefficient estimate reported in Table 7 for time trends (*Time*) is significant ($p < 0.001$) for Byggtorget and indicates that these stores, over time, become less efficient.

Figure 6 visualises the mean retail store chain efficiencies by year. As the figure depicts, inventory turnover efficiency evolves differently over time for the retail chains examined. The efficiency frontier for Xl-bygg is principally steady over the time period, with only minor changes year by year. Stores affiliated with Byggtorget do, however, evolve in a bearish manner and indicate a significant drop in efficiency. A decline is noted for Byggmakker as well, but it is not as substantial as that for the latter stores. Extracting the mean inventory efficiency score by each retail chain on the two last years of observations reveals that Byggtorget underperforms Xl-bygg by 10.5 percentage points. A similar estimation for Byggmakker relative to Xl-bygg returns a 4.9 percentage point inferior efficiency score.

Differences in technology and strategy are likely explanations for inventory turnover efficiency varying among retail chains over time. Such factors may affect efficiency at the chain level as well as at the store level. The implementation and use of technology, such as software for resource planning, is important in running a successful retail store. To keep track of core business operations or processes, such software aims to monitor, among others, customer services, sales, accounting and, most importantly, inventory management. The latter focuses on forecasting demand, inventory replenishment and monitoring status in stock-keeping units. In recent decades, decisions on software have been made by the store owner and local management. As the increase in purchase orders and invoices started to run through the retail chain enterprise, recommendations on what software to use at the store level were generally made by chain management or even as a single supported option. There are many advantages to running the same software throughout all chain stores; this is especially true when centralised systems are used. The advantages that stem from such solutions may be faster and less costly transactions on orders and invoices, improved forecasting of demand and the possibility of adjusting prices from chain headquarters as part of common advertising and sales campaigns or the maintenance of product data on stock keeping units (SKU). Furthermore, in terms of strategic decisions, several conditions may explain chain differences over time. One such may be that as a main rule, terms and conditions for the purchase and choice of vendors are negotiated at the chain level. The added difference in purchase volume over time substantiates the notion that larger chains have advantages in regard to actual product price, fast delivery, and terms and conditions for purchasing, for instance, more store-friendly requirements regarding relinquishment, which underpin inventory performance.

Finally, the *SOA* estimates reported in Table 7 are significant at the $p < 0.01$ level for Byggmakker and at the $p < 0.05$ level for XL-bygg. However, these estimates have different signs. An increase in *SOA* for Byggmakker reduces inefficiency, whereas it has the opposite effect for XL-bygg. This is in line with the study of Shockley and Turner (2015), who report a positive relationship between firm performance and SOA, but also one that vary considerably between different retail industry segments. Moreover, as total assets, in addition to inventory, also include cash, accounts receivable, property, plant and equipment, this metric encompasses several dimensions that can signal a firm's efficient operation. For instance, the literature report a positive association is previously made between accounts receivable and firm profitability (Rumyantsev & Netessine, 2007b). Some likely explanations for the differences in the SOA estimates may be connected to decisions that stem from strategy, such as whether the plant or store is leased or owned and whether it is listed in the balance sheet of the retail store. Similarly, SOA may be influenced by other assets being owned, leased or rented, such as software, shop fittings or assets for internal materials handling, such as forklifts. Similarly, cases where the delivery of goods from the store to the customer is an in-house service, which necessitates the need for one or several trucks or vans, would increase assets and lower the SOA measure. If, however, hired transporters provide this service, it might slightly increase sales and thus increase the SOA measure. Decisions such as these may originate from more or less deliberate actions taken in regard to the moulding of strategy or due to operational convenience. On the other hand, a low measure of sales on assets, at least in the short-term, may result from investments in property and plants to support future growth ambitions.

## Conclusions

In this paper, we are concerned with determining how inventory turnover is associated with key financial figures, store- and chain-specific measures, and environmental factors, with a particular emphasis on how the environment surrounding the individual firm affects efficiency.

### *Main findings*

First, to estimate efficiency scores of inventory management, we examine two external environmental factors. However, to be able to produce unbiased efficiency estimates, it is necessary to control for regional differences. The results indicate that regional location (*REG*) plays a significant role in inventory turnover ratios and that noteworthy regional differences exist. The results show lowest inventory turnover ratios for those stores located in the most northern regions (*REG*1 and *REG*2). We explain this result by pointing towards generally increasing lead times for regions located further away from the capital of Oslo, especially since the surrounding area of Oslo often serves as a logistic hub in Norway.

The second environmental variable and the first to contribute to explain efficiency is the categorical variable that represents municipal centrality. This variable represents how close or remote the store is located (at the municipal level) to another larger urban area. The results indicate that inventory turnover efficiency differs depending on store location and generally improves when stores are located in more urban areas. However, we find the most remote municipalities to deviate from this general trend, as the results indicate that the stores belonging to this group are the most efficient.

The third environmental variable is population, which is modelled as an interaction variable with location centrality. As shown from the results, inventory turnover efficiency rises as population increases across the three statistically significant cohorts but at a diminishing rate. The results further indicate that inventory turnover efficiency varies in magnitude, depending on location and municipal centrality. An increase in market concentration and demand density supports such progress.

Economies of scale are important within most business research topics and this is no less true for inventory management. We find inventory efficiency to increase as the number of employees rises, but also that these effects differ between the retail chains examined in this paper. We conclude that scale effects apply for efficiencies and vary among chains of retailers, and that effective inventory management requires high operating standards, which are more likely to be present in larger firms.

We find the time trend in the inventory turnover efficiency to vary among the retail chains. While the mean efficiency for one of the retail chains is principally steady over the time period examined, with only minor changes year by year, stores affiliated with the least efficient retail chain show a significant drop in inventory efficiency over time. This might be a result of differences in technology and strategy.

Sales over total assets less inventory (SOA) is an indicator that expresses how efficiently the firm is able to make assets generate revenue. The results also show that the retail chains examined in this paper vary greatly on this efficiency metric. The results further suggest that SOA has contradictory effects on inventory turnover efficiency among the examined retail chains. Such differences may also be attributed to decisions that stem from strategy, such as different approaches to investing in property and equipment.

## Managerial implications

While firm-specific measures play an important role in assessing relative inventory levels, environmental factors cannot be neglected as a significant influence, both in the regional setting and even from the perspective of local market conditions.

When using inventory turnover as a benchmark for performance, analysts, chain and store management should consider including environmental factors such as the population and centrality of the municipality of store location, as well as regional belonging, in the analysis. Similarly, these or equivalent variables should be part of strategic planning when making decisions about product variety and merchandise depth. In addition, such environmental factors are found to impact decisions about the design of central warehousing versus direct store delivery from suppliers and vendors and solutions for transportation to bring SKUs to the retail store. They are key to reducing the lead time and its associated variation, thereby causing uncertainty in product availability at the store level. Moreover, environmental factors should be embedded in contract terms with suppliers and vendors to guarantee a given service level and maximum lead time and variability for all chain stores. In addition, chain management is recommended to support store management and staff on inventory management and training, software programmes to improve inventory control and the monitoring of inventory levels at the SKU level, replenishment procedures and inventory record inaccuracy.

Stores located in sparsely populated areas with a small customer base are likely to have less product variety and merchandise depth. This makes them vulnerable for online competition. Such stores should have an inventory policy that is agile and that makes the store able to respond to customers' demand in terms of ordering products outside the determined assortment and returning items to the supplier when necessary.

As traditional brick and mortar retail stores face increased competition with online retailers, attention to cost and operating performance is even more important. Only managerial comprehension of this problem and effective actions may avoid further impairment of inventory turnover and thus financial performance.

## Limitations and further research

As this sample of retailers represents approximately 30% of the Norwegian home improvement and building materials industry, the claim of generalisation would be inappropriate. In addition, while the geographic location of this market, with stores located in the Arctic Circle, makes it expedient to clarify the regional and environmental effects on inventory performance, such outcomes are likely to be different from those in more densely populated areas such as central Europe and the US, where the effects for environmental variables may be less conclusive. Even though the data include three complete retail chains, the geographic store locations may not be representative of the domestic market, and the results must be interpreted accordingly.

There are several areas where research on inventory performance in the future can be of importance. First, effects that stem from local market conditions such as the number of competitors, the level of competition and the market growth rate are to some extent covered by centrality and changes in population size. However, better instruments for these measures could bring about further insights regarding such effects. As this research points out, there are large differences between geographic regions, and further research is needed to unveil more specific details about what causes these differences in inventory performance, such as effects from long-term demand changes, lead times and other closely related logistical topics.

## Acknowledgements

Thanks to Anders Arntzen for the contribution on the data collection.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Notes

1. According to the exchange rate NOK/EUR at 27.04.2021. NOK = Norwegian Krone.
2. According to the exchange rate NOK/EUR at 27.04.2021.

## Notes on contributors

*Jørgen Breivik* is a Ph.D Candidate at UiT The arctic university of Norway. He holds an M.Sc. in business administration and has extensive experience from management positions. Breivik's work has been published in international journals such as the *Journal of Business Research,* and *Managerial and Decision Economics*.

*Nils Magne Larsen* is professor at UiT The artic university of Norway. He holds a Ph.D. from Brunel University in London and has published in journals such as *Journal of Business Research*, *Managerial and Decision Economics*, *Journal of Air Transport Management*, and *Perspectives of Behavior Science*.

*Sverre Braathen Thyholdt* is an associate professor at UiT The arctic university of Norway. He holds a Ph.D. from UiT The arctic university of Norway and has published in journals such as *Energy Policy*, *European Review of Agricultural Economics*, and *Marine Resource Economics*.

*Øystein Myrland* is a professor at UiT The arctic university of Norway. He holds a dr. scient. in economics from University of Tromsø and has been published in international journals such as *European Review of Agricultural Economics*, *Agricultural Economics*, *Marine Resource Economics*, and *Empirical Economics*.

## ORCID

*Jørgen Breivik* http://orcid.org/0000-0002-3611-7548
*Nils Magne Larsen* http://orcid.org/0000-0001-7671-0250

## References

Statistics Norway. (1999). Regionale inndelinger - En oversikt over standarder i norsk offisiell statistikk (Regional classifications - An overview of standards in Norwegian official statistics). https://www.ssb.no/a/publikasjoner/pdf/nos_c513/nos_c513.pdf.

Statistics Norway. (2008). *Norwegian Standard Industrial Classification (SIC2007).* https://www.ssb.no/a/publikasjoner/pdf/nos_d383/nos_d383.pdf.

Byggeindustrien. (2018). *Solid vekst for byggevaremarkedet (Solid growth for the building materials market)*, Bygg.no. Retrieved September 17, 2018, from http://www.bygg.no/article/1345914.

Statistics Norway. (2018). *Population and population changes.* Statistics Norway. https://www.ssb.no/en/befolkning/statistikker/folkemengde/aar-per-1-januar.

CIA. (2020). *The world factbook, central intellligence agency.* Retrieved December 3, 2020, from https://www.cia.gov/library/publications/the-world-factbook/geos/no.html.

R Core Team. (2020). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. URL https://www.R-project.org/.

Aiello, F., & Bonanno, G. (2016). Bank efficiency and local market conditions: Evidence from Italy. *Journal of Economics and Business*, *83*, 70–90. https://doi.org/10.1016/j.jeconbus.2015.09.002

Aigner, D., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, *6*(1), 21–37. https://doi.org/10.1016/0304-4076(77)90052-5

Alan, Y., Gao, G. P., & Gaur, V. (2014). Does inventory productivity predict future stock returns? A retailing industry perspective. *Management Science*, *60*(10), 2416–2434. https://doi.org/10.1287/mnsc.2014.1897

Assaf, A. G., Barros, C., & Sellers-Rubio, R. (2011). Efficiency determinants in retail stores: A Bayesian framework. *Omega*, *39*(3), 283–292. https://doi.org/10.1016/j.omega.2010.07.005

Azzi, A., Battini, D., Faccio, M., Persona, A., & Sgarbossa, F. (2014). Inventory holding costs measurement: A multicase study. *The International Journal of Logistics Management*, *25*(1), 109–132. https://doi.org/10.1108/IJLM-01-2012-0004

Baker, P. (2007). An exploratory framework of the role of inventory and warehousing in international supply chains. *The International Journal of Logistics Management*, *18*(1), 64–80. https://doi.org/10.1108/09574090710748171

Ballou, R. H. (2005). Expressing inventory control policy in the turnover curve. *Journal of Business Logistics*, *26*(2), 143–164. https://doi.org/10.1002/j.2158-1592.2005.tb00209.x

Baltas, G. (2005). Exploring consumer differences in food demand: A stochastic frontier approach. *British Food Journal*, *107*(9), 685–692. https://doi.org/10.1108/00070700510615062

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, *20*(2), 325–332. https://doi.org/10.1007/BF01205442

Ben-daya, A. M., & Raouf, A. (1994). Inventory models involving lead time as a decision variable. *The Journal of the Operational Research Society*, *45*(5), 579–582. https://doi.org/10.1057/jors.1994.85

Bos, J. W. B., and Kool, C. J. M. (2006). Bank efficiency: The role of bank strategy and local market conditions. *Journal of Banking and Finance*, *30*(7), 1953–1974. https://doi.org/10.1016/j.jbankfin.2005.07.008

Breivik, J. (2019). Retail chain affiliation and time trend effects on inventory turnover in Norwegian SMEs. *Cogent Business and Management*, *6*(1), 1–17. https://doi.org/10.1080/23311975.2019.1604932

Cannon, A. R. (2008). Inventory improvement and financial performance. *International Journal of Production Economics*, *115*(2), 581–593. https://doi.org/10.1016/j.ijpe.2008.07.006

Capkun, V., Hameri, A., & Weiss, L. (2009). On the relationship between inventory and financial performance in manufacturing companies. *International Journal of Operations & Production Management*, *29*(8), 789–806. https://doi.org/10.1108/01443570910977698

Carlino, G. A., & Voith, R. (1992). Accounting for differences in aggregate state productivity. *Regional Science and Urban Economics*, *22*(4), 597–617. https://doi.org/10.1016/0166-0462(92)90004-K

Chen, H., Frank, M. Z., & Wu, O. Q. (2007). U.S. retail and wholesale inventory performance from 1981 to 2004. *Manufacturing & Service Operations Management*, *9*(4), 430–456. https://doi.org/10.1287/msom.1060.0129

Ciccone, A., & Hall, R. E. (1996). Productivity and the density of Economic activity. *American Economic Review*, *86*(1), 54–70. https://doi.org/10.2307/2118255

Coelli, T., & Henningsen, A. (2017). *Frontier: Stochastic frontier analysis*. https://CRAN.R-Project.org/package = frontier.

DeHoratius, N., & Raman, A. (2008). Inventory record inaccuracy: An empirical analysis. *Management Science*, *54*(4), 627–641. https://doi.org/10.1287/mnsc.1070.0789

Delen, D., Kuzey, C., & Uyar, A. (2013). Measuring firm performance using financial ratios: A decision tree approach. *Expert Systems with Applications*, *40*(10), 3970–3983. https://doi.org/10.1016/j.eswa.2013.01.012

Diaz, M. A., & Sanchez, R. (2008). Firm size and productivity in Spain: A stochastic frontier analysis. *Small Business Economics*, *30*(3), 315–323. https://doi.org/10.1007/s11187-007-9058-x

Dinlersoz, E. M. (2004). Firm organization and the structure of retail markets. *Journal of Economics & Management Strategy*, *13*(2), 207–240. https://doi.org/10.1111/j.1530-9134.2004.00009.x

Doms, M. E., Jarmin, R. S., & Klimek, S. D. (2004). Information technology investment and firm performance in US retail trade. *Economics of Innovation and New Technology*, *13*(7), 595–613. https://doi.org/10.1080/1043859042000201911

Eroglu, C., & Hofer, C. (2011a). Lean, leaner, too lean? The inventory-performance link revisited. *Journal of Operations Management*, *29*(4), 356–369. https://doi.org/10.1016/j.jom.2010.05.002

Eroglu, C., & Hofer, C. (2011b). Inventory types and firm performance: Vector autoregressive and vector error correction models. *Journal of Business Logistics*, *32*(3), 227–239. https://doi.org/10.1111/j.2158-1592.2011.01019.x

Eroglu, C., & Hofer, C. (2014). The effect of environmental dynamism on returns to inventory leanness. *Journal of Operations Management*, *32*(6), 347–356. https://doi.org/10.1016/j.jom.2014.06.006

Foster, L., Haltiwanger, J., & Krizan, C. J. (2006). Market selection, reallocation, and restructuring in the U.S. Retail trade sector in the 1990S. *Review of Economics and Statistics*, *88*(4), 748–758. https://doi.org/10.1162/rest.88.4.748

Gaur, V., Fisher, M. L., & Raman, A. (2005). An econometric analysis of inventory turnover performance in retail services. *Management Science*, *51*(2), 181–194. https://doi.org/10.1287/mnsc.1040.0298

Gaur, V., & Kesavan, S. (2009). The effects of firm size and sales growth rate on inventory turnover performance in the U.S. Retail sector. *International Series in Operations Research and Management Science*, *122*, 25–52. https://doi.org/10.1007/978-0-387-78902-6_3

Harris, F. (1990). How many parts to make at once. *Operations Research*, *38*(6), 947–950. https://doi.org/10.1287/opre.38.6.947. [Reprinted from Factory: The Magazine of Management 10(2), 1913, pp. 135–136].

Hernant, M., Andersson, T., & Hilmola, O. P. (2007). Managing retail chain profitability based on local competitive conditions: Preliminary analysis. *International Journal of Retail and Distribution Management*, *35*(11), 912–935. https://doi.org/10.1108/09590550710828236

Hill, R. C., Griffiths, W. E., & Lim, G. C. (2011) *Principles of econometrics*. 4th ed. John Wiley & Sons Ltd.

Isaksson, O. H. D., & Seifert, R. W. (2014). Inventory leanness and the financial performance of firms. *Production Planning and Control*, *25*(12), 999–1014. https://doi.org/10.1080/09537287.2013.797123

Jarmin, R. S., Klimek, S. D., & Miranda, J. (2009). The role of retail chains: National, regional and industry results. In T. Dunne, J. B. Jensen, & M. J. Roberts (Eds.), *Producer dynamics: New evidence from micro data* (pp. 237–262). University of Chicago Press. http://www.nber.org/chapters/c0487.

Kesavan, S., Kushwaha, T., & Gaur, V. (2016). Do high and low inventory turnover retailers respond differently to demand shocks? Manufacturing & Service Operations Management, *18*(02), 198–215. https://doi.org/10.1287/msom.2015.0571

Ko, K., Chang, M., Bae, E. S., & Kim, D. (2017). Efficiency analysis of retail chain stores in korea. *Sustainability*, *9*(9), 1–14. https://doi.org/10.3390/su9091629

Kolias, G. D., Dimelis, S. P., & Filios, V. P. (2011). An empirical analysis of inventory turnover behaviour in Greek retail sector: 2000-2005. *International Journal of Production Economics*, *133*(1), 143–153. https://doi.org/10.1016/j.ijpe.2010.04.026

Kosová, R., & Lafontaine, F. (2012). Much ado about chains: A research agenda. *International Journal of Industrial Organization*, *30*(3), 303–308. https://doi.org/10.1016/j.ijindorg.2011.12.010

Kumar, V., & Karande, K. (2000). The effect of retail store environment on retailer performance. *Journal of Business Research*, *49*(2), 167–181. https://doi.org/10.1016/S0148-2963(99)00005-3

Kumbhakar, S. C., & Lovell, C. A. K. (2000). *Stochastic frontier analysis*. Cambridge University Press.

Meeusen, W., & van Den Broeck, J. (1977). Efficiency estimation from cobb-douglas Production functions with composed error. *International Economic Review*, *18*(2), 435. https://doi.org/10.2307/2525757

Monahan, S., Ward, J., Zimmerman, M., Sonthalia, B., & Vanhencxthoven, M. (2017). Accelerating into uncertainty. *CSCMP's Annual state of logistics report*, pp. 1–46.

Moser, P., Isaksson, O. H. D., & Seifert, R. W. (2017). Inventory dynamics in process industries: An empirical investigation. *International Journal of Production Economics*, *191*(January), 253–266. https://doi.org/10.1016/j.ijpe.2017.06.019

Otsuka, A. (2017). Regional determinants of total factor productivity in Japan: Stochastic frontier analysis. *The Annals of Regional Science*, *58*(3), 579–596. https://doi.org/10.1007/s00168-017-0808-7

Perrigot, R. (2006). Services vs retail chains: Are there any differences? Evidence from the French franchising industry. *International Journal of Retail and Distribution Management*, *34*(12), 918–930. https://doi.org/10.1108/09590550610714648

Rajagopalan, S., & Malhotra, A. (2001). Have U.S. Manufacturing inventories really decreased? An empirical study. *Manufacturing & Service Operations Management*, *3*(1), 14–24. https://doi.org/10.1287/msom.3.1.14.9995

Rumyantsev, S., & Netessine, S. (2007b). Inventory and its relationship with profitability: Evidence for an international sample of countries. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2319862

Rumyantsev, S., & Netessine, S. (2007a). What can be learned from classical inventory models? A cross-industry exploratory investigation. *Manufacturing & Service Operations Management*, *9*(4), 409–429. https://doi.org/10.1287/msom.1070.0166

Rumyantsev, S., & Netessine, S.. (2007c). Should inventory policy be lean or responsive? Evidence for US public companies. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2319834

Salam, A., Panahifar, F., & Byrne, P. J. (2016). Retail supply chain service levels: The role of inventory storage. *Journal of Enterprise Information Management*, *29*(6), 887–902. https://doi.org/10.1108/JEIM-01-2015-0008

Shockley, J., & Turner, T. (2015). Linking inventory efficiency, productivity and responsiveness to retail firm outperformance: Empirical insights from US retailing segments. *Production Planning and Control*, *26*(5), 393–406. https://doi.org/10.1080/09537287.2014.906680

Weill, L. (2008). Leverage and corporate performance: Does institutional environment matter? *Small Business Economics*, *30*(3), 251–265. https://doi.org/10.1007/s11187-006-9045-7

Williams, B. D., & Tokar, T. (2008). A review of inventory management research in major logistics journals: Themes and future directions. *The International Journal of Logistics Management*, *19*(2), 212–232. https://doi.org/10.1108/09574090810895960

Yao, A. C., & Carlson, J. G. (1999). Impact of real-time data communication on inventory management. *International Journal of Production Economics*, *59*(1), 213–219. https://doi.org/10.1016/S0925-5273(98)00234-5