

Torben Engelmeyer

Managing Intermittent Demand



Springer Gabler

Managing Intermittent Demand

Torben Engelmeyer

Managing Intermittent Demand



Springer Gabler

Torben Engelmeyer
Wuppertal, Germany

Doctoral Thesis - University of Wuppertal, 2015

ISBN 978-3-658-14061-8 ISBN 978-3-658-14062-5 (eBook)
DOI 10.1007/978-3-658-14062-5

Library of Congress Control Number: 2016939049

Springer Gabler

© Springer Fachmedien Wiesbaden 2016

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

This Springer Gabler imprint is published by Springer Nature
The registered company is Springer Fachmedien Wiesbaden GmbH

Contents

List of Figures	VII
List of Tables	XI
List of Symbols	XIII
1 Introduction	1
I Fundamentals and Methodology	5
2 Inventory Management	7
2.1 Supply Chain Performance Measurement	7
2.2 Relevant Costs	12
2.3 Inventory Policies	16
2.3.1 Stochastic Inventory Models	20
2.3.2 Determination of the Order-Up-To-Level S	20
2.3.3 Determination of the Reorder Point s	22
3 Demand Analysis and Forecasting	29
3.1 Time Series Analysis	30
3.2 Croston-Type Models	33
3.3 Integer-Valued Autoregressive Moving Average Processes . .	43
3.3.1 Model Specification	44
3.3.2 Process Estimation and Identification	47
3.3.3 Forecasting in Pure INAR Processes	50
3.3.4 Forecast Aggregation	54

3.3.5	Point Forecasts	58
3.4	Forecasting Performance Measures	60
4	Demand Classification	63
4.1	ABC Classification	63
4.2	Forecast-Based Classification	66
4.3	Multi-Criteria Inventory Classification	70
II	Empirical Analysis	73
5	Simulation Design	75
5.1	Data Description and Preparation	75
5.2	Classification	77
5.3	Simulation Procedure	79
5.4	Implementation	83
6	Results	87
6.1	Forecasts	88
6.2	Inventory Simulation	91
6.2.1	α -Service Level Target	92
6.2.2	β -Service Level Target	99
6.3	Summary	106
7	Conclusion	109
A	Appendix	113
	Bibliography	149

List of Figures

2.1	Inventory levels of one SKU over five weeks	8
2.2	Different inventory policies	17
2.3	Reorder point determination subject to an α -service constraint	24
2.4	Reorder point determination subject to a β -service constraint	26
3.1	Theoretical ACF and PACF of an AR(2) and an MA(2) process	33
3.2	Simulated compound Bernoulli process	35
3.3	Parameter fitting of the Croston procedure	39
3.4	Simulated INAR(1) process	46
3.5	Graph representation of the Markov chain of an INAR(1) .	52
3.6	Graph representation of the Markov chain of an INAR(2) .	53
3.7	Forecast of the future PMF of an INAR process	54
3.8	Graph representation of the Markov chain of an INAR(2) .	56
4.1	Pareto chart of the revenue for a German wholesaler	65
4.2	SKU clusters based on three single-criteria classifications . .	66
4.3	Classification scheme	68
4.4	Distribution of the ABC and HIL clusters	69
5.1	Revenue and advertisement over time	77
5.2	Distribution of the inventory risk index	79
5.3	Different samples of a rolling simulation	80
5.4	Rolling forecast over time	81
5.5	Inventory simulation of an SKU over 30 periods	83
5.6	Implementation of the inventory simulation algorithm . . .	85
5.7	Structure of the parallelization setup	86

6.1	One-step-ahead forecast performance separated according to risk clusters	88
6.2	One-step-ahead percentage better forecast performance of all SKUs	89
6.3	Distribution of one-step-ahead MASE separated according to methods	90
6.4	Difference between achieved and target service in case of an α -service constraint	92
6.5	Achieved service vs. mean inventory levels (α -service target)	94
6.6	Distribution of the α -service level separated according to methods	98
6.7	Comparison of the resulting inventory level and the inventory risk clusters	99
6.8	Difference between achieved and target service in case of a β -service constraint	101
6.9	Achieved service vs. mean inventory levels (β -service target)	102
6.10	Distribution of the β -service level separated according to methods	104
6.11	Comparison of the resulting inventory levels and the inventory risk clusters	106
A.1	Five-step-ahead forecast performance separated according to risk cluster	113
A.2	Five-step-ahead percentage better forecast performance of all SKUs	114
A.3	Five-step-ahead percentage better forecast performance of M cluster	114
A.4	Five-step-ahead percentage better forecast performance of N cluster	114
A.5	Five-step-ahead percentage better forecast performance of O cluster	115

A.6 One-step-ahead percentage better forecast performance of M cluster	115
A.7 One-step-ahead percentage better forecast performance of N cluster	115
A.8 One-step-ahead percentage better forecast performance of O cluster	116
A.9 Distribution of five-step-ahead MASE separated according to method	116
A.10 Distribution of the inventory level separated according to method	117
A.11 Inventory level separated according to inventory risk clusters (CRO/Gamma)	118
A.12 Inventory level separated according to inventory risk clusters (CRO/Normal)	118
A.13 Inventory level separated according to inventory risk clusters (ES/Gamma)	118
A.14 Inventory level separated according to inventory risk clusters (ES/Normal)	119
A.15 Inventory level separated according to inventory risk clusters (LEV/Gamma)	119
A.16 Inventory level separated according to inventory risk clusters (LEV/Normal)	119
A.17 Inventory level separated according to inventory risk clusters (SYN/Gamma)	120
A.18 Inventory level separated according to inventory risk clusters (SYN/Normal)	120
A.19 Inventory level separated according to inventory risk clusters (TEU/Gamma)	120
A.20 Inventory level separated according to inventory risk clusters (TEU/Normal)	121
A.21 Distribution of the inventory level separated according to method	133

A.22 Comparison of the resulting inventory level and the inventory risk cluster (CRO/Gamma)	134
A.23 Comparison of the resulting inventory level and the inventory risk cluster (CRO/Normal)	134
A.24 Comparison of the resulting inventory level and the inventory risk cluster (ES/Gamma)	134
A.25 Inventory level separated according to inventory risk clusters (ES/Normal)	135
A.26 Inventory level separated according to inventory risk clusters (LEV/Gamma)	135
A.27 Inventory level separated according to inventory risk clusters (LEV/Normal)	135
A.28 Inventory level separated according to inventory risk clusters (SYN/Gamma)	136
A.29 Inventory level separated according to inventory risk clusters (SYN/Normal)	136
A.30 Inventory level separated according to inventory risk clusters (TEU/Gamma)	136
A.31 Inventory level separated according to inventory risk clusters (TEU/Normal)	137

List of Tables

2.1 Exemplary demand series with corresponding inventory . . . 9

2.2 Expected interest rate and gross margin of European industry sectors. 15

4.1 Different weighting schemes of the MCIC approach 72

5.1 Summary of variables 76

A.1 Summary of achieved α -service (CRO/Gamma) 122

A.2 Summary of achieved α -service (CRO/Normal) 123

A.3 Summary of achieved α -service (ES/Gamma) 124

A.4 Summary of achieved α -service (ES/Normal) 125

A.5 Summary of achieved α -service (INAR) 126

A.6 Summary of achieved α -service (LEV/Gamma) 127

A.7 Summary of achieved α -service (LEV/Normal) 128

A.8 Summary of achieved α -service (SYN/Gamma) 129

A.9 Summary of achieved α -service (SYN/Normal) 130

A.10 Summary of achieved α -service (TEU/Gamma) 131

A.11 Summary of achieved α -service (TEU/Normal) 132

A.12 Summary of achieved β -service (CRO/Gamma) 138

A.13 Summary of achieved β -service (CRO/Normal) 139

A.14 Summary of achieved β -service (ES/Gamma) 140

A.15 Summary of achieved β -service (ES/Normal) 141

A.16 Summary of achieved β -service (INAR) 142

A.17 Summary of achieved β -service (LEV/Gamma) 143

A.18 Summary of achieved β -service (LEV/Normal) 144

A.19 Summary of achieved β -service (SYN/Gamma)	145
A.20 Summary of achieved β -service (SYN/Normal)	146
A.21 Summary of achieved β -service (TEU/Gamma)	147
A.22 Summary of achieved β -service (TEU/Normal)	148

List of Symbols

α	Probability of satisfying the demand in a period directly from stock
β	Share of demand, which could be delivered directly from stock with no delay
δ	Expected number of periods between two consecutive positive demands
η	Inventory turnover
$\gamma(h)$	Autocovariance function at lag h
μ_y	Expectation of demand series
μ_{2ltd}	Second moment of the demand during lead time
μ_Y^+	Expectation of positive demands
ω_i	CAPM risk measure
π_y^+	Probability of a positive demand in period t
π_{ltd}	Probability of a positive demand during lead time
$\rho(h)$	Autocorrelation function at lag h
σ_y	Standard deviation of demand
σ_Y^+	Standard deviation of positive demands

σ_{ltd}	Standard deviation of demand during lead time
ε_t	Error terms
ξ	Probability vector of current Markov state
a_x	Selection vector
B_i	Bernoulli distributed random variable
C_i	Clustering criteria
c_{ij}	j -th criteria of the i -th SKU
CV^2	Squared coefficient of variation
D	Gap between s and S
f_{ltd}	Probabiliy density function of the demand during lead time
G	Maximal plausible demand in a period
h	Holding costs per unit per period
I_t	Inventory level in period t
J	Number of criteria in MCIC
K	Fixed order costs
L	Lead time
M	Transition matrix of an INAR(p)-process
P_x	Set of all paths, where the sum of the weights of the visited vertices equals x
p_{ltd}	Probability mass function of the demand during lead time

Q	Order quantity
q_t	Scaled forecasting error
r	Reorder interval
S	Order-up-to level
s	Reorder point
T	Time series length
U	Number of SKUs in MCIC
u_f	Return of a risk free asset
u_i	Return of asset i
u_m	Return of the market portfolio
w_{ij}	Weight of the j -th criteria of the i -th SKU
X_t	Random variable modeling the probability of a positive demand in period t
y_f	First positive demand
Y_t	Random variable modeling the demand in period t
y_t	Observed demand in period t
Y_t^+	Random variable modeling the positive demand in period t