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Role of inventory and assets in shareholder value creation

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In this study is examined the role of inventories and assets in the financial and shareholder value creation of a company. Research builds several Data Envelopment Analysis (DEA) models (staged), and tests their connections with each other. Research concerns publicly traded manufacturing and trade companies of Finland and three Baltic States (Estonia, Latvia and Lithuania) during the years 2010–2018. Logical and in two stages proceeding DEA eﬃciency model gets statistical significance, and there is support that inven- tory and asset related measures will lead to revenue, profits and cash flow, which together will eventually result in higher shareholder value (like stated in operations and supply chain management theories such as theory of constraints). However, this finding has weakness as explanation power is low, and there is a lot of noise. It could also be so that inventories and assets are part of bunch of other inputs, which to- gether directly create shareholder value. Therefore, it remains as an open question whether inventory and assets should be managed through classical and logical stages in companies through organization hierar- chy, or if inventory and assets should be just a part of group of factors, which together aim to increase shareholder value.

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# Introduction

In Operations and Supply Chain Management (OSCM) research inventory management is seen as an essential part of success, and inventory amounts should always be decreased, if it is pos- sible without hurting internal eﬃciency, deliveries and/or sales too much. Contrary to financial and asset perspectives, in OSCM, inven- tory is seen as a liability rather than an asset class (like Theory of Constraints or Just in Time branch; ([de Haan & Yamamoto, 1999](#_bookmark15); [Eroglu & Hofer, 2011](#_bookmark23); [Ikeziri, de Souza, Gupta & Fiorini, 2019](#_bookmark27)). It is also argued in these OSCM theories that eﬃcient inventory management will result on higher sales, profits and profitability. Empirical findings from the retail sector argue that it is not nec- essarily gross or profit margin, that matter, as margins may be [low, but on the other hand inventory turns are high (Gandhi & Shankar, 2016;](#_bookmark24) [Ga](#_bookmark25)[ur, Fisher & Raman, 2005). This will eventually](#_bookmark24) lead to high return on investment and absolute profits. Lower in- [ventory also enables strategic flexibility or agility (Purvis, Gosling & Naim, 2014), helping company to better adapt to market and](#_bookmark40) technological changes. Low inventory also drives production pro- cesses, streamlines the supply chain and lowers used lot sizes (or

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even individualistic lot sizes of one). With the argued inventory linkage to financial success of company, it is evident that inven- tory must have role in shareholder value creation (in this research defined as changes of adjusted annual share prices). If inventory has such a critical role in short-term financial success and strate- gic flexibility, then it must have clear connections to shareholder value. However, this all was commonly agreed upon before the global financial crisis of 2008–2009, but thereafter implemented low (or zero) interest rates have since changed the common opin- ion. Based on recent studies, it is found that increasing invento- [ries are the fact among companies (and in some industries, Moser, Isaksson & Seifert, 2017), and these could enable even shareholder](#_bookmark37) [value creation success in this new environment (Bendig, Brettel & Downar, 2018;](#_bookmark16) [S](#_bookmark42)[teinker & Hoberg, 2013). These recent empiri-](#_bookmark16) cal studies in the field argue that inventory can grow during the short-term to enable responsiveness, however, in the longer-term it should stay in good level, and not to deteriorate to lower inven- tory turns and constantly higher inventory holdings.

In this research empirical material is gathered from smaller Eu- ropean countries (Finland and three Baltic States: Estonia, Latvia and Lithuania), and selected companies represent manufacturing and retail. Domestic markets in these countries are small and ex- periencing aging population effects, so most of the companies have significant international operations as well. Research data arising

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from these smaller countries is simultaneously strength and weak- ness of this study, and its generalization. As said, companies are typically rather international, but on the other hand, their pub- lic stock trading at exchanges is having moderate or low volume as compared to other larger countries. This is the main limitation of this study – operative performance changes do not necessarily turn to shareholder value immediately. All four countries are part of the European Union, and in the recent years they all have joined the Euro currency area (Finland being founding members as Esto- nia joined 2011, Latvia in 2014 and Lithuania in 2015). Before join- ing the Euro currency, all three Baltic States had very stable cur- rencies – practically Estonia and Lithuania had more than decade same peg rate to Euro (prior joining Euro zone), and Latvia’s sit- uation did not differ that much as its currency rate movements

were ±1% to Euro ([Anghel, Pinzaru, Dinu & Treapat, 2014](#_bookmark17)). All four

countries have enjoyed from on-going lowering of interest rates

during the examination period (2010–2018), and in recent years interest rates have started to approach zero. This study does not include year 2009 in the analysis as the global financial crisis hit abnormally hard to some of these countries, especially Baltic States ([Hilmola, 2013](#_bookmark28)), where Gross Domestic Products declined by 15– 19%. Research problem of this study could be stated with follow- ing research questions: What is the role of different inventory and asset measures in financial and shareholder success of a company (eﬃciency in terms of how converting from inputs to stated out- puts)? What is the route to shareholder value creation, indirect vs. direct, or both? DEA models in this research work follow Theory Of Constraints (TOC) approach, where traditional staged model from inventory (all inventory classes from balance sheet in total) and as- sets (all balance sheet assets in total) result to intermediate output success of financial measures, and eventually to shareholder value ([Gupta, 2012](#_bookmark26); [Hilmola & Gupta, 2015](#_bookmark29); [Ikeziri et al., 2019](#_bookmark27)). DEA has been used in small extent within TOC frameworks, and mostly research works have concerned manufacturing job-shop schedul- ing ([Arango-Marín, Giraldo-García & Castrillión-Gómez, 2014](#_bookmark18)), con- [straint identification and elevation in manufacturing (Shurrab, Al- Refaie, Mandahawi & Shurrab, 2018) as well as building supply](#_bookmark41) chains towards leagility ([Banerjee & Mukhopadhyay, 2016](#_bookmark19)). Contri- bution of this work is to enlarge DEA in TOC reasoning of inven- tory, assets and operational performance, which is argued to lead into financial success and shareholder value.

This research is structured as follows: In [Section 2](#_bookmark3), previous

DEA eﬃciency research works is reviewed, which have used inven- tory (and assets) in their evaluation models of for-profit compa- nies. Research methodology and environment follows in [Section 3](#_bookmark2), where used DEA models of this study are introduced and cor- relation analysis is being completed between different variables. [Section 4](#_bookmark7) provides empirical data analysis, where causality and re- gression models between different DEA models are thoroughly an- alyzed. Research is concluded in [Section 5](#_bookmark13), where also new avenues for future studies are being proposed.

# Role of inventory and assets in DEA research

Since the seminal research published from DEA eﬃciency eval- uation method, there has been four decades of time to make re- search works from different disciplines. As thousands of research works have already been published ([Emrouznejad & Yang, 2018](#_bookmark22)) estimated that until 2016 the total amount of DEA journal pub- lications was 10,300), it is evident that inventory eﬃciency has been dealt with in earlier research. A literature review revealed that most often inventory and assets are considered in retail sector [eﬃciency evaluations (](#_bookmark31)[Gandhi & Shankar, 2016](#_bookmark24)[; Joo, Nixon & Stoe-](#_bookmark31) [be](#_bookmark38)[rl, 2011;](#_bookmark31) [Mhatr](#_bookmark36)[e, Seong-Jong & Lee, 2014; Wu, Kao, Wu & Cheng,](#_bookmark31) [2006), and surprisingly very rarely in that of manufacturing or pro-](#_bookmark38) duction ([Dev, Shankar & Debnath, 2014](#_bookmark21)). Sometimes inventory or

inventory eﬃciency are not considered at all, but it is being exam- ined from the eﬃciency of managing inventory through existing resources ([Jatuphatwarodom, Jones & Ouelhadj, 2018](#_bookmark30)) or from crit- ical parameters causing inventory, like supply lead time and review period frequency ([Dev et al., 2014](#_bookmark21)). These two studies had also dif- ferent outputs (in [Jatuphatwarodom et al., 2018](#_bookmark30): inventory costs, delivery time & turnover rate; in [Dev et al., 2014](#_bookmark21): fill rate) as com- pared to rest of the research. In other research works, which are directly dealing inventory and asset eﬃciency, they were typically [including inventory in absolute terms (nominal value; Joo et al., 2011;](#_bookmark31) [Mhatr](#_bookmark36)[e et al., 2014;](#_bookmark31) [Wu](#_bookmark38) [et al., 2006), but in one study inven-](#_bookmark31) [tory turns were taken as an input (Gandhi et al., 2016). Joo et al. (2011) examined eﬃciency through three different models (moti-](#_bookmark31) vated by return on assets methodology), which included different sub-classes of assets in two models (current, fixed and other as- sets, and in another one cash, accounts receivable and inventory). Similarly, [Wu et al. (2006)](#_bookmark38) included in the model current assets separately. For output, DEA models typically used revenue or sales ([Joo et al., 2011](#_bookmark31); [Mhatre et al., 2014](#_bookmark36); Gandhi et al., 2016), however, Wu (2006) included both sales and gross margin.

Findings of retail sector DEA eﬃciency analyses contained quite

much variation in eﬃciency, even if the retail sector should have small differences between companies due to high competition and small margins. [Wu et al. (2006)](#_bookmark38) study find that different sub- sectors of retail have very different eﬃciency levels, with textile sales being the most diﬃcult to manage eﬃciently. General mer- chandise and vehicle part sales had much higher average eﬃciency values. [Wu et al. (2006)](#_bookmark38) also examined the relationship of differ- ent input items on sales and gross margin. Their regression model indicated that higher inventory investment would result on lower sales, however, the statistical significance of this was not high enough. Typically, other studies concluded that Walmart was ex- emplary in its eﬃciency (Gandhi et al., 2016), whatever the DEA model being used ([Joo et al., 2011](#_bookmark31)). Margins of Walmart are not high, however, asset turns are high and capital is employed very eﬃciently, which ensures high performance. In recent years, we have witnessed a remarkable decline of traditional retailers e.g. in USA, and those being hurt most could be found from these earlier studies as being the lowest performing and having declining eﬃ- [ciency in the observation period (see e.g.,](#_bookmark36) [Joo et al., 2011](#_bookmark31)[; Mhatre et al., 2014). So, high eﬃciency in the traditional model seems to](#_bookmark36) provide some hedge in the era of technological change.

# Research methodology

This research concerns manufacturing and trade companies in Northern Europe, and the data consists 33 different companies (Baltic Main List and Baltic Secondary List) from three Baltic States (Estonia, Latvia and Lithuania), and 39 companies from Finland (“industrials”, “information technology”, “consumer services” and “materials”). Companies are listed in [Appendix A](#_bookmark32), and basically all available companies were included in this study, without any size restrictions. It is notable that not all companies had complete data from the observation period of this study from years 2010–2018. Mostly this was due to public listing of a number of companies during the examination period, so accounting records and stock market share price data were simply unavailable from some years. Annual reports, accounting data, and adjusted share price data (for currency changes, stock splits or reverse splits) were mostly gath- ered from Nasdaq Baltic (2019) and Nasdaq Nordic (2019) company based information sources or alternatively from company investor webpages. Each company had its own spreadsheet from gathered data, and these were merged together into a database, which was used to get data for eﬃciency analysis using Data Envelopment Analysis.

Negativity in items such as profit and loss, cash flow and share price change (adjusted, annual) was avoided by adding a fixed amount in all of these in order to have them be on scale from zero onwards (like in other DEA studies, see [Pastor & Ruiz, 2007](#_bookmark39)). In profit and loss, it was added 3789,001 EUR (thousands) to each real number, in cash flow the amount was 1454,001 EUR (thou- sands), while in share price changes it was added one (1). Also inventory turns needed to be modified for the purposes of DEA re- search as in general it is so that higher input amounts should lead to higher outputs (having the same and consistent direction be- tween inputs and outputs). Therefore, inventory turns was calcu- lated as an inverse number (lower the inventory turns, the higher the input number).

Cash Flow (operative) {O/I} Adj. stock price change {O}

1.000

To increase the validity of the following eﬃciency analyses (e.g. [Lin, 2007](#_bookmark33)), correlation analysis was made from the used eﬃciency model variables (see [Table 1](#_bookmark4) in below). Only adjusted stock price change (%) in annual basis had no correlation at all with other input and output variables. This is somewhat surprising, too, as annual results in terms of profits and losses as well as operative cash flow is analyzed not to have any relation with share price change. Adjusted stock price change (%) was also further analyzed with the effect of time delay of one year or two years (time lag from other variables of this study could be having time lag to grand output – changes of today e.g. in inventory eﬃciency could be present in adjusted stock price in two years), however, this did not change the situation, and same non-correlation persisted. Sim- ilarly, profit and loss was having only two correlations (positive) – these with absolute inventory investment amount and operative cash flow. The third mostly output variable, revenue, had a number of correlations. In statistically significant terms, revenues increase as absolute inventory investment, total assets, and cash flow in- crease. However, if inventory is getting too large role in total assets (%), then it will decrease revenue as does inverse inventory turns. Among only input variables (which do not represent any model as output), there exist correlations, however, these are in both direc- tions (negative and positive). Interestingly, absolute inventory in- vestment and inverse inventory turns do not have any causality at all. Correlations between input factors could be seen as weakness of this study, but as causalities are in both directions, this should not be major validity issue. Also, many asset-based measures are tied to each other due to industrial branch features, investments made and type of customers served.

**Table 1**

Correlation matrix of DEA variables used in research (inputs and outputs; *n* = 619 for variables apart of adj. stock price change, where *n* = 586).

Inventory (assets-%) {I}

Assets {I}

Revenue {O/I}

Profit/loss {O/I}

1.000

−0.243∗∗∗

−0.227∗∗∗

−0.053

−0.182∗∗∗

0.024

1.000

0.938∗∗∗

0.042

0.612∗∗∗

−0.037

1.000

0.056

0.701∗∗∗

−0.046

1.000

0.481∗∗∗

0.038

1.000

0.000

As research used number of DEA models, and especially the

Inventory turns (rev.) {I}

stage 4 model ([Fig. 2](#_bookmark6)) was having so many input-output vari- ables (eight), that it was logical to pool together all observations [from different years as a single analyzed group (like Mhatre et al., 2014 did for retail sector analysis, as](#_bookmark36) [Ko](#_bookmark34)[zmetsky & Yue, 1998 did](#_bookmark36) in semiconductor industry). This increased the reliability of results significantly. Eﬃciency analysis was completed with EMS software (ver. 1.3.0). This software is rather old, but is an often applied pro- gram in eﬃciency analysis. Models in the following assume that eﬃciency frontier is based on “constant return on scale” (CCR), and models are input driven ([Charnes, Cooper & Rhodes, 1978](#_bookmark20)). It could be argued that “variable return on scale” as eﬃciency fron- tier should have been used as company sizes differed so greatly in this research work (e.g. revenues from several millions to billions of EUR). However, when running eﬃciency analyses, it became evi- dent that smaller companies were able to perform well with larger ones, and need for frontier adjustments felt unnecessary.

Inventory {I}

Inventory {I}

Inventory turns (revenue) {I} Inventory (assets-%) {I} Assets {I}

Revenue {O/I} Profit/loss {O/I}

Cash Flow (operative) {O/I} Adj. stock price change {O}

[1.000](#_bookmark20)

−0.078

−0.189∗∗∗

0.863∗∗∗

0.868∗∗∗

0.181∗∗∗

0.659∗∗∗

−0.041

1.000

0.384∗∗∗

−0.105∗∗

−0.126∗∗

−0.034

−0.094∗

0.049

∗∗∗ statistically significant with *<*0.001 level.

∗∗ statistically significant with *<*0.01 level.

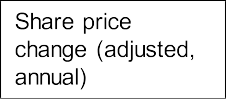
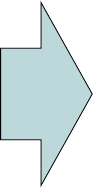
∗ statistically significant with *<*0.05 level.

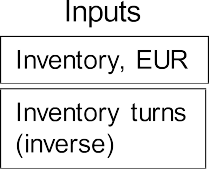
Regression analysis in the following was firstly completed with Excel’s data analysis tool (Excel 2016). Later on regression anal- yses were also completed and expanded in RStudio (ver. 1.1.456 for Ubuntu/Linux). In the following linear regression models are reported using ordinary least squares models. However, these are supported with Tobit regression models (like [Tasnim & Afzal, 2018](#_bookmark35)), which limit regression model to the area from 0 (lower) to 1 (up-

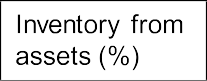




**Fig. 1.** Staged DEA model used for the role of inventory and assets (stages 1–3).

per limit). In the analysis significant differences between two re- gression model approaches were not found, and research supports further findings of [McDonald (2009)](#_bookmark35) .

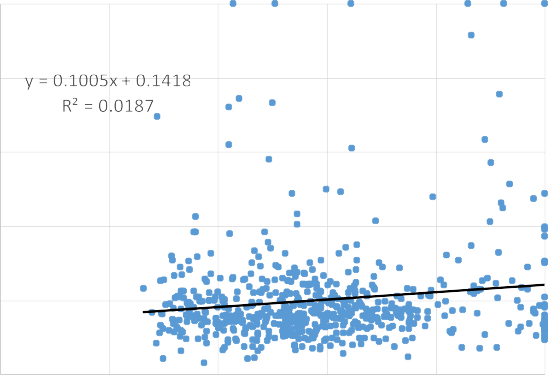
# Empirical data analysis

Logic from inventory and asset inputs to revenue, profits and cash flow, and eventually to shareholder value creation sounds rea- sonable and logical, but in this eﬃciency study this is only sup- ported in moderate fashion. [Fig. 3](#_bookmark8) illustrates DEA eﬃciency corre- lation between models of transforming inventory and asset inputs to revenue, profits and cash flow (stage 1) and then turning these intermediate outputs to inputs and seeing as true output adjusted share price change (stage 2). Regression model between these two DEA models is very poor in explanation power (R2 being 1.87%), but it is statistically significant (both fixed term and co-eﬃcient are having *p*-value of *<*0.001). However, as examining in details [Fig. 3](#_bookmark8), it seems that most of the companies are having positive regression relationship in two models, but then there are some companies, which are clearly over-performing in stage 2 of DEA model. This basically means that adjusted stock price change has been achieved with rather mediocre input performance (revenues, profits and cash flow). In regression line of [Fig. 3](#_bookmark8), when eﬃciency of DEA model at stage 1 improves with one percentage point, it will lead to improvement of stage 2 model with 0.1005 percentage points. As [Fig. 1](#_bookmark5) regression is ordinary least squares model, corre- lation data was also used to estimate Tobit regression model (with lower limit of 0 and upper limit of 1; see [Appendix B](#_bookmark14) for details). This model also supports argument existence of route from stage 1 to stage 2, however, the co-eﬃcient in Tobit regression is pretty much the same as in [Fig. 3](#_bookmark8).

Interestingly, there exists causality between DEA models of stage 2 and stage 3. Performance is statistically significant, and linear regression curve proceed in rather equal fashion – if stage 2 model improves one percentage point, then stage 3 model im- proves by 0.9746 percentage points (explanation power of regres- sion model is rather high, R2 being 51.8%). Causality is having some weaknesses as heteroscedasticity seems to be present, and in some observations both DEA models could give highest possible frontier performance (1 or 100%), while the other is much lower. Overall, it seems that inventory and asset inputs do have role, but it could be a merely direct role to shareholder value creation. Tobit regression model ([Appendix B](#_bookmark14)) similarly shows statistical significance and co- eﬃcient with [Fig. 4](#_bookmark9) model.

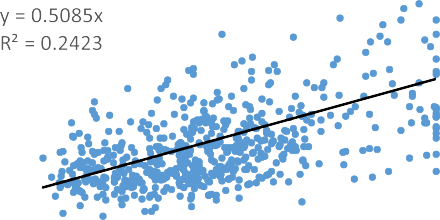
Direct model from inputs to shareholder value (stage 3) is also having causality with initial model (stage 1), where inventory and assets were connected to revenue, profits and cash flow ([Fig. 5](#_bookmark11)).

**Fig. 2.** Staged DEA model used for the role of inventory and assets (stages 4).

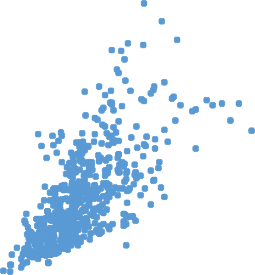


**Fig. 3.** DEA eﬃciency correlation with regression model between stage 1 model (x- axis) and stage 2 model (y-axis).

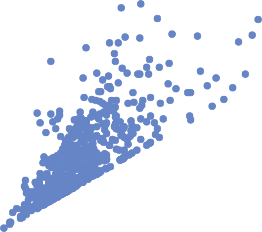
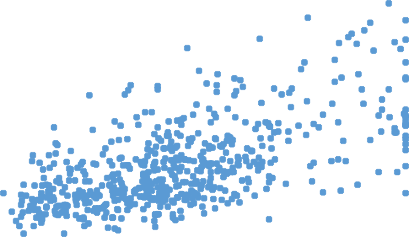




**Fig. 6.** DEA eﬃciency correlation with regression model between stage 1 model (x- axis) and stage 4 model (y-axis).

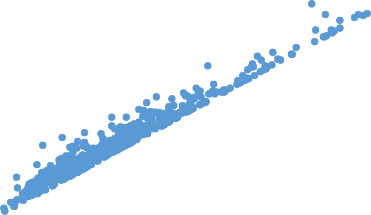


**Fig. 4.** DEA eﬃciency correlation with regression model between stage 2 model (x- axis) and stage 3 model (y-axis).



**Fig. 7.** DEA eﬃciency correlation with regression model between stage 2 model (x- axis) and stage 4 model (y-axis).

**Fig. 5.** DEA eﬃciency correlation with regression model between stage 1 model (x- axis) and stage 3 model (y-axis).



Every time stage 1 model improves by one percentage unit, it leads to improvement of 0.5546 in stage 3 model. Therefore, causality is not as strong as in previous model, however, it surely exists. Expla- nation power of model is also rather high, 31% (R2 value). Model is also statistically significant. Again, Tobit regression model is show- ing similar results ([Appendix B](#_bookmark14)), and it is statistically significant and the co-eﬃcient is rather similar with [Fig. 5](#_bookmark11).

Causality between DEA model stage 4 and other three mod- els (stages 1 to 3) was rather interesting as in all three situations correlation is positive, and regression models are all statistically significant ([Figs. 6](#_bookmark9) to [8](#_bookmark12)). Explanation power is lowest in between stage 4 and stage 1, where scatter plot observations are having more variation around linear curve. However, explanation power is 24.23%, and regression model contains only coeﬃcient as fixed term is not statistically significant. As eﬃciency in stage 1 model improves by one percentage point, then this corresponds to change of 0.5085 percentage points in stage 4 model. The same applies to Tobit regression model ([Appendix B](#_bookmark14)), where model is statistically significant (one fixed term, Intercept 1 is not, like ordinary least squares model in [Fig. 6](#_bookmark9)), and the co-eﬃcient is similar to [Fig. 6](#_bookmark9).

As DEA models in stages 2, 3 and 4 share plenty of similari- ties in inputs and have the same output, eﬃciency results are in the same neighbourhood, and explanation power is high in both of the models (in [Fig. 7](#_bookmark10), it is 69.15%, and in [Fig. 8](#_bookmark12), it is 91.6%). It is interesting to note that stage 2 model (using as inputs revenue, profits and cash flow), improvement will result in much higher





**Fig. 8.** DEA eﬃciency correlation with regression model between stage 3 model (x- axis) and stage 4 model (y-axis).

improvement in stage 4 model. This again illustrates further con- nection between inventory and asset management on shareholder value creation. Between DEA models stage 3 and 4 improvement in eﬃciency, the former will result in similar kind of magnitude change in the latter one. However, the models are rather similar, so this was expected. Tobit regression models for stages 2 & 4 ([Fig. 7](#_bookmark10)) and stages 3 & 4 ([Fig. 8](#_bookmark12)) show similar results, and they are both statistically significant. In both Tobit models, co-eﬃcient is having somewhat higher values, especially in stage 2 & 4 model. How- ever, in this latter model, interpretation of results is rather diﬃcult

as heteroscedasticity is clearly present (in Tobit model there was warning about Hauck-Donner effect).

# Conclusions

As was found in the literature review, there are not many re- search works concerning the role of inventory (and assets) within manufacturing and retail. Most often these models were rather simple, and output was revenue or sales. Attempt in this re- search work was to expand inventory perspective and models as more complex, and also multi-staged. Output included revenues, profit/loss, cash flow (operative) and adjusted share price change (annual). Inputs were inventory and asset related. While analyzing causality of models, this research gave further proof that inven- tory and asset measures will lead to intermediate financial suc- cess and eventually to shareholder value creation. It is notable that this process has its uncertainty, and error in regression model was high. However, research also indicated other options to inventory relevance exist. It could be so that inventory performance is just bunch of measures, which leads to higher financial performance or shareholder value creation. Some of these models were having high causality with other models, and very low error effect. As a conclusion, it could be stated that inventories (and assets) are still having significant role in financial success and shareholder value creation. It is rather open issue, how this relevance is built in com- panies – through stages or directly.

For further research in this field, it would be natural to enlarge

this study to larger economies, and possibly to main European ex- change listed companies or North American ones. The retail sec- tor in these markets has globally leading companies present, which would make examination of this sector fruitful. As manufacturing is increasingly Asian based, this would be another interesting di- rection to follow. In both of these possible further studies inven- tory and asset role should be examined further to shed more light on issues found in this research. Another possibility for further re- search would be to take earlier years in data from times before the global financial crisis. Using older data would enable to exam- ine the era, when there were higher interest rates. This ought to stress the importance of inventory and assets.

# Declaration of Competing Interest

None.

# CRediT authorship contribution statement

**Olli-Pekka Hilmola:** Conceptualization, Methodology, Software, Data curation, Writing - original draft, Visualization, Investigation, Validation, Writing - review & editing.

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# Appendix A. . List of companies of this research work

*Baltic States*

Apranga, Auga, Baltika, Brivais Vilnis, Ditton, Grigeo, Grindex, Grobina, HansaMatrix, Harju Elekter, Kurzemes Atslega 1, Latvi- jas balzams, Linas, Linas Agro Group, Linda Nektar, Madara, Olain- farm, Pieno žvaigžde˙ s, Prfoods, RER, Riga Shipyard, RJR, Rokiškio

su¯ ris, SAF, Silvano Fashion, Skano Group, Snaige, Tallinna Kauba- maja, Utenos trikotazas, Valmiera glass, Vilkyškių pienine˙ , Vilniaus Baldai, and Zemaitijos Pienas.

*Finland*

Afarak, Ahlstrom-Munksjö, Aspocomp, Cargotec, Componenta, Efore, Elecster, Exel, Glaston, Huhtamäki, Incap, Kamux, Kemira, Kesko, Kesla, Kone, Konecranes, Metso, Metsä, Neo Industrial, Nokia, Outokumpu, Outotec, Ponsse, Raute, Robit, Scanfil, Stock- mann, StoraEnso, Teleste, Tikkurila, Tokmanni, Tulikivi, UPM, Up- onor, Uutechnic, Vaisala, Valmet, and Wärtsilä.

# Appendix B. Tobit regressions for staged DEA efficiency models

Variable Stage 1 & 2*p* valueStage 2 & 3*p* valueStage 1 & 3*p* value (Intercept):1 0.1414 ∗∗∗ 0.065451 ∗∗∗ −0.06016 ∗∗

(Intercept):2 −2.02472 ∗∗∗ −2.073645 ∗∗∗ −1.89134 ∗∗∗

Co-eﬃcient 0.10146 ∗∗∗ 1.008733 ∗∗∗ 0.56057 ∗∗∗

Signif. Codes: 0 ‘∗∗∗’ 0.001 ‘∗∗’ 0.01 ‘∗’ 0.05 ‘.’ 0.1 ‘ ’ 1

Variable Stage 1 & 4*p* valueStage 2 & 4*p* valueStage 3 & 4*p* value (Intercept):1 −0.003951 0.020527 ∗ 0.025498 ∗∗∗

(Intercept):2 −1.798547 ∗∗∗ −2.306453 ∗∗∗ −2.912798 ∗∗∗

Co-eﬃcient 0.517239 ∗∗∗ 1.407402 ∗∗∗ 1.023515 ∗∗∗

Signif. Codes: 0 ‘∗∗∗’ 0.001 ‘∗∗’ 0.01 ‘∗’ 0.05 ‘.’ 0.1 ‘ ’ 1

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