# ADVANCE BOOKING IN AGRICULTURAL INPUT SUPPLY CHAIN


A THESIS

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# Abstract

Agricultural inputs are materials directly used in farming to enhance productivity and ensure successful crops. These include seeds, fertilizers, and agrochemicals (pesticides, herbicides). Agricultural inputs have short selling periods and require long production time, therefore Advance Booking (AB) has become a widely used practice in the Agricultural Input Supply Chain (AISC). It offers multiple benefits to the seller (manufacturer), such as better demand information, reduced risk, and better cash flow. It also benefits the buyers (wholesalers), as they receive a discounted price and assured deliveries without being subjected to market fluctuations.

Several seed producers in India, such as Penna Seeds, Aadhaar Seeds, and Kirtiman Agrogenetics, offer advance booking for seeds of crops like maize, wheat, and paddy. Similarly, agrochemical manufacturers like UPL Limited, Dhanuka Agritech, and Tropical Agro provide booking schemes for a variety of herbicides and pesticides. Manufacturers typically offer advance booking schemes to the wholesalers a few months before the selling season begins. A discounted price is offered in the AB period; based on whether full or partial payment is required for booking the products, there are two types of advance booking schemes: full payment advance booking (FPAB) scheme and Token advance booking (TAB) scheme, which we study in Chapter 2 (Problem 1) and 3 (Problem 2) of the thesis, respectively. The wholesaler can influence her demand by exerting sales effort in the form of promotional activities, hiring sales staff, offering her customers services like free delivery etc.

For the manufacturer, the AB information is important as it gives him a better idea of the upcoming demand and helps him to make better production-related decisions. On the other hand, the Stackelberg leadership position offers him the opportunity to be the first mover to make his decision, anticipating the wholesaler's reaction.

In the first problem of the thesis, we discuss two supply chain structures: one high-

lights the AB information and another Stackelberg leadership. As we have two players and the decisions of one player depend on the response of the other player, we study the supply chain from a dyadic view. We model the AISC as a single product, two player (manufacturer and wholesaler) game with AB discount and sales effort-dependent stochastic demand. We develop two models: the Wholesaler Stackelberg (WS) model, where the manufacturer prefers AB information above the SC leadership position, and the Manufacturer Stackelberg (MS) model, where he is the leader.

We find that the wholesaler always puts in higher (or equal) sales effort when she is the Stackelberg leader (WS setup). On the other hand, we find that for low levels of AB discount, the manufacturer produces higher quantities when he is the Stackelberg leader. A comparison of the two players' profits in the two setups shows that getting AB information by becoming a follower in the supply chain (WS setup) brings higher profits to the manufacturer. Also, for moderately high levels of AB discount, the WS setup creates a win-win situation for both the players.

We also design a returns contract not commonly studied in the AISC to check if it can benefit the players. We solve the AB with a returns contract model and find that for intermediate levels of AB discount and manufacturing cost, the returns policy benefits both the players and the supply chain.

In the second problem of the thesis, we study the Token Advance Booking scheme with a quantity discount in presence of a sales effort-dependent stochastic demand. In this scheme, the wholesaler pays only a portion (token amount) of the selling price to place a booking order. We develop the model, solve it to determine the equilibrium strategies of the players, and analyze the results.

Overall, this thesis aims to study the interaction of sales effort-dependent stochastic demand with two varieties of advance booking schemes (FPAB and TAB) in the context of the agricultural input supply chain. We develop analytical models and analyze them to understand and gain insights into agricultural input supply chain decisions.

# Contents

# Chapter 4

# Conclusion and Discussion

This thesis examines the interaction of advance booking discount scheme with sales effort-dependent stochastic demand in the context of the agricultural input supply chain. We begin by discussing the agriculture and agricultural input supply chain and how advance booking and sales effort exerted by the wholesaler plays a crucial role in that. We study two variants of advance booking schemes popular in the agricultural input supply chain, namely, full payment advance booking and token advance booking, in the second and third chapters of the thesis.

In the second chapter of the thesis, we attempt to investigate whether advance booking information or Stackelberg leadership benefits the players more. We prepare two models, one in which the manufacturer is the Stackelberg follower and makes his decision of production quantity after observing the wholesaler's decision, while in the other, he is the Stackelberg leader. We solve both models and compare the results to generate insights into the problem.

We further extend the model by designing a returns contract, in which the manufacturer offers an option of returning the excess quantity if the wholesaler's realized demand falls short of the booking quantity by making a refund of a portion of the booking amount to the wholesaler. We solve the problem to draw further insights into how an advance

booking with a returns policy can benefit the two players.

In the third chapter of the thesis, we study the token advance booking scheme along with quantity discount which is quite prevalent in the agriculture input supply chain. We develop an analytical model to derive the equilibrium decision outcomes of the manufacturer and wholesaler we also conduct a numerical analysis to generate valuable insights into the problem.

## 4.1 Research Contribution

This thesis contributes to the literature of advance booking (or advance selling) by studying the manufacturer's decision of production quantity and the wholesaler's decision of advance booking quantity and sales effort in wholesaler and manufacturer Stackelberg setups with a sales effort-dependent stochastic demand. The study of returns contracts under an advance booking scheme is another important contribution offered by this thesis.

We also contribute to the sparsely available literature on agricultural input supply chains with a focus on two popular variants of advance booking namely full payment advance booking and token advance booking.

From a managerial perspective, we contribute by suggesting that advance booking information brings higher profits to the manufacturer in comparison to Stackelberg leadership position, therefore he should make his decision after observing the wholesaler's booking quantity. Moreover, our results suggest that under certain conditions of advance booking discount, the manufacturer being a follower in the Stackelberg game not only benefits him but also the wholesaler and the entire supply chain, creating a win-win situation for everyone. We also find that in supply chains where the wholesaler acts as the Stackelberg leader, they exert greater sales effort, and the manufacturer typically responds by increasing production quantity.

Another important managerial contribution we make is related to the returns policy. It is perceived that a returns policy along with an advance booking scheme can harm the profits of the manufacturer. However, we show that under certain conditions, there is a possibility that it can benefit both the manufacturer and the wholesaler and create a win-win situation in the supply chain.

From the results of Chapter 3, we find that when the manufacturer sets a lower quantity discount threshold, the wholesaler is more likely to place an order in the higher discount bracket. However, when the threshold is set too high, the wholesaler prefers to remain in the lower discount bracket.

## 4.2 Limitations and Future Research

There are certain limitations and assumptions made in this thesis which can be extended and addressed with further investigation. First, we limit the scope of this thesis to a single manufacturer and single wholesaler setup to avoid the competitive or collaborative dynamics among the players. It will be interesting to study a setup with more than one manufacturer and/or wholesaler and how it impacts the results. Second, we consider a uniformly distributed demand to keep the model simple and mathematically tractable, it will be interesting to check and verify the results with different demand distributions like Gaussian distribution, Beta distribution or other generalized distributions. Relaxing this assumption may impact the ability to obtain closed-form solutions. In such cases, numerical methods could prove valuable for solving the problem. Third, we consider all the prices as exogenous to focus on the dynamics of manufacturing and advance booking quantities with sales effort dependent demand; it could be interesting to endogenize the prices as decision variables and observe their impact on the model and the results. although increasing the number of decision variables can add complexity and potentially make the solution intractable, it may be necessary to simplify the problem by introducing additional assumptions. Fourth, inspired from the literature, we consider an additive

effect of sales effort on the demand. However, it would also be interesting to explore and verify the results under a multiplicative effect. Fifth, we do not consider any budgetary constraints for the manufacturer or the wholesaler, we assume that they have enough cash or they can arrange it. However, it will be interesting to check the players decisions under financial constraints. Sixth, as observed in Chapter 2, a returns contract can be beneficial for both players in a token advance booking with a quantity discount schedule as well. Therefore, extending Chapter 3 to incorporate a returns policy and analyzing its impact on the outcomes would be an interesting direction for further study. Lastly, we consider a fixed advance booking discount rate with respect to time. However, in practice, some manufacturers implement a time-based discount schedule, where the earlier a wholesaler places a booking order and pays the booking amount, the higher the discount they receive. Incorporating this aspect into the model could provide valuable insights into the equilibrium decisions under time based advance booking discount schedule.

# Bibliography


Anderson, E. and Monjardino, M. (2019). Contract design in agriculture supply chains with random yield. *European Journal of Operational Research*, 277(3):1072–1082.

Bai, Y., Li, H., and Gu, M. (2024). Advance selling policies with stochastic consumer valuations and advertising effects: dynamic pricing and inventory decisions. *International Journal of Production Economics*, 277:109401.

Bellemare, M. F. and Novak, L. (2017). Contract farming and food security. *American Journal of Agricultural Economics*, 99(2):357–378.

Borodin, V., Bourtembourg, J., Hnaien, F., and Labadie, N. (2016). Handling uncertainty in agricultural supply chain management: A state of the art. *European Journal of Operational Research*, 254(2):348–359.

Burlig, F., Jina, A., Kelley, E. M., Lane, G. V., and Sahai, H. (2024). Long-range forecasts as climate adaptation: Experimental evidence from developing-country agriculture. Technical report, National Bureau of Economic Research.

Burwell, T. H., Dave, D. S., Fitzpatrick, K. E., and Roy, M. R. (1997). Economic lot size model for price-dependent demand under quantity and freight discounts. *International Journal of Production Economics*, 48(2):141–155.

Cachon, G. P. and Feldman, P. (2017). Is advance selling desirable with competition? *Marketing Science*, 36(2):214–231.

Cao, Y., Yi, C., Wan, G., Hu, H., Li, Q., and Wang, S. (2022). An analysis on the role of blockchain-based platforms in agricultural supply chains. *Transportation Research Part E: Logistics and Transportation Review*, 163:102731.

Chen, Z. and Xie, W. (2021). Regret in the newsvendor model with demand and yield randomness. *Production and Operations Management*, 30(11):4176–4197.

Cheng, Y., Li, H., and Thorstenson, A. (2018). Advance selling with double marketing efforts in a newsvendor framework. *Computers & Industrial Engineering*, 118:352–365.

Chernonog, T. and Goldberg, N. (2018). On the multi-product newsvendor with bounded demand distributions. *International Journal of Production Economics*, 203:38–47.

Choi, S. C. (1996). Price competition in a duopoly common retailer channel. *Journal of retailing*, 72(2):117–134.

Chu, L. Y. and Zhang, H. (2011). Optimal preorder strategy with endogenous information control. *Management Science*, 57(6):1055–1077.

Customer market insights (2024). India fertilizer market 2024–2033. `https://www.custommarketinsights.com/report/india-fertilizer-market` [Accessed: (25 november 2024)].

Dana, Jr, J. D. (1998). Advance-purchase discounts and price discrimination in competitive markets. *Journal of Political Economy*, 106(2):395–422.

Desiraju, R. and Shugan, S. M. (1999). Strategic service pricing and yield management. *Journal of marketing*, 63(1):44–56.

Ding, W. and Song, H. (2020). Financing the price-setting newsvendor with sales effort. *Journal of Management Analytics*, 7(4):564–590.

Dowrick, S. (1986). von stackelberg and cournot duopoly: choosing roles. *The RAND Journal of Economics*, pages 251–260.

Economic survey (2024). Production, imports and consumption of fertilizers. `https://www.indiabudget.gov.in/economicsurvey/doc/stat/tab122.pdf` [Accessed: (25 november 2024)].

Evenson, R. E. and Gollin, D. (2003). Assessing the impact of the green revolution, 1960 to 2000. *science*, 300(5620):758–762.

FAOSTAT (2021). Visualize data, crops and livestock products. `https://www.fao.org/faostat/en/#data/QCL/visualize` [Accessed: (25 november 2024)].

Gale, I. L. and Holmes, T. J. (1992). The efficiency of advance-purchase discounts in the presence of aggregate demand uncertainty. *International Journal of Industrial Organization*, 10(3):413–437.

Gale, I. L. and Holmes, T. J. (1993). Advance-purchase discounts and monopoly allocation of capacity. *The American Economic Review*, pages 135–146.

Guo, L. (2009). Service cancellation and competitive refund policy. *Marketing Science*, 28(5):901–917.

Han, J.-W., Zuo, M., Zhu, W.-Y., Zuo, J.-H., Lü, E.-L., and Yang, X.-T. (2021). A comprehensive review of cold chain logistics for fresh agricultural products: Current status, challenges, and future trends. *Trends in Food Science & Technology*, 109:536–551.

He, Y., Zhao, X., Zhao, L., and He, J. (2009). Coordinating a supply chain with effort and price dependent stochastic demand. *Applied Mathematical Modelling*, 33(6):2777–2790.

Huang, Y.-S., Ho, J.-W., Jian, H.-J., and Tseng, T.-L. B. (2021). Quantity discount coordination for supply chains with deteriorating inventory. *Computers & Industrial Engineering*, 152:106987.

Jucker, J. V. and Rosenblatt, M. J. (1985). Single-period inventory models with demand uncertainty and quantity discounts: Behavioral implications and a new solution procedure. *Naval Research Logistics Quarterly*, 32(4):537–550.

Khan, M. A.-A., Shaikh, A. A., Konstantaras, I., Bhunia, A. K., and Cárdenas-Barrón, L. E. (2020). Inventory models for perishable items with advanced payment, linearly time-dependent holding cost and demand dependent on advertisement and selling price. *International Journal of Production Economics*, 230:107804.

Ladany, S. and Sternlieb, A. (1974). The interaction of economic ordering quantities and marketing policies. *AIIE Transactions*, 6(1):35–40.

Lal, R. and Staelin, R. (1984). An approach for developing an optimal discount pricing policy. *Management science*, 30(12):1524–1539.

Lashgari, M., Taleizadeh, A. A., and Ahmadi, A. (2016). Partial up-stream advanced payment and partial down-stream delayed payment in a three-level supply chain. *Annals of Operations Research*, 238:329–354.

Leitmann, G. (1978). On generalized stackelberg strategies. *Journal of optimization theory and applications*, 26(4):637–643.

Li, C. and Zhang, F. (2013). Advance demand information, price discrimination, and preorder strategies. *Manufacturing & service operations management*, 15(1):57–71.

Li, H., Yang, K., Yao, Y., and Zhang, G. (2024). Selling mode choice and return policy for advance selling in an e-commerce platform with social influence. *Computers & Industrial Engineering*, 197:110620.

Li, K. J. and Li, X. (2023). Advance selling in marketing channels. *Journal of Marketing Research*, 60(2):371–387.

Ma, P., Wang, H., and Shang, J. (2013). Supply chain channel strategies with quality and marketing effort-dependent demand. *International journal of production economics*, 144(2):572–581.

Ma, S., Li, G., Sethi, S. P., and Zhao, X. (2022). Advance booking discount strategies: competition, information transparency and spot market. *Transportation Research Part E: Logistics and Transportation Review*, 158:102589.

Market research future (2024). Indian seed sector analysis market overview. `https://www.marketresearchfuture.com/reports/indian-seed-sector-analysis-market-24920` [Accessed: (25 november 2024)].

McCardle, K., Rajaram, K., and Tang, C. S. (2004). Advance booking discount programs under retail competition. *Management Science*, 50(5):701–708.

Moe, W. W. and Fader, P. S. (2002). Fast-track: Article using advance purchase orders to forecast new product sales. *Marketing science*, 21(3):347–364.

Monahan, J. P. (1984). A quantity discount pricing model to increase vendor profits. *Management science*, 30(6):720–726.

Özer, Ö. and Wei, W. (2004). Inventory control with limited capacity and advance demand information. *Operations Research*, 52(6):988–1000.

Parlar, M. and Wang, Q. (1994). Discounting decisions in a supplier-buyer relationship with a linear buyer's demand. *IIE transactions*, 26(2):34–41.

Peng, W. and Tian, Z. (2022). Information acquisition, selling effort and pre-order strategy. *International Journal of Production Economics*, 249:108538.

Petruzzi, N. C. and Dada, M. (1999). Pricing and the newsvendor problem: A review with extensions. *Operations research*, 47(2):183–194.

Ponte, B., Puche, J., Rosillo, R., and de la Fuente, D. (2020). The effects of quantity discounts on supply chain performance: Looking through the bullwhip lens. *Transportation Research Part E: Logistics and Transportation Review*, 143:102094.

Prasad, A., Stecke, K. E., and Zhao, X. (2011). Advance selling by a newsvendor retailer. *Production and Operations Management*, 20(1):129–142.

Rosenblatt, M. J. and Lee, H. L. (1985). Improving profitability with quantity discounts under fixed demand. *IIE transactions*, 17(4):388–395.

Rubix (2024). Rubix industry insights: Agrochemicals. `https://www.rubixds.com/wp-content/uploads/2024/05/Rubix-Industry-Insights-Agrochemicals-May-2024.pdf` [Accessed: (25 november 2024)].

Sethi, S. P. (1984). A quantity discount lot size model with disposals. *The International Journal of Production Research*, 22(1):31–39.

Shah, N. H., Shah, P. H., and Patel, M. B. (2021). Retailer's inventory decisions with promotional efforts and preservation technology investments when supplier offers quantity discounts. *Opsearch*, 58(4):1116–1132.

Shugan, S. M. and Xie, J. (2000). Advance pricing of services and other implications of separating purchase and consumption. *Journal of Service Research*, 2(3):227–239.

Statista (2022). Leading pesticide exporting countries worldwide in 2022, based on value. `https://www.statista.com/statistics/737802/export-value-pesticides-worldwide-by-country/` [Accessed: (25 november 2024)].

Su, X. and Zhang, F. (2008). Strategic customer behavior, commitment, and supply chain performance. *Management Science*, 54(10):1759–1773.

Su, X. and Zhang, F. (2009). On the value of commitment and availability guarantees when selling to strategic consumers. *Management Science*, 55(5):713–726.

Sun, Y., Siqin, T., and Mu, L. (2018). Advance selling with part prepayment and consumer returns. *Mathematical Problems in Engineering*, 2018(1):2934698.

Taleizadeh, A. A., Wee, H.-M., and Jolai, F. (2013). Revisiting a fuzzy rough economic order quantity model for deteriorating items considering quantity discount and prepayment. *Mathematical and Computer Modelling*, 57(5-6):1466–1479.

Tang, C. S., Rajaram, K., Alptekinoğlu, A., and Ou, J. (2004). The benefits of advance booking discount programs: Model and analysis. *Management science*, 50(4):465–478.

Tang, W. and Ang, S. (2017). Advance selling with part payment for new to-be-released products. *Journal of Modelling in Management*, 12(3):455–474.

Tang, W. and Girotra, K. (2017). Using advance purchase discount contracts under uncertain information acquisition cost. *Production and Operations Management*, 26(8):1553–1567.

Transchel, S. and Mirner, S. (2008). Coordinated lot-sizing and dynamic pricing under a supplier all-units quantity discount. *Business Research*, 1:125–141.

UN SDGs (2015). United nations sustainable development goals. `https://sdgs.un.org/goals` [Accessed: (18 november 2024)].

Verdouw, C., Robbemond, R. M., Verwaart, T., Wolfert, J., and Beulens, A. J. (2018). A reference architecture for iot-based logistic information systems in agri-food supply chains. *Enterprise information systems*, 12(7):755–779.

Wang, H. H., Wang, Y., and Delgado, M. S. (2014). The transition to modern agriculture: Contract farming in developing economies. *American Journal of Agricultural Economics*, 96(5):1257–1271.

Weng, Z. K. (1995). Channel coordination and quantity discounts. *Management science*, 41(9):1509–1522.

World Bank a (2021). World bank data, agriculture, forestry, and fishing, value added ( `https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?end=2023&locations=IN-1W&most_recent_value_desc=true&start=1961` [Accessed: (18 november 2024)].

World Bank b (2021). World bank data, employment in agriculture ( `https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?end=2022&locations=IN-1W&name_desc=false&start=1991` [Accessed: (18 november 2024)].

Wu, M., Zhu, S. X., and Teunter, R. H. (2021). Advance selling and advertising: A newsvendor framework. *Decision Sciences*, 52(1):182–215.

Xiao, Y. and Zhang, J. (2018). Preselling to a retailer with cash flow shortage on the manufacturer. *Omega*, 80:43–57.

Xie, J. and Gerstner, E. (2007). Service escape: Profiting from customer cancellations. *Marketing Science*, 26(1):18–30.

Xie, J. and Shugan, S. M. (2009). Advance selling theory. In *Handbook of pricing research in marketing*, pages 451–476. Edward Elgar Publishing.

Xie, L., Ma, J., and Goh, M. (2021). Supply chain coordination in the presence of uncertain yield and demand. *International Journal of Production Research*, 59(14):4342–4358.

Xu, X., Chen, X., Hou, J., Cheng, T., Yu, Y., and Zhou, L. (2025). Should live streaming be adopted for agricultural supply chain considering platform's quality improvement and blockchain support? *Transportation Research Part E: Logistics and Transportation Review*, 195:103950.

Yang, P.-C. (2004). Pricing strategy for deteriorating items using quantity discount when demand is price sensitive. *European Journal of Operational Research*, 157(2):389–397.

Yu, M., Kapuscinski, R., and Ahn, H.-S. (2015). Advance selling: Effects of interdependent consumer valuations and seller's capacity. *Management Science*, 61(9):2100–2117.

Yu, Y. and Xiao, T. (2021). Analysis of cold-chain service outsourcing modes in a fresh agri-product supply chain. *Transportation Research Part E: Logistics and Transportation Review*, 148:102264.

Zhao, X., Pang, Z., and Stecke, K. E. (2016). When does a retailer's advance selling capability benefit manufacturer, retailer, or both? *Production and Operations Management*, 25(6):1073–1087.

Zhao, X. and Stecke, K. E. (2010). Pre-orders for new to-be-released products considering consumer loss aversion. *Production and Operations Management*, 19(2):198–215.