Sabbaghnia, Ali; **Razmi, Jafar**; **Babazadeh, Reza**; **Moshiri, Behzad**

Reducing the bullwhip effect in a supply chain network by application of optimal control theory. (English) Zbl 1414.49043

RAIRO, Oper. Res. 52, No. 4-5, 1377-1396 (2018).

Summary: Controlling the bullwhip effect and reducing the propagated inventory levels throughout the supply chain layers has an important role in reducing the total inventory costs of a supply chain. In this study, an optimal controller that considers demand as control variable is designed to dampen propagated inventory fluctuations for each node throughout the supply chain network. The model proves to be very useful in revealing the dynamic characteristics of the chain and provides a proper interface to study decisions taken into account at each node of the supply chain in different periods by decision makers (DMs). In the proposed approach, two feedback loops and online updated values of net stock quantities are used for calculation of the orders. To investigate the efficiency of the proposed approach, a real case of bicycle industry is conducted. The acquired results justify the efficiency of the proposed approach in controlling and dampening the bullwhip effect and reducing inventory levels, net stock quantities and inventory attributed costs throughout the supply chain network layers.

MSC:

49N90 Applications of optimal control and differential games
37N40 Dynamical systems in optimization and economics
47N10 Applications of operator theory in optimization, convex analysis, mathematical programming, economics
78M50 Optimization problems in optics and electromagnetic theory

Keywords:

bullwhip effect; optimal control; supply chain management; inventory control; bicycle industry

Software:

DYNAMO

Full Text: DOI

References:

[1] E.G. Anderson, D.J. Morrice and G. Lundeen, Measuring and avoiding the bullwhip effect: a control theoretic approach. Eur. J. Oper. Res.147 (2003) 567–590.

[2] E.G. Anderson, D.J. Morrice and G. Lundeen, A robust stochastic programming approach for agile and responsive logistics under operational and disruption risks. Prod. Oper. Manag.15 (2006) 262–278.

[3] M. Aoki, Optimal control and system theory in dynamic economic analysis. Prod. Oper. Manag.1 (1976). · Zbl 0349.90030

[4] S.X. Bai and M. Elhafsi, Optimal feedback control of a manufacturing system with setup changes, in Proceedings of the Fourth International Conference on Computer Integrated Manufacturing and Automation Technology (1994) 191–196.

[5] A. Bemporad and N. Giorgetti, Logic-based solution methods for optimal control of hybrid systems. IEEE Trans. Autom. Control51 (2006) 963–976. · Zbl 1366.49034

[6] D.P. Bertsekas, Dynamic Programming and Optimal Control, Vol. 1. Athena Scientific, Belmont, MA (1995) 262–278.

[7] F. Buwalda, E.J. Van Henten, A. De Gelder, J. Bontsema and J. Hemming, Toward an optimal control strategy for sweet pepper cultivation: a dynamic crop model. Acta Hortic.718 (2006) 367–374.

[8] Q. Cao, J. Baker and D. Schniederjans, Bullwhip effect reduction and improved business performance through guanxi: an empiricalstudy. Prod. Oper. Manag.158 (2014) 217–230.

[9] B.-B. Cao, Z.-D. Xiao and J.-N. Sun, A study of the bullwhip effect in supply- and demand-driven supply chain. J. Ind. Prod. Eng.34 (2017) 124–134.

[10] C.S. Carver and M.F. Scheier, Attention and Self-regulation: A Control-Theory Approach to Human Behavior. Springer Science & Business Media (2012).

[11] F. Chen, Z. Drezner, J.K. Ryan and D. Simchi-Levi, The bullwhip effect: managerial insights on the impact of forecasting

and information on variability in a supply chain, in Quantitative Models for Supply Chain Management (1999) 417–439. · Zbl 1052.90503

[12] F. Chen, Z. Drezner, J.K. Ryan and D. Simchi-Levi, Quantifying the bullwhip effect in a simple supply chain: the impact of forecasting, lead times, and information. Manag. Sci.46 (2000) 436–443. · Zbl 1231.90019

[13] F. Chen, J.K. Ryan and D. Simchi-Levi, The impact of exponential smoothing forecasts on the bullwhip effect. Naval Res. Logist. (NRL)47 (2000) 269–286. · Zbl 0968.90006

[14] L. Cheng and M.A. Duran, Logistics for world-wide crude oil transportation using discrete event simulation and optimal control. Comput. Chem. Eng.28 (2004) 897–911.

[15] L.S. Dias and M.G. Ierapetritou, From process control to supply chain management: an overview of integrated decision making strategies. Comput. Chem. Eng.106 (2017) 826–835.

[16] S.M. Disney and D.R. Towill, Eliminating drift in inventory and order based production control systems. Int. J. Prod. Econ.93 (2005) 331–344.

[17] H. Dong and Y.-p. Li, Dynamic simulation and optimal control strategy of a decentralized supply chain system, in Management Science and Engineering, 2009. ICMSE 2009. International Conference on IEEE (2009) 419–424.

[18] K. Egilmez and A. Sharifnia, Optimal control of a manufacturing system based on a novel continuous-flow model with minimal WIP requirement, in Computer Integrated Manufacturing and Automation Technology, 1994. Proceedings of the Fourth International Conference on IEEE (1994) 113–118.

[19] J.L.D. Facó, Nonlinear optimal control approach to scheduling problems, in AIChE Annual Meeting, 2007, Salt Lake City, UT (2007).

[20] B. Fahimnia, J. Sarkis and H. Davarzani, Green supply chain management: a review and bibliometric analysis. Int. J. Prod. Econ.162 (2015) 101–114.

[21] J. Forrester, Industrial Dynamics. Pegasus Communications, Waltham, MA (1961).

[22] J.C. Fransoo and M.J.F. Wouters, Measuring the bullwhip effect in the supply chain. Supply Chain Manag.: Int. J.5 (2000) 78–89.

[23] C.A. Garcia, A. Ibeas, J. Herrera and R. Vilanova, Inventory control for the supply chain: an adaptive control approach based on the identification of the lead-time. Omega40 (2012) 314–327.

[24] L. Di Giacomo and G. Patrizi, Dynamic nonlinear modelization of operational supply chain systems. J. Global Optim.34 (2006) 503–534. · Zbl 1149.90348

[25] D. Giglio, R. Minciardi, S. Sacone and S. Siri, A hybrid model for optimal control of single nodes in supply chains. In Vol. 38 of IFAC Proceedings (2005) 7–12.

[26] K. Govindan, H. Soleimani and D. Kannan, Reverse logistics and closed-loop supply chain: a comprehensive review to explore the future. Eur. J. Oper. Res.240 (2015) 603–626. · Zbl 1338.90006

[27] I. Heckmann, T. Comes and S. Nickel, A critical review on supply chain risk—definition, measure and modeling. Omega52 (2015) 119–132.

[28] M. Holweg and J. Bicheno, The reverse amplification effect in supply chains. Dev. Logist. Supply Chain Manag. (2016) 52–58.

[29] D. Ivanov, A. Dolgui and B. Sokolov, Applicability of optimal control theory to adaptive supply chain planning and scheduling. Annu. Rev. Control36 (2012) 73–84.

[30] D. Ivanov and B. Sokolov, Structure dynamics control approach to supply chain planning and adaptation. Int. J. Prod. Res.50 (2012) 6133–6149.

[31] D. Ivanov, B. Sokolov and J. Kaeschel, Integrated supply chain planning based on a combined application of operations research and optimal control. Central Eur. J. Oper. Res.19 (2011) 299–317.

[32] N. Javadian and R. Tavakkoli-Moghaddam, Controlling the bullwhip effect in a supply chain network with an inventory replenishment policy by a robust control method. J. Optim. Ind. Eng.7 (2014) 75–82.

[33] R.R.P. Langroodi and M. Amiri, A system dynamics modeling approach for a multi-level, multi-product, multi-region supply chain under demand uncertainty. Expert Syst. Appl.51 (2016) 231–244.

[34] H.L. Lee and S. Whang, Information sharing in a supply chain. Int. J. Manuf. Technol. Manag.1 (2000) 79–93.

[35] H.L. Lee, V. Padmanabhan and S. Whang, The bullwhip effect in supply chains. Sloan Manag. Rev.38 (1997) 93–102. · Zbl 0888.90047

[36] H.L. Lee, K.C. So and C.S. Tang, The value of information sharing in a two-level supply chain. Manag. Sci.46 (2000) 626–643. · Zbl 1231.90044

[37] C. Li, Controlling the bullwhip effect in a supply chain system with constrained information flows. Appl. Math. Model.37 (2013) 1897–1909. · Zbl 1349.90101

[38] C. Li and S. Liu, A robust optimization approach to reduce the bullwhip effect of supply chains with vendor order placement lead time delays in an uncertain environment. Appl. Math. Model.37 (2013) 707–718. · Zbl 1351.90028

[39] L. Li, Supply Chain Management: Concepts, Techniques and Practices Enhancing the Value Through Collaboration. World Scientific Publishing Company (2007).

[40] J. Lin, M.M. Naim, L. Purvis and J. Gosling, The extension and exploitation of the inventory and order based production control system archetypefrom 1982 to 2015. Int. J. Prod. Econ.194 (2017) 135–152.

[41] R. Metters, Quantifying the bullwhip effect in supply chains. J. Oper. Manag.15 (1997) 89–100.

[42] M. Miranbeigi, B. Moshiri, A. Rahimi-Kian and J. Razmi, Demand satisfaction in supply chain management system using a full online optimal control method. Int. J. Adv. Manuf. Technol.77 (2015) 1401–1417.

[43] M. Miranbeigi, B. Moshiri and A. Rahimi Kian, Application of distributed control on a large-scale production/distribution/inventory system. Syst. Sci. Control Eng.4 (2016) 68–77.

[44] L. Monostori, P. Valckenaers, A. Dolgui, H. Panetto, M. Brdys and B.C. Csáji, Cooperative control in production and logistics. Annu. Rev. Control39 (2015) 12–29.

[45] T. O'donnell, L. Maguire, R. McIvor and P. Humphreys, Minimizing the bullwhip effect in a supply chain using genetic algorithms. Int. J. Prod. Res.44 (2006) 1523–1543. · Zbl 1128.90529

[46] M. Parsanejad and H. Matsukawa, Work-in-process analysis in a production system using a control engineering approach. J. Jpn. Ind.Manag. Assoc.67 (2016) 106–113.

[47] E. Perea, I. Grossmann, E. Ydstie and T. Tahmassebi, Dynamic modeling and classical control theory for supply chain management. Comput. Chem. Eng.24 (2000) 1143–1149.

[48] F.L. Pereira and J.B. De Sousa, On the receding horizon hierarchical optimal control of manufacturing systems. J. Intell. Manuf.8 (1997) 425–433.

[49] T.M. Pinho, J.P. Coelho, A.P. Moreira and J. Boaventura-Cunha, Model predictive control applied to a supply chain management problem, in CONTROLO. Springer (2017) 167–177.

[50] B. Ponte, X. Wang, D. de la Fuente and S.M. Disney, Exploring nonlinear supply chains: the dynamics of capacity constraints. Int. J. Prod. Res.55 (2017) 4053–4067.

[51] L.S. Pontryagin, V.G. Boltyanskii, R.V. Gamkrelidze and E. Mishchenko, The Mathematical Theory of Optimal Processes (International Series of Monographs in Pure and Applied Mathematics). Interscience, New York (1962).

[52] J. Razmi and A. Sabbaghnia, Racing the impact of non-uniform forecasting methods on the severity of the bullwhip effect in two-and three-level supply chains. Int. J. Manag. Sci. Eng. Manag.10 (2015) 297–304.

[53] C.E. Riddalls and S. Bennett, The optimal control of batched production and its effect on demand amplification. Int. J. Prod. Econ.72 (2001) 159–168.

[54] C.E. Riddalls, S. Bennett and N.S. Tipi, Modelling the dynamics of supply chains. Int. J. Syst. Sci.31 (2000) 969–976. · Zbl 1080.93603

[55] C.A.G. Salcedo, A.I. Hernandez, R. Vilanova and J.H. Cuartas, Inventory control of supply chains: mitigating the bullwhip effect by centralized and decentralized Internal Model Control approaches. Eur. J. Oper. Res.224 (2013) 261–272. · Zbl 1292.90013

[56] S. Serdarasan, A review of supply chain complexity drivers. Comput. Ind. Eng.66 (2013) 533–540.

[57] S.P. Sethi and G.L. Thompson, Optimal Control Theory Applications to Management Science and Economics. Springer (2000). · Zbl 0998.49002

[58] S. Seuring, A review of modeling approaches for sustainable supply chain management. Decis. Support Syst.54 (2013) 1513–1520.

[59] H.A. Simon, On the application of servomechanism theory in the study of production control. Econometrica (1952) 247–268. · Zbl 0046.37804

[60] L.V. Snyder, Z. Atan, P. Peng, Y. Rong, A.J. Schmitt and B. Sinsoysal, OR/MS models for supply chain disruptions: a review. IIE Trans.48 (2016) 89–109.

[61] H. Stadtler, Supply chain management: an overview. Supply Chain Manag. Adv. Plan.15 (2015) 3–28.

[62] E. Sucky, The bullwhip effect in supply chains—an overestimated problem? Int. J. Prod. Econ.118 (2009) 311–322.

[63] P.H. Sun, L. Tang and L.Y. Tang, Application of optimal control in inventory management of production. Appl. Mech. Mater.29 (2010) 2503–2508.

[64] U. Tosun, T. Dokeroglu and A. Cosar, A new parallel genetic algorithm for reducing the bullwhip effect in an automotive supply chain. IFAC Proc. Vol.46 (2013) 70–74.

[65] D.R. Towill, Supply chain dynamics. Int. J. Comput. Integr. Manuf.4 (1991) 197–208.

[66] M. Udenio, E. Vatamidou, J.C. Fransoo and N. Dellaert, Behavioral causes of the bullwhip effect: an analysis using linear control theory. IISE Trans.49 (2017) 980–1000.

[67] X. Wang and S.M. Disney, The bullwhip effect: progress, trends and directions. Eur. J. Oper. Res.250 (2016) 691–701. · Zbl 1346.90061

[68] A.S. White and M. Censlive, The effect of smoothing filters on supply chain performance. Int. J. Inventory Res.3 (2016) 134–165.

[69] H. Xu, P.Sui, G. Zhou and L. Caccetta, Dampening bullwhip effect of order-up-to inventory strategies via an optimal control method. Numer. Algebra Control Optim.3 (2013) 655–664. · Zbl 1276.90033

[70] B. Yan, J. Wu, L. Liu and Q. Chen, Inventory management models in cluster supply chains based on system dynamics. RAIRO – Oper. Res.51 (2017) 763–7788. · Zbl 1384.90008

[71] X. Zhang and L. Lv, Optimal control policies for a supply chain with perishable products, in Wireless Communications, Networking and Mobile Computing, 2008. WiCOM'08. 4th International Conference on IEEE (2008) 1–4.

[72] L. Zhou, M.M. Naim and S.M. Disney, The impact of product returns and remanufacturing uncertainties on the dynamic performance of a multi-echelon closed-loop supply chain. Int. J. Prod. Econ.183 (2006) 487–502.