MAT JOURNALS

Journal of Industrial Mechanics
Volume 3 Issue 1

Comparative study of Bullwhip effect in Centralized and Decentralized supply chain of an FMCG industry

Prof. Mrs. ShivangiViralThakker
Assistant Professor, Department of Mechanical Engineering, K J Somaiya College of Engineering, India

Abstract

The choice of supply chain strategy significantly impacts competitive performance of Business organizations. The purpose of this paper is to quantify and compare the bullwhip effects in centralized and decentralized supply chain of a Fast Moving Consumer Good (FMCG) industry. This paper aims to distinguish between two strategies of supply chain in terms of bullwhip effect present between the stages of each strategy. Bullwhip effects are quantified by simulation and validated by analytical method to study the variations in demands at different stages of supply chain. Moving average forecasting method is used for simulations. The paper gives guidelines to managers in supply chain about the importance of selection of strategy for maximizing profit and reducing bullwhip effect.

Keywords: *bullwhip effect, quantification, FMCG industry, simulation*
Paper type: Research paper

INTRODUCTION

The growth of supply chain aims to improve profitability, consumer reaction and ability to deliver fee to the customers and additionally to enhance the interconnection and interdependence amongst companies. because of marketplace increasing from domestic marketplace to international marketplace, there was growth in patron needs, for instance disturbing decrease expenses, faster shipping, better quality services or products and type of items(Christopher, 2000). in line with will (2003) and Christopher (2011), the quit consumer inside the market today is determined via the success or failure of deliver chains management practices. They stated that getting the right product, at the proper charge, on the proper time to the patron is the key to survival. Lee et al., (2000) and Towill (1997) advise that the sharing of retail income information is a first-rate strategy for countering the bullwhip impact.

The paper is organized as follows. Section 2 is literature survey on bullwhip effect. Bullwhip effect in FMCG industry, various causes of bullwhip effect and quantification methods are presented in this section. Section 3 gives methodology of the paper and hypothesis development. Section 4 gives results and discussions on results. Section 5 is conclusion with managerial insights and scope for future work.

Literature Survey

The literature has been divided into two sections as Bullwhip effect, its causes and methods for determining it in Fast moving consumer goods industry.

Bullwhip Effect in FMCG industry

The report analysis (Warburton, 2004) describes how the store's order charge quick grows to exceed the steady consumer call for price as the amplification in orders is on account of the retailer's ordering policy. Because the manufacturers consolidate their order coverage, the carrier levels have to be dependent on frequencies of replenishment rate. The producer's scenario is complex with the aid of both, shipments to a couple of stores and orders to many providers. Ouyang (2010) refers to the bullwhip effect as "a phenomenon in supply chain operations where the fluctuations in the order sequence are typically greater in upstream downstream of a sequence". The phenomenon affects profitability at some point of the community with luxurious inventory stages and positioning (Chopra and Meindl, 2007; Rahimzadeh, 2013).Lee (1997) have acknowledged four chief causes of the bullwhip impact as Order batching, fee fluctuation, demand forecasts and shortage gaming. For attaining the organizations dreams, the bullwhip effect is majorly studied for resolving those troubles (Samvedi,2013; Glas, 2013; Hasan, 2013; Sucky, 2009).

Causes and Methods to Quantify

The Bullwhip Effect has been documented as a significant problem in an experimental and managerial context.(Gravier and Kelly, 2012; Nepal, 2012; Carlsson and Fuller, 2000; Chen al, 2000; Dejonckheere et al., 2003; Kahn, 1987; Lee et al.,1997a, b; Metters, 1997; Zhou and Disney, 2006). Many researchers have proposed strategies for mitigating the Bullwhip Effect and have a history of successful application (Clark 1994; Gill and Abend1997; Hammond 1993; Towill 1997). Fine (2000) discusses the Bullwhip Effect as one of the two laws that govern supply chain dynamics, focusing on the strategic issues that arise. Anderson and Morrice (2000) analyzed the Bullwhip Effect in service industries, which cannot hold inventory hence backlogs can only be managed by adjusting capacity. Anderson, Fine, and Parker (2000) suggest the amplification of demand volatility is particularly large in distribution and component parts supply chains, e.g., machine tools Forrester (1961) had defined a simplified form of the equations describing the relation between inventory and orders. Forrester (1958) pioneered the simulation approach and established the importance of integrating information flow with material flow. Burbidge (1961) emphasized the principles of cycle time reduction and order synchronization. He later coined Law of Industrial Dynamics (Burbidge 1984): "If demand is transmitted along a series of inventories using stock control ordering, then the demand variation will increase with each transfer."Simulation has since been employed extensively to analyze supply chains (Berry and Towill 1995; Disney and Towill 2003, 2006; D.C. Chatfield, 2013).

Methodology

A four stage supply chain is considered for the simulation. Retailer follows a simple periodic inventory review policy with review period as 1.Constant z is safety factor and is chosen from statistical tables. Simple Moving average method for forecasting is used.

One measurement of bullwhip effect is ratio of output order rate to input order rate.

$$\text{Bullwhip effect} = \frac{\text{Ordering Quantity by Retailer}}{\text{Consumer Demand}} \quad (1)$$

For a fixed lead time faced by retailer as L, a simple periodic review policy is followed for placing orders. The base stock level is calculated as

$$BaseStockLevel = L * AVG + z * \text{STD} * \sqrt{\text{L}} \quad (2)$$

Retailers must estimate average and standard deviation based on customer demand hence order-up-to point may change daily. Order-up-to point in period t is estimated as

$$q_t = \widehat{\mu_t} L + z * \sqrt{LS_t} \quad (3)$$

Considering Moving average method for forecasting, mean demand and standard estimation of demand are estimated for each period.

$$\widehat{\mu_t} = \frac{\sum_{i=t-p}^{t-1} D_i}{p} \quad (4)$$

$$S_t^2 = \frac{\sum_{i=t-p}^{t-1} (D_i - \widehat{\mu_t})^2}{p-1} \quad (5)$$

$$q_t = (1 + {}^{L}/_{p}) D_{t-1} - ({}^{L}/_{p}) D_{t-p-1} + z(\widehat{\sigma_t} - \widehat{\sigma_{t-1}}) \quad (6)$$

$$\text{Var}\ (q_t) = \left[1 + \left(\frac{2L}{p} + \frac{2L^2}{p^2}\right)(1 - \rho^p)\right] Var(D) \quad (7)$$

For every period, a new mean and standard deviation are calculated based on observations of demand (p). The increase in variability is quantified for manufacturer and retailer. Variance of customer demand seen by retailer Var (D) and Variance of orders placed by retailer to Manufacturer Var (q_t) satisfies the Equation (7).

Supply chain with centralized demand information

A four stage supply chain is considered with a single retailer, wholesaler, distributor and factory. As demand information is centralized, each stage can use actual customer demand data to create more accurate forecasts.

Variance of the orders placed by kth stage of supply chain, Var (q^k), relative to the variance of customer demand , Var(D) is given by,

$$\frac{\text{Var}\ (q^{k})}{\text{Var}\ (D)} \geq 1 + \frac{2\sum_{i=1}^{k} L_i}{p} + \frac{2(\sum_{i=1}^{k} L_i)^2}{p^2} (8)$$

Where L_i is the Lead time between stagei and stage i+1.

This expression of orders placed by kth stage is similar to expression of single stage supply chain with single lead time L replaced by k stage lead time$\sum_{i=1}^{k} L_i$.

Supply chain with decentralized demand information

For the same four stage supply chain, as retailer doesn't make its forecast mean and variance in demand available to reminder of supply chain. The variance of the orders placed by the kth stage of supply chain, Var (q^k), relative to the variance of customer demand, Var(D) satisfies

$$\frac{\text{Var}\ (q^{k})}{\text{Var}\ (D)} \geq \prod_{i=1}^{k} \left(1 + \frac{2L_i}{p} + \frac{2{L_i}^2}{p^2}\right) \quad (9)$$

A four chain supply chain is considered for simulation. Yearly demand, cost and lead time data are selected based on industrial datasheets. The simulation results are plotted and bullwhip effect is studied.

Data collection and Simulation of Four stage supply chain

A four stage supply chain; Consumer, retailer, Wholesaler and Manufacturer is simulated for demonstrating bullwhip effect. The data is taken from industry research database of FMCG Company (Table 2) and simulation results are plotted in the graph. FMCG industry has provided lead time, demand data on yearly basis, ordering, holding and set up cost for the year 2014. Order quantity for centralized and decentralized supply chains are calculated based on customer orders given by the industry.

Table 2: *Demand and Cost data for simulation(Source: FMCG sector)*

Description	**Symbol**	**Consumer**	**Retailer**	**Wholesaler**	**Manufacturer**
Order Quantity	Q- Dec	500	517	573	652
	Q- Cent	500	517	544	567
Yearly Demand	D	10,000	10,000	10,000	10,000
Ordering & Setup Cost (Rs.)	S	75.00	25.00	50.00	100.00
Holding Cost (Rs.)	H	6.00	5.55	5.00	4.10
Delivery Lead time (days)	L	5	1	10	7
Reorder Point	R	200	40	400	280

Calculation of Bullwhip effect and comparison of Centralized and Decentralized systems

Bullwhip effect measure over the entire supply chain allows compare different system configurations from the stability point of view. To identify the bullwhip occurrence at each stage of the supply chain it is proposed to compare a standard deviation of demand faced by the neighbor supply chain stages by calculating a ratio BE_i as shown in Equation (10)

$$BE_i = \frac{\text{STD}(Q_i)}{\text{STD}(Q_{i-1})} \in (0,\infty), i = 1,2..n. \quad (10)$$

$$BE_g = \sqrt[n]{BE_1 * BE_2..BE_n} \quad (11)$$

$$BE_a = \frac{\sum_{i=1}^{n} BE_i}{n}, for BE_i > 1 \quad (12)$$

Calculating the geometrical mean of the BE_iratios by a Equation (11) determines the existence of the bullwhip effect between first and last supply chain stages. Values of orders placed by stages i, n-1 are the demand received by stages i+1, n and they are cancelled performing multiplication operation. As a result the increase in variability of demand between the first, i.e. customer and the last supply chain stage is found.

Hypotheses Development

Hypotheses are developed for comparing centralized and decentralized systems in supply chain.

Hypothesis 1:

Null Hypothesis (H_0): Magnitude of amplification of Bullwhip effect across supply chain stages is same.

Alternative Hypothesis (H_a): Magnitude of amplification of Bullwhip effect across supply chain stages is *not* same.

Hypothesis 2:

Null Hypothesis (H_0): The variance of bullwhip effect is same for centralized and decentralized supply chain.

Alternative Hypothesis (H_a): The variance of bullwhip effect is *not* same for centralized and decentralized supply chain.

RESULTS AND DISCUSSION

Figure 1 is the simulation plot of a four stage supply Chain. Keeping yearly demand of products fixed, the results shows that the variation in demand is largest at Tier 3 and closer to actual demand at Tier1.

Magnitude of amplification along the supply chain

Whether the amplification of order oscillations will decrease between levels as a result of inventory exposure is less clear. Theory suggests the bullwhip will not occur when the demand distribution is known and stable, whether or not inventory information is shared (Chen 1998). However, we saw that the bullwhip effect does appear when inventory information isnot available.

$$\overline{\sigma_2}/\overline{\sigma_1} = 1.73, \quad \boldsymbol{\overline{\sigma_3}/\overline{\sigma_2} = 2.11}, \quad \overline{\sigma_4}/\overline{\sigma_3} = 1.48$$

Comparison of Centralized and decentralized systems

The proposed bullwhip impact usual degree permits determination of the steadiness of the whole deliver chain considering only the conditions while variability of the demand increases. The proportional splitting of the boom in variability among all deliver chain tiers makes feasible to analyze distinct deliver chain systems and configurations.

Calculated values of the ratio BE_i for all four deliver chain stages perceive that the growth in demand variability is present in all degrees. The measure of the bullwhip effect over the whole supply chain is calculated as proposed in (11) and (12).

The smaller is the value the less significant is the increase in variability as we travel up in the supply chain. Since there is a

MAT JOURNALS

Journal of Industrial Mechanics
Volume 3 Issue 1

measure for the bullwhip effect over the entire supply chain the difference between the stability (BE_a) for both supply chain alternatives could be expressed in percentages – variation of demand in the supply chain with centralized information is by 23% smaller than in the supply chain with decentralized information.

Centralized Supply Chain Bullwhip effect: **BE_g =1.39, BE_a= 1.40**

Decentralized Supply Chain Bullwhip effect: **BE_g = 1.82, BE_a= 1.84**

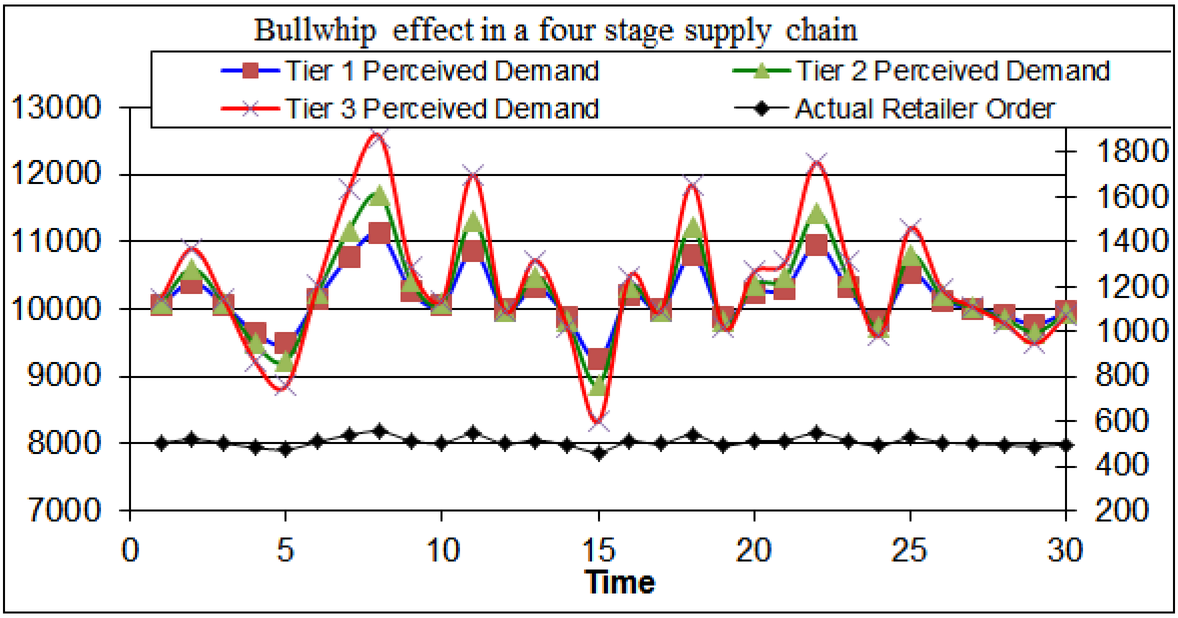

***Fig 1:** Simulation result for Bullwhip effect in a four stage supply chain*

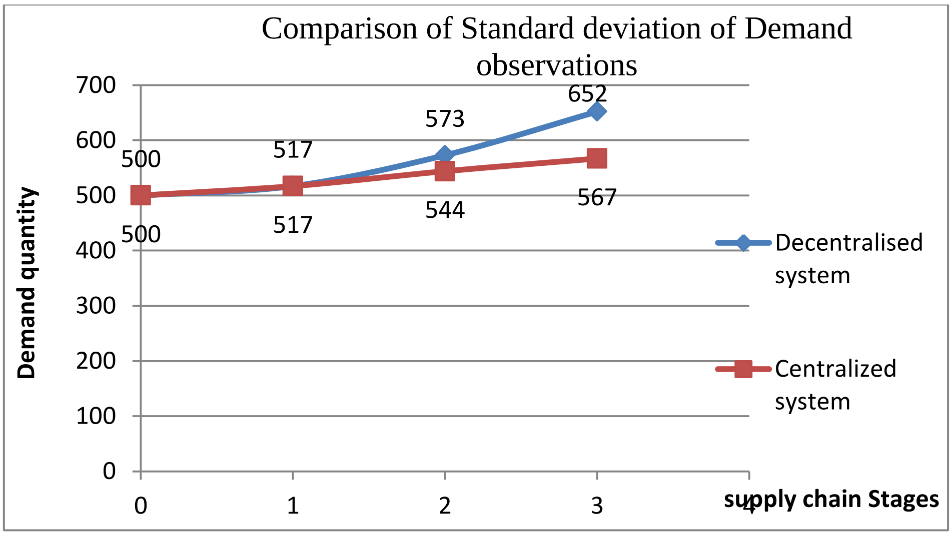

***Fig 2:** Standard deviation of Demand observations*

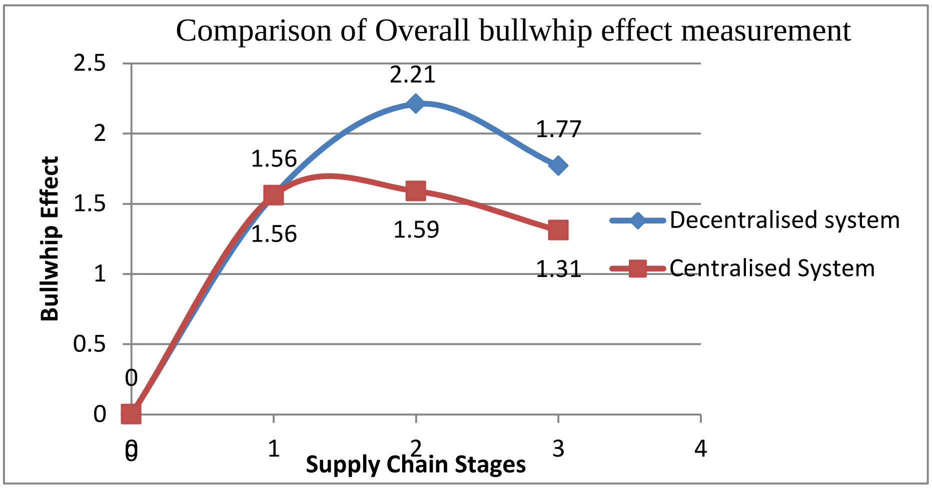

Fig 3: *Comparison of Overall bullwhip effect*

Testing Hypothesis 1: F Test for Variance amplification in supply chain

$\sigma_2{}^2/\sigma_1{}^2 = 5.10$
$\sigma_3{}^2/\sigma_2{}^2 = 4.401$
$\sigma_4{}^2/\sigma_3{}^2 = 25.09$

Table 3: *Results of F test*

Parameter	**F-Test Two-Sample for Variances between stage 1-2**		**F-Test Two-Sample for Variances between stage 2-3**		**F-Test Two-Sample for Variances between stage 3-4**	
	Actual Demand	*Stage 1 Perceived Demand*	*Stage 2 Perceived Demand*	*stage 3 Perceived Demand*	*Stage 3 Perceived Demand*	*Stage 4 Perceived Demand*
Mean	499.3666667	499.4666667	499.4666667	499.4733333	499.1666667	499.4733333
Variance	135.1367816	26.46436782	26.46436782	6.012367816	150.9022989	6.012367816
Observations	30	30	30	30	30	30
df	29	29	29	29	29	29
F	**5.106367269**		**4.401654826**		**25.09864723**	
P(F<=f) one-tail	1.7078E-05		7.35419E-05		6.93553E-14	
F Critical one-tail	**1.860811435**		**1.860811435**		**1.860811435**	

As the table value of F critical at 5 percent level of significance for dof 29 is **1.860** and the calculated values for F for all stages is more than table value, **Null Hypothesis is rejected** and it is concluded that magnitude of amplification of Bullwhip effect across supply chain stages is not same.

Hypothesis Testing 2: t test for Comparison of Bullwhip effect in Centralized and Decentralized supply chains

Table 4: *Results of t test*

t-Test: Two-Sample Assuming Unequal Variances										
	Mean	Variance	Observations	Hypothesized Mean Difference	df	t Stat	P(T<=t) one-tail	t Critical one-tail	P(T<=t) two-tail	t Critical two-tail
Variable 1	1.385	0.9259	4	0	6	**0.4417630**	0.3370685	**1.94318028**	0.67413706	2.44691185
Variable 2	1.115	0.568	4							

As stat value of t=0.441 which is less than t critical for one sided tail which is 1.94 at 5 per cent level of significance, hence null hypothesis is rejected. This means that the mean and variance of bullwhip effect in both types of supply chain strategies is not same.

Conclusion and managerial insights

The supply chain function is very important and critical function in organization which holds more than 50 percent of wealth in FMCG industries. This paper presents a systematic way for quantifying and understanding the impact of supply chain strategy on the bullwhip effect. The results provide practical understanding for supply chain managers.

The focus of study is on selection of supply chain strategy based on bullwhip effect. By comparing the increase in variability of bullwhip effect for centralized and decentralized supply chain, it is shown how the demand sharing and forecast sharing improves the supply chain. Four stage supply chains of centralized and decentralized strategy are simulated for presenting bullwhip effect.

The case study and empirical research reported in this paper are specific to the FMCG industries and there would be benefit in extending the research into other sectors. The scope of this paper is limited to distinguishing Centralized and decentralized supply chains in terms of amplification of bullwhip effect across the supply chain.

ACKNOWLEDGEMENT

The author is thankful to the FMCG Industry (whose name is withheld on request) for providing data to conduct the experiments.

REFERENCES

1. A.Y. Chang, H.F. Yu, T.H. Yang, (2013), ‘A study of the key factors contributing to the bullwhip effect in the supply chain of the retail industry’, Journal of Industrial and Production Engineering, vol. 30, n° 7, pp. 433–442.
2. Buchmeister, D. Friscic, I. Palcic, (2013), ‘Impact of demand changes and supply chain's level constraints on bullwhip effect’, International Journal on Advances in Production Engineering & Management, vol. 8, pp. 199-208.
3. C.A. Garcia Salcedo, A.I. Hernandez, R. Vilanova, J. H. Cuartas, (2013), ‘Inventory control of supply chains: Mitigating the bullwhip effect by centralized and decentralized Internal Model Control approaches’, European Journal of Operational Research, vol. 224, pp. 261-272.
4. Costantino, G.D. Gravio, A. Shaban, M. Tronci, (2013), ‘Exploring the bullwhip Effect and Inventory Stability in a Seasonal Supply Chain’, International Journal of Engineering

Business Management, vol. 5, pp. 1-12.

5. D. Van Le, L. Trung Huynh, K. VasileClaudiu, M. Achim, 'The impact of inventory sharing on the bullwhip effect in decentralized inventory systems', Logist. Res., vol. 6, (2013), pp. 89–98.
6. H.L. Lee, V. Padmanabhan, S. Whang, (2004), 'Comments on information distortion in a supply chain: The bullwhip effect: Reflections, Management Science, vol. 50, n° 12, pp. 1887-1893.
7. Li, S.M. Disney, G. Gaalman, (2013), 'Avoiding the bullwhip effect using Damped Trend forecasting and the Order-Up-To replenishment policy', International Journal Production Economics,
8. Lu, P. Humphreysa, R. McIvora, L. Maguireb, F. Wiengarten,(2012), 'Applying genetic algorithms to dampen the impact of price fluctuations in a supply chain', International Journal of Production Research, vol. 50,n° 19, pp. 5396–5414.
9. M. Hussain, P.R. Drake, D.M. Lee, (2012), 'Quantifying the impact of a supply chain's design parameters on the bullwhip effect using simulation and Taguchi design of experiments', International Journal of Physical Distribution & Logistics Management, Vol. 42, n° 10, pp. 947-968.
10. M.A. Badar, S. Sammidi, L. Gardner, (2013), 'Reducing the Bullwhip Effect in the Supply Chain: A Study of Different Ordering Strategies', Journal of Technology Studies- Springer, vol. 39, pp52-63.
11. Nepal, A. Murat, R.B. Chinnam, (2012), 'The bullwhip effect in capacitated supply chains with consideration for product life-cycle aspects', International Journal of Production Economics, vol. 136, pp. 318-331.
12. Rahimzadeh, A. Haji, A.J. Makui, (2013), 'Bullwhip Effect Measure When Supply Chain Demand is Forecasting', Journal of Basic and Applied Scientific Research, vol. 2, , n° 4, pp. 4227-4232.
13. Y. Ma, N. Wang, A. Che, Y. Huang, J. Xu, (2013)a, 'The bullwhip effect under different information-sharing settings: a perspective on price sensitive demand that incorporates price dynamics', International Journal ofProduction Research, vol. 51, n° 10, pp.3085–3116.
14. Y. Wei, H. Wang, C. Qi, (2013), 'On the stability and bullwhip effect of a production and inventory control system', International Journal ofProduction Research, vol. 51, n° 1, pp. 154
15. Zotteri, (2013), 'An empirical investigation on causes and effects of the Bullwhip effect: Evidence from the personal care sector', International Journal Production Economics, vol. 143, pp. 489-498.

