The Rise of Digital Platforms, Direct Procurement, Channel Substitution and Impact on Farmer and Consumer Welfare

Nikita Gupta, Ayush Gupta, Sachin Jayaswal, Ranjan Ghosh*

2024

*Nikita Gupta, Ayush Gupta, Sachin Jayaswal, Ranjan Ghosh -Indian Institute of Management Ahmedabad

Abstract

There has been an exponential rise in digital agricultural platforms such as Big Basket, Ninjacart, and Cogz. These platforms have revolutionized agricultural procurement by directly procuring from the farmers via digital channels. Direct procurement from the farmers was not feasible in many developing countries due to governmental policy regulations. However, in the last few decades, a few countries, such as Nigeria, Tanzania, Malawi, and India, have introduced agricultural market reforms that have allowed farmers to bypass intermediaries and sell their agricultural produce directly to retailers and consumers. These reforms have enabled such platforms to procure directly from farmers through digital channels.

Policymakers argue that allowing farmers to bypass the intermediaries and sell via such alternate marketing channels (AMCs) increases farmer welfare, asserting that expanding the marketing channel choice will help farmers receive better prices. While at the outset it might look like a win-win for both platforms and farmers, however, such policies have been met with strong resistance from not just the traders but also the farmers. Thus, in this context of the digital revolution and governmental regulations enabling farmers to sell via alternate marketing channels, we develop a game theoretical model to examine the impact of this policy shift on key stakeholders: farmer welfare, the profitability of traders and platforms, and consumer welfare. Additionally, we capture the heterogeneity in transportation costs, farmer's direct selling cost, and market competition.

Firstly, our findings suggest that contrary to the arguments of policymakers, allowing farmers to directly sell to digital platforms can decrease the farmer's welfare if direct selling costs are high for the farmers. Interestingly, our results also show that traders would continue to exist and can be more profitable despite governmental regulations allowing farmers to bypass the traders. Our results indicate that this policy increases platform profits only when the market size is substantial and there is high competition between the traders and the digital platform in the downstream market. Additionally, our results show that under certain market conditions, farmers, traders, and platforms can benefit simultaneously. However, undermining its intended goal, this policy decreases consumer welfare. Our results hold significance for the policymakers as a) they suggest that the government should consider lowering farmers' direct selling costs while implementing policies that facilitate AMC. b) they dispel fears regarding AMCs eliminating traders in agricultural wholesale markets.

1 Introduction

The digital revolution is reshaping food supply chains, providing farmers with unprecedented opportunities. Globally, a transformative wave is sweeping through food supply chains, driven by the emergence of digital platform buyers like Otrafy, RealEats, Ositrade, and Tenzo. These innovators adhere to the 'farm to fork' model, cutting out intermediaries by directly procuring from farmers and delivering to consumers (Dani, 2015). These platforms are, thus, shortening the length of the supply chain and removing inefficiencies by reducing the large number of intermediaries involved in taking the produce from farmers to consumers. India mirrors this revolution with pioneering agri-startups such as Crofarm, DeHaat, Ninjacart, KrishiHub, and Farmizen, reshaping the traditional landscape of agricultural produce distribution. While direct procurement from farmers was not feasible in many developing countries due to governmental policy regulations, few countries have introduced agricultural market reforms that now allow direct procurement from farmers.

Governments in various developing countries eased restrictions and allowed farmers to sell their produce outside traditional markets. This shift is particularly notable in African nations like Malawi, Tanzania, Madagascar, and Nigeria, where economic reforms between the 1980s and 2000s emphasized moving away from state control (Abdulai, 2000). India, too, joined this wave, amending its Agricultural Produce Market Committee (APMC) Act in 2003, granting farmers the freedom to sell outside regulated wholesale markets known as 'mandis.' This change has opened up alternate channels for farmers to sell their produce, ushering in a fresh era in agricultural marketing. Thus, in a transformative shift, digital platforms previously reliant on wholesalers (traditional traders) can now directly source agricultural produce from farmers due to regulatory changes. Platforms like Big Basket, embracing innovative strategies, have adopted dual-sourcing approaches. This entails acquiring produce not only directly from primary suppliers (farmers) but also from secondary suppliers (traditional traders). This reflects the adaptability of platforms to leverage diverse sourcing channels for enhanced efficiency and market responsiveness.

Direct procurement can revolutionize the agri-value chains by breaking the monopoly-like power of the traders (due to trader collusion) both as buyers from the farmers and as sellers of agricultural produce to retailers (including digital platforms). This can benefit farmers and consumers by increasing the prices farmers earn while reducing the prices for the final consumers. Past literature suggests that regulated markets in many countries involve high market inefficiencies due to factors such as trader collusion and the presence of many intermediaries before the agricultural product finally reaches the end consumer. Thus, selling to digital platforms not only helps farmers increase their bargaining power to get better prices for their produce due to greater competition in procurement but also helps them bypass intermediaries and other inefficiencies involved in selling via traditional channels. While farmers selling to alternate channels like digital platforms stand to gain higher prices, even those farmers continuing to sell to traditional channels may benefit from heightened competition of traders with the platform, leading to increased prices for their produce.

Thus, proponents of these reforms argue that expanding farmers' choices to include alternate marketing channels like digital platforms enhances farmer welfare by enabling better price realization. Additionally, platforms may benefit from dual sourcing, reducing reliance on intermediaries and gaining flexibility in procurement. However, traders or intermediaries in traditional channels fear they will be eliminated if the platform is allowed to procure directly from farmers. While at the outset, it might look like a win-win for both platforms and farmers, such policies have been met with strong resistance from not just the traders but also the farmers. For example, India witnessed one of the largest farmer protests in its history in 2021, driven by concerns that the elimination of intermediaries could reduce farmers' access to working capital traditionally provided by traders, ultimately undermining farmer welfare. This raises a critical question: Do farmers always benefit from reforms allowing direct procurement?

Even with the advent of these reforms, platforms like Big Basket have chosen a dual-sourcing strategy, procuring from both traders and farmers. This leads to the next question: Does allowing platforms to procure directly from farmers fully substitute traditional traders? While it may appear that consumers would benefit from reduced prices due to direct procurement, there are complexities in pricing dynamics. Platforms might pay higher prices to farmers but pass these costs on to consumers. Meanwhile, traders facing competition from platforms might also raise prices due to reduced supply from farmers, further increasing costs for consumers. This presents another critical question: Are consumers truly better off when platforms are allowed to procure directly from farmers?

The impact of reforms allowing direct procurement by digital platforms is debatable. To address these complex dynamics, this paper develops a game-theoretic model to examine the effects of direct procurement by digital platforms on key stakeholders: farmer welfare, trader profitability, platform performance, and consumer welfare. The model captures critical heterogeneities such as transportation costs, direct selling costs for farmers, and the intensity of market competition. We contribute to three major streams of literature: agricultural marketing channels, dual sourcing in supply chains, and the economics of digital platforms. While prior research has explored factors influencing farmers' channel choice and compared profitability between traditional and alternate channels, no study has comprehensively analyzed the effects of direct procurement on the welfare of all stakeholders. While there are studies showing why a manufacturer may switch from single to dual sourcing or opt for supplier diversification, we model for a unique setting whereby the firm's (platform) secondary supplier (trader) can purchase from the primary supplier (farmer) in the upstream market, and secondary supplier (trader) competes with the firm (platform) for market share in the downstream market. Also, no specific work has examined digital platforms as procurers in dual-sourcing models; our setting is unique as digital platforms can source from all sellers regardless of location. While extant literature has looked at competition between digital platforms and physical stores while supplying to consumers, to the best of our knowledge, no work has looked at competition between platforms and traders during procurement.

Our results show that allowing the platform to procure directly from farmers will not completely substitute the traders. In fact, surprisingly, direct procurement can make the traders better off, while farmers can become worse off, depending on the farmer's direct selling cost to the platform. These results carry two significant implications, both in shaping policies and guiding managerial strategies for digital platforms. Firstly, this study addresses concerns that introducing new marketing channels would either fully replace traditional traders or always disadvantage them. Thus, it holds significance for policy, particularly in the context of APMC reforms in India, by dispelling fears that allowing direct procurement would bypass traders in agricultural wholesale markets (mandis). Secondly, since the farmers can benefit from direct procurement only if the cost of selling directly to the platform is low, government initiatives opening new marketing channels should prioritize maintaining low direct selling costs. For instance, the government can reduce direct selling costs by doing away with fees paid by farmers (mandi fee as per APMC act) for transactions with the platform or any private player outside the regulated market.

Our results indicate that the platform stands to gain from dual sourcing when the market size is substantial and there is high competition between traditional traders and the platform in the downstream market. Thus, from a managerial perspective, platforms should actively opt for dual sourcing when there are large numbers of consumers who can easily substitute between buying from a trader or platform. One would expect that when the platform is allowed to procure directly from farmers, its cost of procurement might decrease as it can now also bargain better prices with the traders. This might be passed downstream as decreased prices to the consumers, consequently increasing consumer welfare. However, contrary to intuition, our results show that policies allowing direct procurement always hurt consumers. It is because the fall in price that consumers have to pay to the platform due to direct procurement is less than the price increase they have to pay to traders, which decreases overall consumer welfare. Finally, our results show that direct procurement can lead to a win-win situation for traders, farmers, and the platform (depending on parameters such as market size, market competition, and direct selling cost).

Next (Section 2), we discuss the background and provide an overview of various literature to which this study contributes. Section 3 discusses the main model setting. Section 4 is the main analysis whereby we discuss the effect of the farmer's cost of selling directly to the platform, market competition on the profits of traders, the platform, farmer welfare, and consumer surplus. Section 5 deals with the impact of allowing direct purchasing by the platform on farmer welfare, consumer surplus, and the profits of traders and the platform. In this section, we compare farmers' profits when the platform procures only from them vs. when the platform procures from both traders and farmers.

2 Background and Literature Review

2.1 Background

India and many other developing countries had limited marketing channel choices for farmers because of government restrictions. Most of the produce was sold to either local traders or traders in the government-regulated bodies. In India, Agricultural Produce Market Committees, APMCs, are the traditional institutional mechanism overseeing agricultural markets. These markets, known as 'mandis,' were entrusted with several responsibilities, including setting up market infrastructure, regulating the entry of traders, and determining licensing and fee structures (such as market fees and commission rates). The prices in 'mandis' were determined by open auction. However, the APMC system faced challenges, including corruption and collusion among traders, which depressed farmers' prices (Banerji & Meenakshi, 2004). In response, the Government of India introduced the "Model APMC Act" in 2003 [1]. The 2003 Act introduced provisions for alternative marketing channels, including direct marketing, which allowed private entities to establish markets outside government-regulated APMCs, granting farmers and private buyers more flexibility to transact outside the confines of APMCs, a practice previously

[1]The implementation and extent of these reforms were left to the discretion of individual state governments, resulting in varying timelines and approaches.

prohibited. These reforms aimed to enhance market efficiency and increase farmer welfare.

Some studies indicate that direct marketing and farmer-consumer markets resulting from these reforms expanded marketing options, providing farmers with some price advantages (Bhanot et al., 2021; Negi et al., 2018). Post-reforms, many companies and supermarkets also established collection centers. However, these off-market collection centers were still subject to APMC fees as per the Model Act, as the provisions for direct marketing, farmer-consumer markets, and contract farming remained under the purview of APMCs (S. Singh, 2018). Moreover, these reforms were not adopted by all states in India, with different states adopting different aspects of the reforms in different phases. Thus, in 2019, the central government introduced the Farmers' Produce Trade and Commerce (Promotion and Facilitation) Ordinance, 2020, also known as 'farm laws'. These laws were introduced with the objective of increasing farmer income by allowing them to trade outside the 'mandis' and increasing the marketing selling choice of farmers in all states. Also, these laws did not allow for any fees on such transactions outside 'mandis' (which was levied in model APMC Act 2003), thereby decreasing farmers' direct selling costs. While these laws encompassed various provisions aimed at the welfare of farmers, some of which were open to debate, what no one anticipated was the widespread protest and farmer discontent that would ensue in response to these welfare measures.

The protest against the 'farm laws' started in September 2020 and went on for more than a year till the farm laws were repealed in December 2021 (The repeal bill was introduced in November 2021 in the Lok Sabha).[2] Farmer organizations and farm union leaders called for a 'Bharat bandh' or nationwide lockdown to protest against farm laws.[3] While farmers were protesting against the farm laws, the academicians had a different stand. Many academicians in India support these farm laws as they believe that increasing competition due to greater marketing channel choice will help farmers receive competitive prices and thus benefit them.[4] Even though many argue that the new laws (FPTC, 2020) were better than Model APMC Act, 2003, as they allowed farmers to transact outside the 'mandis' without paying mandi fees, thus reducing farmer's direct selling costs, we still observed India's one of the longest-running protests of the farmers against these laws.[5] Some perspective on this issue could be gained by understanding how such reforms in other developing countries (characterized by large number

[2]https://prsindia.org/billtrack/the-farm-laws-repeal-bill-2021

[3]https://economictimes.indiatimes.com/news/economy/agriculture/is-this-the-beginning-of-another-mega-farmer-protest-kno
articleshow/100970308.cms?from=mdr

[4]https://www.hindustantimes.com/india-news

[5]https://www.business-standard.com/article/current-affairs/pm-modi-withdraws-three-farm-laws-urges-protesters-to-return-h
1.html

of small landholdings with majority population employed in agriculture) affected the farmer welfare.

Several developing countries, especially in Africa, have experienced transformations in their agricultural markets, resulting in increased marketing channel choices for farmers. These changes were primarily driven by economic reforms (between the 1980s and 2000s), emphasizing the deregulation and privatization of sectors previously under state control (Abdulai, 2000). In countries like Madagascar and Nigeria, agricultural reforms reducing government regulations have allowed farmers to engage directly with private traders (Barrett, 1997; Ezealaji and Adenegan, 2014). In Tanzania, when traders were allowed to procure directly from farmers by 1990 (Coulter and Golob, 1992), there was growth in the private sector's share of maize trade, surging from 43% in 1980/1981 to 83% in 1987/88. (Santorum and Tabaijuka, 1992). Even in Malawi, marketing reforms enabled farmers to shift from selling to government-regulated channels like the Agricultural Development and Marketing Corporation (ADMARC) to selling directly to private traders (Jayne et al., 2014; Smith, 1995). In Zambia, the government enacted the Food Reserves Act in 1995, which led to the liberalization of maize marketing and heightened private-sector involvement.[6].

These developments in the upstream agri-supply chain due to government reforms were accompanied by the rise of platforms like ProduceMart in the UK, Khula and Complete Farmer in Africa[7] which have enhanced consumers' connectivity with suppliers. In India, bigbasket.com stands out as the largest online food and grocery store, delivering fruits, vegetables, rice, dal, and spices directly to consumers.[8] Almost 70% of its produce is procured directly from farmers through its procurement centers (Hari, 2019). The 'Farm Connect' program boasts 50 collection centers across 15 different states, where farmers bring their produce to sell.[9] Other digital platforms such as Otipy, Farmers Fresh Zone, FarmLink, WayCool, and Croafarm in India are disrupting the traditional supply chain by connecting farmers directly to the market.[10]. Digital Platforms such as KrishiHub, DeHAAT, and Ninjacart empower farmers to sell their produce directly to institutional buyers, including restaurants, vendors, hotels, and stores. [11]

Government reforms allowing platforms to procure directly from farmers and the rise in digi-

[6] https://pdf.usaid.gov/pdf_docs/PNACF335.pdf

[7] https://www.producemart.com/,https://khula.co.za/,https://www.completefarmer.com/

[8] https://www.bigbasket.com/about-us/

[9] https://www.livemint.com/industry/retail/e-grocers-double-down-on-farm-to-plate-sourcing-models-11598531979890.html

[10] https://otipy.com/,https://www.farmersfz.com/,https://farmlink.net/,https://waycool.in/,https://crofarm.com/

[11] https://www.crunchbase.com/organization/krishihub,https://agrevolution.in/,https://ninjacart.in/

tal platform buyers sourcing majorly from farmers by setting procurement centers near them have significantly transformed the supply chain dynamics. It has helped increase farmers' marketing channel choice, thereby increasing their bargaining power. It has helped combat downward pressure on prices to some extent due to trader collusion. Still, we see farmers' protests regarding reforms to increase marketing channels due to apprehensions about the concentration of power with players in new channels. There are apprehensions that, in the long run, the substitution of traditional channels by platform buyers will lead to a decrease in the price received by farmers from the platform as they emerge as the sole buyer of agricultural produce. The divided stand on this issue in academia, by the government and the farmers themselves, calls for delving deeper into questions such as who gains from such reforms that remove trade restrictions and how.

2.2 Literature Review

Our study is related to two major streams of literature. Firstly, it relates to the growing literature on farmers' marketing channel choice. Secondly, it relates to the literature on dual sourcing by the firms. The first stream focuses on the farmer's choice between selling to traditional vs. alternate marketing channels. i.e., direct marketing channels whereby farmers sell directly to consumers or intermediated marketing channels where farmers sell to platform buyers. The research stream has mainly focused on comparing the mean and volatility of farmer's prices (Michelson et al., 2012), yield and input use (Hernández et al., 2007), effects on poverty (Rao & Qaim, 2011), farmers' income (Detre et al., 2011; Govindasamy et al., 1999) and profits (Hardesty & Leff, 2010; Lee et al., 2020) from selling in traditional vs. alternate marketing channels. Additionally, our paper looks at the profits of platform buyers in sourcing from traditional, alternate channels, or both via game theoretic modeling.

There are studies answering questions like where farmers sell and why, i.e., factors affecting the choice of farmers to sell in the market or not (Fafchamps & Hill, 2005) and factors affecting the type of marketing channel where farmers sell. In addition to price (Schipmann & Qaim, 2011), factors such as the proximity to the wholesale market (Chirwa, 2009) or access to market information (Donkor et al., 2021) also play a prominent role in determining a farmer's marketing channel choice. Others have also examined the impact of farm characteristics like farm size, quantity sold, and use of pesticides and fertilizers (Xaba & Masuku, 2012). The role of farmer characteristics like years of experience, farm as a primary occupation, education, and membership in producer organizations have also been explored in determining the marketing channel choice of farmers (Sartwelle et al., 2000; Shiimi et al., 2012). Past literature helps us understand how different factors affect the farmer's marketing channel choice; however, the impact of allowing direct procurement by the platform on the consumer welfare and welfare of both sets of farmers (those selling to traders and selling to the platform) and how changes in direct selling costs to the platform or market competition affect the welfare of stakeholders has not been explored before.

While past literature has empirically compared outcomes of farmers selling in one channel with outcomes of farmers selling in another channel and concluded about greater prices or market efficiency in one channel over another, however, such studies are plagued with endogeneity issues. This is because farmers who are choosing to sell to one channel over another might have common characteristics, thus leading to self-selection bias. Even if studies have in some way (through various econometric techniques) been able to address such issues, they still don't give insight into how changing direct selling costs or market competition could affect the dynamics. Thus, it calls for a deeper understanding via an analytical model whereby strategies of different stakeholders are discussed, given the assumptions, and each tries to optimize and arrive at their equilibrium, given the other player's strategy. One can then understand, through simulation and by changing different parameters, how the welfare of farmers and consumers can change due to policies allowing direct procurement and also due to changes in different parameters.

The other stream of literature relates to dual sourcing, where most work has dealt with firms' strategies to opt for dual sourcing under various conditions. Chen and Guo (2014) have analytically modeled the sourcing strategies of competing retail firms in the presence of supply uncertainty. They find a win-win situation created by a dual-sourcing strategy of the focal firm, causing an increase in retail prices and expected profits for both firms. Tang et al. (2014) present models to identify conditions under which buyers prefer a sole or dual sourcing strategy. They model direct (investment subsidy) or indirect (inflated order quantity) incentives offered to suppliers to improve reliability. Li et al. (2013) find that the insight 'cost is the order qualifier and reliability is the order winner' holds with two suppliers but fails to hold with more suppliers. In their study, Niu et al. (2019) investigate the dual sourcing decision of OEM (Original Equipment Manufacturer). Their findings show that OEMs always prefer supplier diversification even if additional suppliers suffer from unreliable production yields. Dong et al. (2021) show that in the presence of Contract Manufacturer (CM) encroachment, the OEM may shift its strategy from single to dual sourcing as there is an increase in competition level.

Our paper differs from the above studies in two major aspects. Firstly, our model setting is such that there is one primary supplier (farmer) and one secondary supplier (trader) such that the secondary supplier can purchase from the primary supplier. In this setting, we then analyze the dual-sourcing strategy of the platform from its primary and secondary suppliers. To the best of our knowledge, no study has looked at a setting whereby one of the firm's suppliers also sells to another supplier. Secondly, on the demand side, the platform does not have a monopoly in selling to consumers and is competing with the secondary supplier (trader) for market share. Our study is different from the typical horizontal sourcing model as the platform competes with the trader in both upstream and downstream markets. Thus, our study is unique in this setting and context and remains previously unexplored. We add to this body of literature by examining the role of factors like transportation costs, market competition, trader concentration, and the opportunity cost of farmers from selling directly to platforms in determining the marketing channel choice of farmers. We also enquire how the procurement strategy of the platform for dual sourcing is influenced by direct selling cost and market competition. Our study explores how policies allowing farmers to sell directly to the platform may impact farmer and consumer welfare.

3 Model

To understand the effect of allowing farmers to sell outside the regulated market, we first model the setting whereby the platform cannot procure from traders and sources only from farmers. This setting bears similarity to the regulation period in India and other countries like Africa, which restricted farmers from selling outside agricultural wholesale regulated markets or 'mandis.' Thus, in our benchmark model, farmers can sell only to traders, who then sell to the platform and the market (Appendix Figure 7(a)). However, after the agricultural market reforms, which allowed farmers to sell outside regulated markets, many platforms, such as Big Basket, adopted a dual-sourcing model, procuring from both traders and farmers. To model this, we consider a market setting whereby the platform can procure from both farmers and traders and thus engages in dual sourcing. In this dual-sourcing model, farmers can sell their produce to either the platform or the trader, and the trader further sells the produce to the platform and consumers (Appendix Figure 7(b)). In the benchmark model, farmers sell only to traders; however, in the dual-sourcing model, they sell to both the platform and traders. Thus, to understand whether government policy allowing farmers to sell outside the regulated wholesale markets makes traders, farmers, consumers, and the platform better off or worse off, we compare the benchmark model with the dual-sourcing model. This comparison helps shed light on the effect of such policies allowing direct procurement and under what conditions they can benefit or hurt the farmers.

Following Salop (1979), we consider a circular spatial market in which producers (farmers) are distributed uniformly across a circle with a radius 'r' and unit circumference ($r = 1/2\pi$). The model setting is such that there are 'n' traders located equidistant from each other on the circumference of the circle, and these locations are fixed. While traders are distributed equidistantly on the circle, the farmers are distributed equidistantly between these traders (Figure 1)[12]. We use a circular model over the most commonly used linear model in the literature for two main reasons. Firstly, in a linear space, every point's distance from the endpoints is unique. This is not an issue with two traders, as seen in the classic Hotelling setup. However, when multiple traders are placed along a line, those in the middle face competition from both sides, while those at the ends only face competition from one side. It results in the central and corner traders (mandis) facing differential competition. Also, with a platform at the center (as discussed later in dual sourcing), it captures the reality of an even-handed effect on all traders. However, with multiple evenly-spaced traders, ensuring an even-handed effect on all is challenging, especially for those at the borders who are not symmetrically placed. Secondly, even with just one trader in the market, equilibrium prices (in the presence of a platform) would vary depending on the trader's position in linear space. However, in a circular market, any position of a trader cannot be distinguished from other positions, which simplifies our analysis of price equilibrium. Hence, we opt for a circular model.

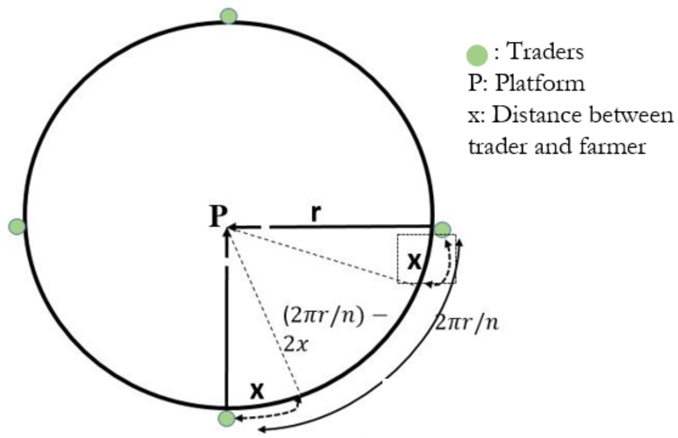


Figure 1: Spatial setting of the circular market

Note: Platform P is at the center of the circle in the dual sourcing model, while in the benchmark model, there is no P at the center as all farmers sell to traders

Each farmer in the market produces a single unit of the standardized product (Chintapalli &

[12]Note that the platform in the center of the circle appears only in dual sourcing as discussed later.

Tang, 2021) with a marginal cost of production 'c', and it is uniform across all farmers. Hence, the total quantity produced in the market is equal to 2πr. We assume that the reservation price of the farmer (i.e., the lowest price the farmer is willing to accept for the produce) is higher than the marginal costs of production. This assumption is important for ensuring the economic viability of the farmer's production. It ensures that the farmer is willing to produce and sell the produce at a price that covers at least the variable costs of production. We also assume the fixed cost of production to be zero. Zero fixed costs allow for easier comparison between different strategies and scenarios and help to isolate the impact of pricing strategies on market outcomes without the confounding effect of fixed costs. We also assume that all produce of the farmers is sold in the market, i.e., there is no unsold inventory or no self consumption. Similarly, we assume that both the platform and the traders release all the purchased quantity from the farmers in the market, i.e., there is no storage of produce.

In line with (Liao & Chen, 2017), we assume that farmers cannot influence the market price and are price takers. This assumption is especially useful for modeling in the context of developing countries where the majority of farmers are small and marginal and cannot influence the market price. Similar to most of the hotelling models, farmers incur travel costs at a linear rate of t per unit of distance to travel to the markets where traders are located (Leng et al., 2013; Zhou & Fan, 2015). The assumption of linear travel costs helps ensure model tractability. Following Hotelling's model, these costs encompass the opportunity cost of time, actual travel expenses, and the hidden costs associated with inconvenience (Balasubramanian, 1998). The concept of transportation cost is broadly defined, playing a crucial role in distinguishing between traders based on their accessibility. As transportation cost, denoted by t, rises, farmers tend to favor the closest trader, leading to greater differentiation among traders. Consequently, this strengthens each trader's influence over nearby farmers, enhancing their market power. Hence, 't' acts as a proxy for the market power of the traders in the mandis (Balasubramanian, 1998). We consider a complete information setting, which implies that the parameters t, θ, and μ are common knowledge to all players.

The actions and strategies available to one trader are the same as those available to all other traders in the game. Due to this symmetry, it is only necessary to examine the price-setting dynamics within a single segment or subgroup of the market. Thus, since the game is symmetric, for traders, the price setting is analyzed in a single segment with a size of $(2\pi r)/n$. The trader has to pay a price P^B_{ft} to the farmer and receives a quantity $(2\pi r)/2n$ from its left or right segment in the circle. In the benchmark model, since farmers are selling all quantity to traders, each trader's share becomes the sum of shares from the left and right segments, i.e.,

Q_{ft}^B=$(2\pi r)/2n$ + $(2\pi r)/2n = (2\pi r)/n$. The welfare of farmers receiving a price P_{ft}^B and bearing unit transportation cost t can be expressed as follows:

$$w_f^B = 2n[\int_{x_b=0}^{(2\pi r)/(2n)}[P_{ft}^B - tx_b]].$$

We not only find farmer welfare but also the welfare of consumers, for which we first define the utility structure. We assume that the utility U^B derived by the consumer is quadratic and strictly concave (N. Singh & Vives, 1984) and is given by:

$$U^B(Q_{tc}^B, Q_{tp}^B) = \alpha_1 Q_{tc}^B + \alpha_2 Q_{tp}^B - [\beta_1(Q_{tc}^B)^2 + \beta_2(Q_{tp}^B)^2 + 2\theta Q_{tp}^B Q_{tc}^B]/2.$$

This utility structure gives rise to inverse demand curves, i.e.,

$$P_{tc}^B = \alpha_1 - \beta_1 Q_{tc}^B - \gamma Q_{tp}^B \text{ and } P_{tp}^B = \alpha_2 - \beta_2 Q_{tp}^B - \gamma Q_{tc}^B.$$

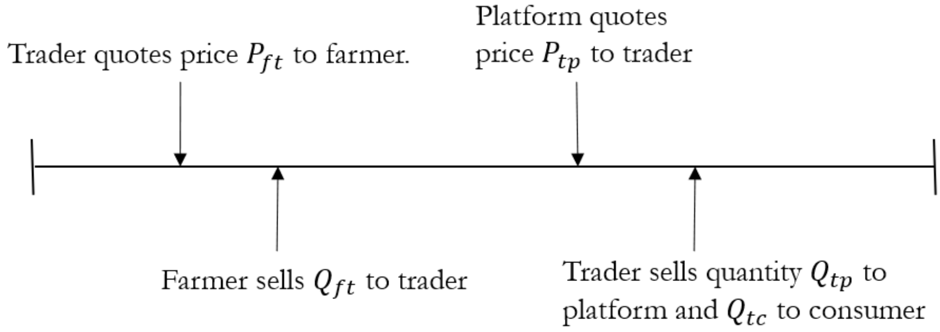
Since, in our model, we have assumed market size (α/β) to be unity[13] along with unitary elasticity of demand $(\frac{\Delta Q}{Q} \div \frac{\Delta P}{P})$, this implies $\alpha_1 = \alpha_2 = \beta_1 = \beta_2 = 1$. Thus, using the above utility function, we find Consumer Surplus as follows:

$$C_s^B = Q_{tc}^B + Q_{tp}^B - [(Q_{tc}^B)^2 + (Q_{tp}^B)^2 + 2\theta Q_{tp}^B Q_{tc}^B]/2 - (Q_{tc}^B P_{tc}^B + Q_{tp}^B P_{tp}^B).$$

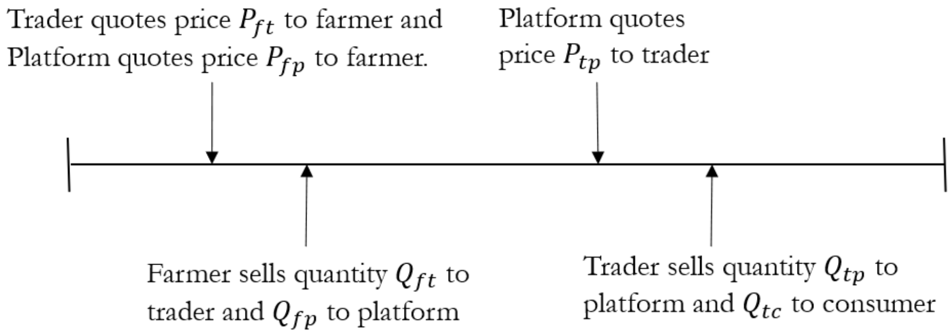
Following is the sequence of decisions for the benchmark model with single sourcing (Figure 2(a)). In stage 1, the traders quote the price at which they will buy the produce from farmers (P_{ft}^B), and farmers sell all quantities (Q_{ft}^B) to traders at that price. In stage 2, the platform decides the price at which it will procure the produce from the trader(P_{tp}^B). This subsequently would determine the quantity the trader sells to the platform (Q_{tp}^B), and the remaining is sold to the consumers in the market (Q_{tc}^B). The farmers sell their produce at a price P_{ft}^B fixed by the trader, and all traders offer the same price. (For simplicity, we do not consider the auction mechanism by which traders procure from the farmers at the mandis). Subsequently, traders in the mandi sell Q_{tp}^B and Q_{tc}^B at prices P_{tp}^B and P_{tc}^B to the digital platform and consumers, respectively.

The circular model setting in the dual sourcing model is borrowed from Balasubramanian (1998), where consumers could buy from a digital platform without having any physical market location in the conventional sense. Similarly, in our model, the farmer can sell the produce to a digital platform, 'p,' located at the center of the circle. This setting allows us to explore the evenly distributed impact of digital platforms on farmers and traders in each Mandi. While the digital platform operates without a fixed physical location, its ability to influence market areas is often strengthened by this absence of location constraints. This is in contrast to traditional literature, where market power primarily stems from physical market presence.

[13]In extension of the model, we relax this assumption and solve the model for a large market size



((a)) Benchmark Model



((b)) Dual Sourcing Model

Figure 2: Sequence of decisions

For the dual sourcing model whereby the platform can procure from traders and farmers, it is assumed that farmers incur costs arising from dis-utility 'μ' while transacting with the digital platform (in line with Balasubramanian (1998)). This dis-utility includes the opportunity cost of not selling to traders (mandis). For instance, farmers tend to choose traders (mandis) for selling their produce as they get capital/loans for sowing in the next cropping cycle (majorly small and medium farmers)(Bardhan, 1980; Basu, 1983; Bhaduri, 1986). Thus, opting to sell to the platform implies that the farmer foregoes the opportunity to receive loans or working capital that they might have obtained by selling to traders. The parameter μ also includes packaging and other compliance costs born by farmers to meet standards and quality checks associated with selling to digital platforms as compared to selling in mandis. The direct selling cost 'μ' may also represent fees paid by farmers for transacting with platform buyers. For instance, in India, as per Model APMC Act 2003, farmers have to pay mandi fees to the APMCS even if they sell to digital platforms (i.e., even for transactions outside the APMC mandis). Thus, if no such fees are required, then μ will be reduced.

Figure 1 shows that traders are distributed equidistant on the circle as shown by green dots (here n=4). Platform P is at the circle's center, and farmers are distributed equidistant between the traders. Even in the dual-sourcing model, because the game is symmetric with respect to traders, we analyze the price setting in a single segment with a size of $1/n$. The trader has to pay a price P^D_{ft} to procure from farmers. A farmer located near the trader (distance less than x) will sell to the trader as the total cost of transportation in selling to the trader (tx) will be less, while a farmer located away from a trader (distance more than x) will sell to the platform and bear direct selling cost of μ. A farmer located at a distance x from the trader is indifferent between selling to the trader or platform when $P^D_{ft} - tx = P^D_{fp} - \mu$. Thus, solving for x, we get $x = (P^D_{ft} - P^D_{fp} + \mu)/t$. Each trader's share Q^D_{ft} is thus, confined to:

$Q^D_{ft} = 2x = 2[\frac{(P^D_{ft} - P^D_{fp} + \mu)}{t}]$

Platform's share Q^D_{fp}, which is the middle segment of the arc away from traders, is:

$Q^D_{fp} = 2\pi r/n - (2x) = \frac{2\pi r}{n} - 2(\frac{(P^D_{ft} - P^D_{fp} + \mu)}{t})$

We compute farmer welfare in the dual-sourcing model as: $w^D_f = 2n[\int_{x_1=0}^{x}(P^D_{ft} - tx_1)dx_1] + n[(Q^D_{fp}(P^D_{fp} - \mu))]$. In the above equation, while the first part of the equation shows the welfare of those set of farmers who are selling to the trader, the second part shows the welfare of those set of farmers selling to the platform[14].

The sequence of events in the dual sourcing model is such that in stage 1, the platform and trader quote purchase price P^D_{fp} and P^D_{ft}, respectively, to the farmer (Figure 2(b)). Based on this price, some farmers will choose to sell to the platform (Q^D_{fp}) and some to traders (Q^D_{ft}). Then, in stage 2, the platform decides on the price P^D_{tp} at which it will purchase from the trader. Then, the trader decides on the quantity Q^D_{tp} they want to sell to the platform, which also means that the trader will sell the remaining quantity Q^D_{tc} to consumers. The variables, notations, and their descriptions are summarized in Table 1.

4 Analysis

This section analyzes the equilibrium behavior of the platform and traders. We first find the effect of direct selling cost (μ) on the profits of traders and the platform and welfare of farmers and consumers. Section 4.1 discusses the benchmark setting whereby the platform is not allowed to procure directly from the farmers. Then, in section 4.2, we discuss the setting where the

[14]Note: To get the welfare of one farmer, the welfare of all farmers selling to the platform or trader is divided by the number of farmers selling to the platform or trader. Thus, we get the welfare of a farmer selling to a trader as $w^D_{ft} = \left(2n\int_{x_1=0}^{x}(P^D_{ft}) - tx1)\,dx1\right)/2x$, and the welfare of a farmer selling to the platform as $w^D_{fp} = (nQ^D_{fp}(P^D_{fp} - \mu))/((2\pi r/n) - 2x)$.

Table 1: Description of Variables and Parameters

Parameters	Description
μ	Costs incurred by farmers in selling directly to the platform.
t	Travel expenses per unit distance incurred by farmers when selling to traders.
θ	Market competition (consumer's degree of substitution between buying from platform or trader).
r	Distance between platform (at the center of hotelling circle) and farmers or traders (located on the circumference of the circle).
n	Trader concentration (total number of traders).
Subscripts	
f	farmer
p	platform
t	trader
c	consumer
Decision Variables	
P_{fp}	Price at which platform procures from farmer.
P_{ft}	Price at which trader procures from farmer.
P_{tp}	Price at which platform procures from trader.
Q_{tp}	Quantity sold by trader to platform.
Derived Variables	
Q_{tc}	Quantity sold by trader to consumer.
Q_{fp}	Quantity sold by farmer to platform.
Q_{ft}	Quantity sold by farmer to trader.
Q_{pc}	Quantity sold by platform to consumer.
P_{tc}	Price at which trader sells to consumer.
P_{pc}	Price at which platform sells to consumer.
Outcome Variables	
π_y	Profit of the trader (if $y = t$), Profit of the Platform (if $y = p$).
w_z	Farmer welfare (if $z = f$), Welfare of a farmer selling to traders (if $z = ft$), Welfare of a farmer selling to the platform (if $z = fp$).
C_s	Consumer Surplus.
Superscripts	
D	Dual Sourcing model: When platform can procure directly from farmers.
B	Benchmark model: When a farmer cannot sell to platform.

platform is allowed to procure directly from the farmers. We solve the game using backward induction to arrive at the sub-game perfect Nash Equilibrium for all prices, quantities, and profits, given in Appendix Table 2 and 3.

4.1 Benchmark Setting

We solve the game using backward induction to arrive at the subgame perfect Nash equilibrium. Equilibrium profits of trader and platform, along with unique Nash for farmer and consumer welfare, are given in Appendix Table 4. An increase in transportation costs t for farmers should decrease farmer welfare. But if a change in t also affects prices quoted by the trader, we do not know whether welfare will increase or decrease, which leads us to the following lemma.

Lemma 1 $\partial f^B/\partial t > 0$ *and* $\partial \pi_t^B/\partial t < 0$

With the increase in transportation costs, farmer welfare may increase due to the higher price that the trader now pays to the farmer. Even in the benchmark model, when the platform does not procure from farmers, the trader competes with other traders for procuring from farmers. Thus, the trader will offer higher prices to farmers such that it overcompensates for an increase in transportation costs and farmer welfare increases. The traders' cost of procurement is low as they are directly sourcing from farmers and selling to consumers, while the platform is sourcing from traders and then selling to consumers. Thus, even though the price at which the consumer buys from the platform is always greater than the price at which the consumer buys from the trader, the trader does not increase prices for consumers when t increases. Rather, we observe that increased costs of procurement for the trader are not passed downstream to the platform and consumer, i.e., $\partial P_{tp}^B/\partial t = 0$ and $\partial P_{tc}^B/\partial t = 0$. Thus, because of higher prices paid to the farmers, the profit of the traders decreases as t increases.

In addition to transportation costs, factors such as market competition might also affect the profits of traders and the platform. Since, with an increase in market competition θ, consumers can easily substitute between buying from two channels, the prices consumers pay to platform and traders may decrease. Thus, we have the following lemma.

Lemma 2 *a)* $\partial \pi_p^B/\partial \theta < 0$ & $\partial \pi_t^B/\partial \theta < 0$

b) $\partial C^B/\partial \theta > 0$.

In equilibrium, there is an increase in consumer welfare along with a reduction in the profit of the trader or platform because a higher θ implies greater substitutability between buying from either platform or trader.[15] Because of the ease of switching in buying from another channel if prices in one channel increase, there is a reduction in prices that consumers have to pay to the platform (P^B_{pc}) or traders (P^B_{tc}), which increases consumer welfare (Appendix Table 5). There is a decline in the profit of the platform as θ increases because although both the cost of procurement of the platform P^B_{tp} and the price received from consumers P^B_{tc} decreases with θ, however the decrease in price received from consumers is greater than the decrease in the price paid by the platform to traders, i.e., $\partial P^B_{tp}/\partial\theta < \partial P^B_{pc}/\partial\theta$. With an increase in market competition, the price that the trader receives from both the platform and the consumer decreases. Hence, the profit of the trader also decreases.

4.2 Dual Sourcing Model

The dual sourcing model, where the platform purchases from both traders and also directly from farmers, is solved using backward induction to arrive at sub-game perfect Nash equilibrium. Under assumptions of the model, a unique (pure strategy) Nash equilibrium in prices exists at n>1, $\theta < \frac{-n^2+4nt+n+2t}{n-n^2}$ and $\mu^L < \mu < \mu^U$. While in the dual-sourcing model, the platform is now allowed to procure from farmers, it may not procure from both traders and farmers for all ranges of μ as discussed in lemma 3 below.

Lemma 3 $Q^D_{tp} > 0$ *only if* $\mu > \mu^L$, *where* $\mu^L = \frac{-2n^3(\theta-1)+6n^2t+n(t+2\theta-2)-t}{2n(6n^2+5n+1)}$

For very low direct selling costs, some farmers will sell to traders, and some to the platform, but no quantity will be procured by the platform from traders. It is because a very low direct selling cost allows the platform to efficiently meet market demand by exclusively sourcing from farmers. Additionally, the farmers will stop selling to the platform when $\mu > \mu^U$, i.e., if the direct selling cost of farmers is very high then all farmers sell to the trader[16] (same as benchmark).

In the dual-sourcing scenario, farmers now have greater selling options. If the platform offers very high prices, it could be the case that all farmers shift to selling to the platform (even if direct selling costs are high). Thus, there might be complete channel substitution or elimination of intermediaries (traders) in the traditional supply chain. Even government reforms that allowed direct procurement by the platform led to protests by traders because of apprehensions of farmers

[15] It is to be noted that the consumer surplus in equilibrium is independent of transportation costs (t) born by the farmers for selling to traders, while in equilibrium, farmer welfare is independent of market competition (θ) between the two channels (traders and platform).

[16] Note that for dual sourcing, the model is valid till the upper limit of μ which is $\mu^U = \frac{-2(\theta-1)^2n^4+2(\theta-1)n^3(-\theta+4t+1)+n^2\left(2(\theta-1)^2+8t^2-\theta t+t\right)+2n\left((\theta-1)^2+4t^2-2(\theta-1)t\right)+t(-\theta+2t+1)}{2n\left(\theta+4(\theta-1)n^3+n^2(9\theta-8t-9)+n(6\theta-8t-6)-2t-1\right)}$

bypassing the traders. However, our results show the contrary, as discussed in Proposition 1 below.

Proposition 1 *Direct selling by farmers to the platform will not eliminate the traders.*

If the platform wants to attract all the farmers such that zero quantity is sold to the traders, i.e., $Q_{ft}^D = 0$, then the platform will have to offer a very high price so that it can procure from not only farmers away from traders (region $(2\pi r)/n) - 2x)$) but also the farmers who are in proximity of traders in mandi (region x) (figure 1). This will lead to a high cost of procurement, and since it is not profitable for the platform to offer very high prices, some farmers will continue selling to the traders. Thus, the traders in mandi will not be fully substituted by platform buyers.

In dual sourcing scenario where the platform is allowed to procure from farmers, if the direct selling costs are very low such that $\mu < \mu^L$, then following lemma 3, quantity sold by the trader to the platform or Q_{tp}^D will be 0. It means that under very low direct selling costs, the platform will only procure from farmers. Thus, it becomes crucial to answer if all farmers will sell to the platform or if some will continue to sell to traders, i.e., will the traders be completely substituted in this scenario? Thus, we solve the model for $\mu < \mu^L$ to arrive at sub-game perfect Nash equilibrium. The equilibrium prices, quantities, and profits are given in the Appendix Table 4. We find that under assumptions of the model, $Q_{ft}^D > 0$ i.e., farmers will continue to sell to traders. Thus, traders will continue to exist even for a very low direct selling cost to the platform.

While we know that the platform never offers very high prices to farmers, such that there is complete channel substitution, we do not know whether farmers receive greater prices from traders or platforms. If the platform quotes a very low price to the trader, less than it quotes to the farmer, the trader will have no incentive to sell to the platform as not only its cost of procurement from farmers will increase, but also remuneration from the platform decreases drastically, thus adversely affecting its profits. Also, it might seem intuitive that the platform procures from traders at a lesser price than the price at which the trader sells to the consumers because the platform also has to earn profits by selling the procured product to consumers. However, what is not clear is why it will be in the trader's interest to sell to the platform at a lower price than it sells to the consumer, which is discussed in the lemma below.

Lemma 4 $P_{tc}^D > P_{tp}^D > P_{fp}^D$

We observe that $P_{tp}^D > P_{fp}^D$ because if the platform procures at a high price from farmers, then the trader's cost of procurement from the farmers will also increase. Traders will sell at a high price to the platform, thus further increasing the platform's overall cost of procurement. Thus, it is in the platform's interest to procure at a lesser price from farmers than from traders. We find that it is not in the trader's interest to release a greater quantity at a lower price in the market (lower than it sells to the platform).

It is because if all the quantity is released by the trader in the market, then the price that the trader receives from the market (P_{tc}) will decrease drastically, whereas if some of it is sold to the platform, then there will be less decline in P_{tc}. Thus, we can observe two effects: one is the direct effect of a decline in price due to releasing greater quantity in one's own market, and the other is the indirect effect of a decline in price in one's own market due to the release of quantity in competitor's market. The greater the degree of substitution amongst consumers buying from a platform or trader (θ), the less will be the difference between P_{tc} and P_{tp}. We observe that if there is perfect substitution such that θ is one, then P_{tc} becomes equal to P_{tp}.

When farmers sell directly to the platform, their direct selling costs might increase due to various factors, such as regulations requiring fees charged from farmers for direct trade or there may be an increase in packaging and compliance costs for farmers. This can affect the platform's decision with regard to the price quoted to traders and farmers, which in turn can affect the quantity sold by farmers and traders to the platform. Thus, high direct-selling costs can cause farmers to sell more to traders and increase traders' profits, while it may reduce the platform's profits and vice versa. Thus, to understand the effect on profits and the welfare of stakeholders, we discuss the following proposition.

Proposition 2 *High direct selling costs for farmers in a dual-sourcing model benefit traders, platforms, and consumers but harm the farmers.*

The reason for the increase in consumer welfare and profits of traders and the platform and can be explained as follows. With an increase in μ, more farmers sell to the traders, and thus, the price at which the trader buys from the farmer (P_{ft}^D) decreases. Since the trader's cost of procurement decreases with an increase in μ, the trader's profit increases even though the decline in procurement cost is passed on to both the platform and the consumers, i.e., both P_{tp}^D and P_{tc}^D decrease (Appendix Figure 8(a)). This is because the decline in the price at which the trader sells to the consumer or platform is much less than the decline in the price at which the trader procures from the farmer. The platform does not offer more price to attract farmers as μ increases and rather decreases the price paid to farmers Thus, with an increase in μ, the platform can now procure at a low price from both traders and farmers while releasing less quantity in the market at a higher price P_{pc}^D, and thus, the profit of the platform increases with an increase in μ. The decrease in price at which the trader sells to consumers dominates the increase in price at which the platform sells to consumers ($\partial P^D_{tc}/\partial\mu > \partial P^D_{pc}/\partial\mu$) due to an increase in μ such that, on the whole, the consumer benefits in terms of greater consumer welfare. We have summarized the effect of farmer's cost μ of selling directly to the platform on profits, price, and quantity in Appendix Table 6.

It is observed that farmer welfare decreases with an increase in the farmer's direct selling cost μ, which is intuitive; however, the decrease in welfare is also because of less price received by the farmer from both traders and platform when μ increases. While the welfare of both kinds of farmer selling to traders (in region "x") and selling to the platform (in region $((2\pi r/n) - 2x)$) decreases with μ, the farmer selling to a trader has a less decline in welfare as compared to the farmer selling to the platform. It could be because, for a farmer selling to a platform, there is both a decrease in price and an increase in direct selling cost to the platform(μ), whereas, for a farmer selling to a trader, there is only a price decline. Also, note that while the welfare of one farmer selling to a platform decreases at a faster rate than the welfare of one farmer selling to a trader, however, the welfare of all farmers selling to traders decreases at a faster rate than the welfare of all farmers selling to the platform. This is because of two factors: 1) the increase in the number of farmers selling to traders because of the increase in direct selling cost ($\partial x/\partial\mu > 0$) which decreases P^D_{ft}, and 2) the decrease in P^D_{ft} is greater than the decrease in P_{fp} as μ increases. Since the total welfare of all farmers selling to the trader is the welfare of the farmers presently selling to the trader at a lesser price than before, plus the welfare of the new farmers who have shifted from selling to the platform to selling to the trader, thus, the welfare of all farmers selling to traders decreases at a faster rate ($\partial w^D_{ft}/\partial\mu > \partial w^D_{fp}/\partial\mu$).

It is to be noted that the platform can decrease the price (P^D_{fp}) with an increase in μ, possibly due to two reasons. Firstly, if the platform pays a higher price to the farmers (P^D_{fp}), then it will also increase the price paid by the traders to the farmers, which in turn will increase the price at which trader sells to the platform. Thus, to keep the cost of procurement from the trader low, the platform does not increase P^D_{fp} as μ increases. Secondly, if the platform increases the price paid to farmers (P^D_{fp}), it will increase the quantity procured from the farmers (Q^D_{fp}) and decrease the quantity procured from the traders (Q^D_{ft}). Thus, traders will release more quantity in the market (Q^D_{tc}), decreasing the equilibrium market price. The platform's profit might decrease as both its cost of procurement from farmers increases along with less price received from the consumers (P^D_{pc}). It is interesting to note that even though the price paid by the platform to the farmer is always greater than the price paid by the platform to the trader($P^D_{tp} > P^D_{fp}$), still platform does not increase P^D_{fp} as μ increases. Additionally, with an increase in the direct selling cost of farmers to the platform (μ), the price received by farmers from traders (P_{ft}^D) also decreases (Appendix Figure 8(a)). It is due to an increase in the number of farmers selling to traders (Q_{ft}^D) as the cost of selling to the platform (μ) increases.

4.2.1 Impact of market competition in Dual Sourcing model

It is also observed that in the dual sourcing model, with an increase in θ, the quantity bought by consumers from traders increases, and that from the platform decreases (Appendix Table 5). It could be because even if there is a decline in the market price of both traders and the platform, consumers always pay a higher price to the platform than to traders. Thus, as soon as market channel substitutability increases, some consumers shift from the platform to buying from traders at a lower price. Since market demand for the platform decreases, it procures less quantity from the farmers.

When the quantity procured by the platform declines, there is an increase in the number of farmers selling to traders, and thus, traders can procure at a lower price. It is interesting to note that with an increase in θ, traders want to release more quantity in the consumer market and less quantity to the platform. However, we see that both quantities sold to the platform and consumer have increased. It is because once the quantity that the trader has bought from the farmer is fixed, then less proportion is sold to the platform and more to the consumer. However, since the quantity procured from farmers increases with an increase in θ, overall, we see an increase in the quantities sold to consumers and the platform in the dual sourcing model.

5 Who benefits from Dual Sourcing?

In the dual-sourcing model, where the platform is allowed to procure directly from farmers, the selling choice for farmers increases, and this may be beneficial for farmers because of their higher bargaining power for greater prices. However, if prices received by farmers in dual sourcing become less than the benchmark model, then their welfare will decrease. Also, in the dual sourcing model, the traders face greater competition (in procurement) than the benchmark model, and this may adversely affect their cost of procurement and, subsequently, reduce their profits. However, their profits can also increase if traders' procurement cost decreases or prices received from the platform or consumer become greater than the benchmark. Also, direct procurement might reduce consumer welfare because of higher prices passed on by traders and platforms due to high procurement costs. However, it could also be the case that due to the dual-sourcing model, the platform now sells to consumers at a price less than the benchmark scenario, and consumers become better off. Also, since the platform can now procure directly from the farmers, its profits might increase because of an increase in bargaining power, and it might be able to procure at a cheaper rate from traders. Thus, the question that becomes important to address is who benefits from dual sourcing when the platform is allowed direct procurement. Insights from such comparisons of benchmark and dual-sourcing models become particularly important in the context of government policies that prohibit or allow direct procurement from farmers. To answer these questions, we first try to understand whether the price received by the trader, platform, and farmer increases or decreases in dual sourcing as compared to the benchmark, as discussed in the lemma below.

Lemma 5 *a)* $P_{ft}^D < P_{ft}^B$ *when* $\mu > \mu^e$*; otherwise* $P_{ft}^D > P_{ft}^B$ *where* $\mu^e = \mu \in [\underline{\mu}, \overline{\mu} : P_{ft}^D = P_{ft}^B]$*;*

$$\mu^e = \Big[-2n^4(\theta-1)^2 + 2n^3(\theta-1)(3t-\theta+1) + n^2\left(16t^2 - 3t(\theta-1) + 2(\theta-1)^2\right)$$
$$+ 2n\left(8t^2 - 2t(\theta-1) + (\theta-1)^2\right) + t(4t-\theta+1)\Big]$$
$$\div \Big[2n\left(4n^3(\theta-1) + n^2(-4t+9\theta-9) + n(-4t+6\theta-6) - t + \theta - 1\right)\Big]$$

b) $P_{tp}^D > P_{tp}^B$*; c)* $P_{tc}^D > P_{tc}^B$*; d)* $P_{pc}^D < P_{pc}^B$*.*

The platform can now quote lower prices to traders in the dual-sourcing scenario, as it also has a choice of procuring from farmers. However, we observe that the platform still quotes a higher price to the trader in dual-sourcing as compared to the benchmark model. This is because, in the benchmark model, all farmers are selling to the trader, and if the trader releases all the quantity in his own market, then there will be a drastic reduction in prices received by the trader from the consumer. Thus, the trader will always sell some quantity to the platform in the benchmark, even if the price quoted by the platform is very low. Since the platform anticipates this, it quotes a lower price to the traders in the benchmark model. However, in dual sourcing, since the trader procures less quantity from farmers than benchmark ($Q_{ft}^D < Q_{ft}^B$), there is no fear of oversupply to consumers by the trader and thus no risk of fall in prices received by the trader from consumers. Thus, the platform needs to quote a higher price to the trader to incentivize him to sell some of the quantity to the platform. Also, since the trader procures less quantity from farmers in dual sourcing, it sells less quantity to the platform in dual sourcing ($Q_{tp}^D < Q_{tp}^B$).

In dual sourcing, since less quantity is procured by the trader from the farmers than benchmark ($Q_{ft}^{D} < Q_{ft}^{B}$), less quantity is released by the trader in the final market to consumers ($Q_{tc}^{D} < Q_{tc}^{B}$). As the quantity released in the market increases, the price will decrease, and hence, $P_{tc}^{D} > P_{tc}^{B}$. It is also observed that in the benchmark scenario, the platform sells less quantity to the consumer than the dual sourcing model ($Q_{pc}^{B} < Q_{pc}^{D}$). This is because the platform can buy from both trader and farmer in the dual sourcing model, thus purchasing greater quantities than the benchmark model, where the platform can buy only from the farmer. Since in dual sourcing, more quantity is sold by the platform in the market as compared to the benchmark; the platform sells to consumers at a lesser price than the benchmark, i.e., $P_{pc}^{D} < P_{pc}^{B}$.

Interestingly, even though a greater quantity is bought by traders from farmers in the benchmark as compared to the dual-sourcing model, we still observe that for a very high $\mu > \mu^{e}$, the price paid by the trader to the farmer is less in dual sourcing as compared to benchmark model ($P_{ft}^{D} < P_{ft}^{B}$). This is contrary to intuition, which would suggest that since farmers can now sell to either trader or platform in dual sourcing, their bargaining power should increase. While P_{ft}^{D} is greater than P_{ft}^{B}, however, after μ becomes greater than μ^{e}, P_{ft}^{D} becomes less than P_{ft}^{B}. Mathematically, one can reason that since P_{ft}^{D} decreases in μ, and P_{ft}^{B} is independent of μ, thus, for a very high μ, the price at which the farmer sells to the trader in dual sourcing becomes so low that they are less than the benchmark price.

Additionally, note that in both dual sourcing and benchmark, the price paid by the consumers to the platform is always greater than the price paid to the trader, i.e., ($P_{pc} > P_{tc}$). This is because while in the benchmark, the traders procure from farmers, the platform procures only from traders. Adding an intermediary increases the cost of procurement for the platform, and subsequently, the price at which it sells to consumers is also high. It is noteworthy that even in dual sourcing, where the platform can procure cheaply from the farmers, it still sells to consumers at a higher price than the trader. It is because the platform's cost of procurement from the trader is greater in dual sourcing compared to the benchmark following Lemma 5. Thus, while some part of the cost decreases because of sourcing at a lesser price from farmers, some part of the cost increases because of sourcing at a higher price from traders such that the overall cost of procurement remains high and is passed on to consumers in terms of higher prices.

Till now, we have observed that trader gets higher prices in dual sourcing than the benchmark from both platform and consumer. Does that imply that the trader is always better off due to the platform's dual sourcing? Also, we observe that the platform procures at a higher price in dual sourcing than the benchmark and sells to consumers at a lower price in the former than in

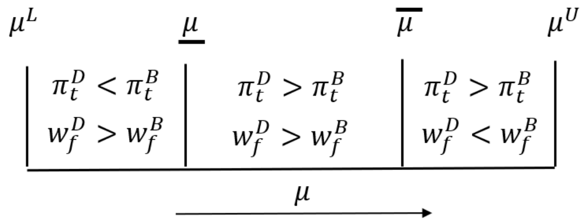


Figure 3: Region where both platform and trader are better off than benchmark

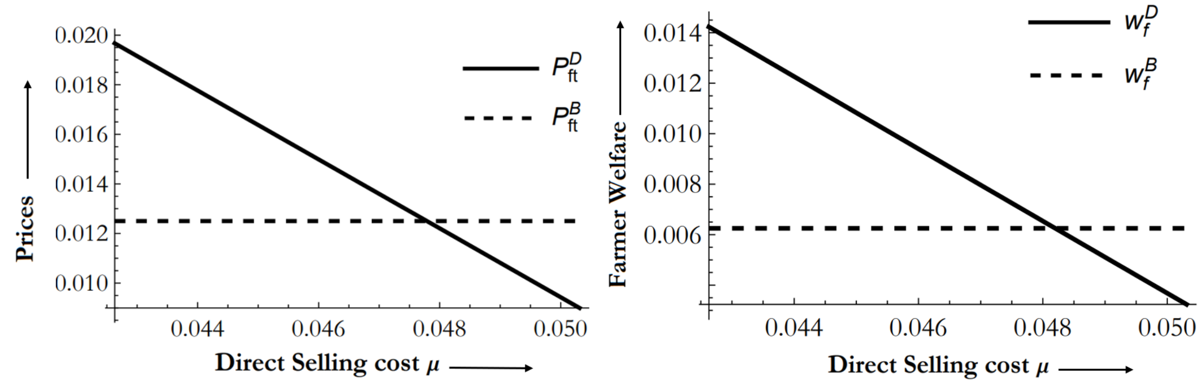
the latter. Does that mean the platform always gets worse off? Also, in dual sourcing, farmers may receive higher or lower prices than the benchmark, depending on the direct selling costs. Based on a comparison of prices received in the two models, what conclusion can we draw for farmer's welfare? To answer these questions, we compare stakeholders' profits when the platform procures exclusively from traders (single sourcing) vs. when it opts for dual sourcing from trader and farmer, as discussed in the proposition below.

Proposition 3 *For a small market size (a=1), policies allowing direct procurement make the consumer and platform worse off. However, it may benefit or hurt farmers and traders depending on the farmer's direct selling cost, as summarized in figure 3.*

Farmer welfare is greater than the benchmark for $\mu < \overline{\mu}$, which is intuitive because in the dual-sourcing model, there is an increase in farmer's selling choice due to which he can bargain better prices. Also, following proposition 2 as μ increases farmer welfare will decrease. However, it is intriguing that despite having greater options to sell, farmer welfare decreases with μ to such an extent that it becomes less than the benchmark (for $\mu > \overline{\mu}$).

To explain why the farmers can be worse off when he has more options to sell as compared to selling only to the trader, we focus on two factors. One factor has the tendency to increase prices and the other to decrease prices that farmers receive from traders. When the platform is allowed to procure directly from the farmers, it increases competition in procurement. The trader will have to increase the prices at which it procures from the farmers to retain market share (in procurement). Thus, the first factor is a tendency for an increase in price received by farmers due to greater competition in the market for procurement. When farmers bear a low cost of selling directly to the platform (low μ), it increases the market competition in procurement, and this factor dominates such that we observe $P_{ft}^D > P_{ft}^B$ and consequently $w_f^D > w_f^B$.

This aspect of greater competition increasing prices is fairly intuitive. What is not intuitive is the tendency for greater competition to decrease prices, which is best explained by the second factor. We first need to understand that in the benchmark setting, the trader was paying the



((a)) Comparison of Prices

((b)) Comparison of farmer welfare

Figure 4: Comparison of Farmer Welfare and price received by farmer from the trader in dual sourcing vs. benchmark model

price to the farmers, taking into account their cost of transportation (tx). All farmers received the same price P^B_{ft} irrespective of distance x away from the trader. The trader pays farmers in arc $(2 * \pi * r)/2n$ (see fig1), keeping in mind the compensation of the farmer at a maximum distance away from the trader. Now, when the platform is allowed to procure from the farmers, the farmers in the arc $((2 * \pi * r)/2n) - 2 * x$ shift to selling to the platform.

In dual sourcing, the farthest farmer is still nearer to the trader as compared to the distance of the farthest farmer in the benchmark scenario. Thus, the price that the trader now pays to all farmers decreases (keeping in mind the farthest farmer) such that it is less than the benchmark. Thus, the second factor is the tendency for P^B_{ft} to decrease as competition increases due to a fall in tx (farthest farmer effect). For a high direct selling cost μ, the second factor (farthest farmer effect) dominated the first factor (competition effect), and hence, for a high μ, we observe that $P^D_{ft} < P^B_{ft}$.

It can be seen from figure 4(b) below that farmer welfare in dual sourcing is decreasing with μ such that it becomes less than the farmer welfare in the benchmark. We can see from the graph that of the total range of μ in which the model is valid ($\mu^L = 0.04263$,$\mu^U = 0.05031$), there exists a small region where the farmer becomes worse off due to dual sourcing, i.e., $w^D_f < w^B_f$ for μ between 0.04820 and 0.05031. It can also be seen that the price received by the farmer from the trader becomes less than the benchmark for μ between 0.04779 and 0.05031 (Figure 4(a)).

While farmers can get worse off in dual sourcing as compared to the benchmark, we further try to understand whether both sets of farmers selling to the trader (in the region 'x') and selling to the platform (region '$((2\pi r)/n) - 2x$') can get worse off. We first take a farmer in region

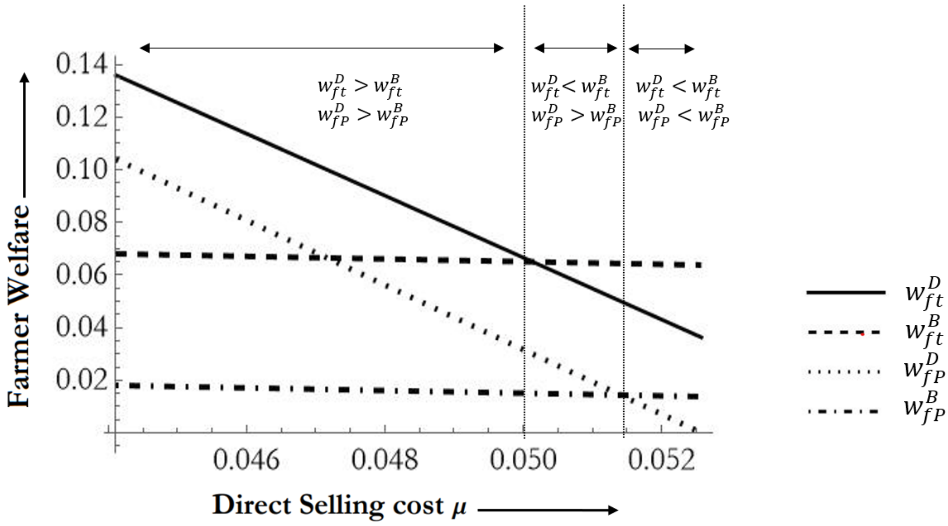


Figure 5: Farmer welfare in dual sourcing as compared to benchmark

'x' who is selling to the trader and compare his welfare in the dual sourcing model (w_{ft}^D) with the benchmark (w_{ft}^B). Secondly, we take a farmer in the region '$((2\pi r)/n) - 2x$' and compare his welfare in benchmark (w_{fp}^B) with dual sourcing (w_{fp}^D) for different values of μ. To clarify, since in the benchmark model the farmer will only be selling to the trader, so w_{fp}^B is not the welfare of the farmer selling to the platform in the benchmark, but rather it is the welfare of that farmer who is far away from traders but still selling to traders in the benchmark. However, after duel sourcing by the platform, this farmer starts selling to the platform. Thus, we compare : $w_{ft}^D = \left(2n\int_0^x (P_{ft}^D) - tx1)\, dx1\right)/2x$ with $w_{ft}^B = \left(2n\int_0^x (P_{ft}^B - tx_b)\, dx_b\right)/((2\pi r/n) - 2x)$

and $w_{fp}^D = (nQ_{fp}^D(P_{fp}^D - \mu))/2x$ with $w_{fp}^B = \left(2n\int_x^{\frac{\pi r}{n}} (P_{ft}^B - tx_b)\, dx_b\right)/((2\pi r/n) - 2x)$.

The comparison of w_{ft}^D with w_{ft}^B and w_{fp}^B with w_{fp}^D is done for different values of μ (see Figure 5 below). It is interesting to note that there will exist a region (between two lines in Figure 5) where an increase in direct selling cost to the platform will make farmers selling to the trader worse off, while farmers selling to the platform might still be better off due to dual sourcing. It is interesting, as one would expect, that since the direct selling cost is born by farmers who are selling to the platform, it is the welfare of farmers selling to a platform that should first become less than the benchmark. We also observe that for a very high μ, both kinds of farmers get worse due to dual sourcing by the platform.

While on the one hand, farmers can get worse off due to dual sourcing, proposition 3 states that traders can also get better off due to dual sourcing even though their competition for procurement increases. One explanation is that an increase in μ decreases the price paid by the trader to a farmer (as discussed above). Since the trader's cost of procurement decreases, traders become better off due to dual sourcing. However, for $\mu > \underline{\mu}$, the profit of the trader becomes greater than the benchmark ($\pi_t^D > \pi_t^B$) even though its cost of procurement between region $\underline{\mu}$ and μ^e (where $\underline{\mu} < \mu^e < \overline{\mu}$) is still higher than the benchmark. It is because, following lemma 5, the trader gets a higher price from the platform in dual sourcing as compared to the benchmark ($P_{tp}^D > P_{tp}^B$), and following lemma 5, the trader gets a higher price from the consumer in dual sourcing as compared to the benchmark ($P_{tc}^D > P_{tc}^B$). Thus, between region $\underline{\mu}$ and μ^e, the high cost of procurement is compensated by the higher price that the trader receives from both the platform and consumer, thereby making the trader better off in dual sourcing as compared to the benchmark,

The consumer is always worse off because, in dual sourcing, the consumer has to pay a higher price to the trader as compared to the benchmark model. Even though the price paid to the platform is less than the benchmark, the decrease in the price paid to the platform is not enough to compensate for the increase in the price paid to the trader. The platform is always worse off in dual sourcing than the benchmark model, even though it now has an option of procuring from farmers, and it is no longer dependent only on traders for procurement. This is because firstly, following lemma 4 platform quotes a higher price to traders in dual sourcing than the benchmark model. Also, following lemma 4, the platform receives a lower price from consumers in dual sourcing compared to the benchmark model. Thus, even though the platform procures from farmers at a lower price than that from traders, however because of dual sourcing, the platform's cost of procurement from traders also increases. High costs along with less remuneration from the market in dual sourcing make the platform worse off compared to the benchmark.[17]

5.1 Extension for large market size

In this section, we demonstrate that our major insights are robust even when the market size is increased. Earlier in our model, we took the inverse demand curve of the form $P = a - bQ$ with unitary elasticity ($\eta = -bP/Q$) and with $a = b = 1$. Now we see how it affects our results if we relax the assumption of a=1 and increase 'a'. While 'a' represents the y-intercept of the inverse demand curve, an increase in 'a' leads to a shift in the demand curve towards the right. This

[17]It is to be clarified that in the dual sourcing model, the platform is allowed to procure from farmers, maybe due to exogenous shock like government policy change. However, in dual sourcing, the platform may choose not to procure from the farmers even if it now has an option to do so. After solving the model for sub-game perfect Nash equilibrium, we find that the platform's Nash lies in procuring from farmers when it is allowed to do so as compared to not procuring from them. This shows that choosing not to procure from farmers when the platform is allowed to do so may have decreased the platform's profits even more than procuring from them.

shift could be caused by factors like increased market size due to an increase in population, etc. Thus, now the inverse demand curve for the benchmark model is : $P^B_{pc} := a - n(Q^B_{tp}) - \theta n Q^B_{tc}$ and inverse demand curve for the dual sourcing model is: $P^D_{pc} := a - n(Q^D_{tp} + Q^D_{fp}) - \theta(nQ^D_{tc})$ where $(a > 1)$. According to proposition 3, the platform is always worse off due to policies allowing direct procurement from the farmers (given the small market size). However, it could be the case that if the market size is increased, then the platform might be able to sell at a higher price to consumers due to an overall increase in demand. Suppose this increase in price received by the platform due to higher demand is more than the increase in its cost of procurement. In that case, increasing the market size can make the platform better off due to dual sourcing as compared to the benchmark, which leads to proposition 4 below.

Proposition 4 *In a consumer market with a large size, policies allowing direct procurement can make the platform better off. Also, there can be a win-win scenario for farmers, traders, and the platform.*

A large market size leads to greater demand for the platform, which is reflected in the higher prices paid by the consumer to the platform, and the platform becomes better off. However, $(\pi^D_p > \pi^B_p)$ if $\theta > [1 + n^2 + n(2 - 4t) - 2t]/(1 + n)^2$, Otherwise, $\pi^D_p < \pi^B_p$. Thus, even for a large market, the platform can benefit from dual sourcing only if consumers can easily substitute between buying from the platform and buying from traders. Figure 6 shows that range of θ (shaded in grey) where all traders, farmers, and the platform can get better off than the benchmark. The market competition θ is on the X axis, and the direct selling cost of farmers μ is on the Y axis. We plot different thresholds of μ $(\mu^L, \underline{\mu}, \overline{\mu})$ for different values of θ, by taking a=1.5, n=2,t=1.4. For platform profit to be greater than the benchmark, θ has to be greater than $[1 + n^2 + n(2 - 4t) - 2t]/(1 + n)^2]$, which is satisfied in the positive X axis. The region between $\underline{\mu}$ and $\overline{\mu}$ is where both traders and farmers are better off (as also seen in figure 3). Since the platform is getting better off for a positive range of θ, the region between $\underline{\mu}$ and $\overline{\mu}$ in the first quadrant such that $\overline{\mu} > \underline{\mu} > \mu^L$ becomes the region where all platform, traders, and farmers can get better off.

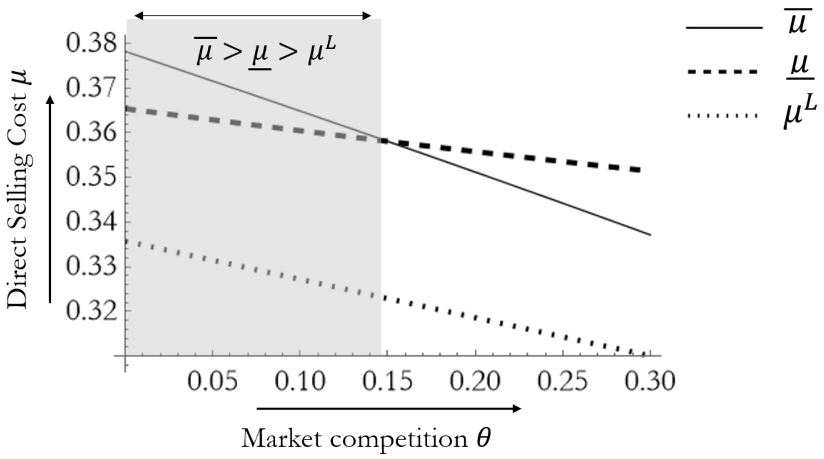


Figure 6: The region where the platform, traders, and farmers are better off due to dual sourcing as compared to benchmark model

6 Conclusion: Implications, Limitations and Way Forward

The primary goal of this chapter is to investigate the impacts of regulations enabling direct procurement by digital platforms from farmers on key stakeholders—farmers, traders, consumers, and the platform itself. Our study has important policy implications in the context of APMC reforms, which allowed farmers to sell agricultural produce outside regulated wholesale markets in India. It is because it disburses the apprehension that adding new marketing channels will either completely substitute traders in traditional channels or will always make them worse off. Through our theoretical model based on certain underlying assumptions, we do not find evidence that allowing direct procurement is always good or bad. Rather, we find that such policies can make farmers and traders worse off or better off depending on certain parameters, such as the farmer's cost of selling directly to the platform. Since farmers benefit from direct procurement or the platform's dual sourcing strategies only if the farmer's cost of selling directly to platform μ is low, thus, government policies should be designed to decrease μ.

For instance, policies like no mandi fee for transactions in the alternate channel (to digital platforms) will reduce farmers' direct selling cost μ. While the Indian Model APMC Act (2003) had an obligation to pay the mandi fee for transactions outside the mandi or designated market area, the FPTC Act (farm laws,2020) did away with the obligation of payment of the mandi fee for outside mandi transactions. While the center rolled back the farm laws of 2020, the government should strive for policies that reduce the cost of selling to the direct buyer. Moreover, the government should strive to improve the financial infrastructure to decrease small and medium farmers' reliance on traders for working capital at the mandis, which will decrease farmer's opportunity cost of selling to the platform. Our results also show that allowing direct procurement always hurts the consumers because of the increase in price they now have to pay to traders. Thus, while implementing policies directly affecting farmers in the upstream market, the government should take into consideration unintended negative consequences for end consumers in the downstream market.

The study's managerial insights highlight the efficacy of dual-sourcing strategies for platforms involved in direct procurement from farmers alongside traditional traders, especially in a market having large size. To benefit from dual sourcing, platforms should procure directly from farmers in those markets where consumers can easily substitute between buying from traders and platforms i.e., when traders and platforms serve more distinct consumer groups. While alluring farmers with excessively high prices can escalate procurement costs from traders, offering financial services like working capital can be a more strategic incentive. This not only reduces the opportunity cost for farmers (in terms of loans forgone), enhancing their welfare in both traditional and digital channels, but also diminishes the platform's reliance on traders. Consequently, the platform can secure larger quantities from farmers at a more economical rate compared to procurement from traders.

The analysis has some limitations. The assumptions about how farmers choose between channels are straightforward. While this simplicity makes the models flexible and robust, it is essential to recognize that the marketing channel choice of farmers is influenced by more complex factors, such as other non-price factors that require separate studies. For instance, factors such as farmers' access to market information regarding prices in different channels and farm and farmer characteristics like farm size can affect marketing channel choice. Farmers often cultivate diverse and unstandardized products, with some opting for collaborative selling through cooperatives. The dynamics within traditional markets ('mandis') may vary, involving potential collusion among traders. Our model does not include any factors that might be specific to exclusively MSP-based (Minimum Support Price) agri-produce. It is designed to apply equally to all commodities, regardless of whether they are covered by MSP. It is crucial to recognize that our analysis simplifies market structures to offer insights, and actual market scenarios are more intricate. Hence, the findings should be understood within the context of the inherent complexity of real-world markets

This model can serve as a base model that can be extended to the case of multiple platforms, i.e., having a case of buyer competition with some traders and many platforms. Potential extensions could investigate scenarios involving trader collusion with platforms or among traders.

Additionally, the model can explore situations of uncertainty in yield from specific regions within the market circle. The current model assumes uniform quality traded in both channels, providing a foundation for future extensions that incorporate variables capturing variations in the quality of agricultural produce—examining the nuances of allowing direct procurement. Subsequent research could explore whether this leads to a division where farmers sell high-quality produce to digital platforms and low-quality produce to traditional traders. Understanding the implications for profits in such scenarios would be a valuable avenue for further investigation. The model's scope can be broadened to explore variations in outcomes based on the nature of agricultural commodities, distinguishing between perishable and non-perishable agricultural produce. To capture exchange relationships such that one player has greater bargaining power over the other, one can further extend the model using a Nash-bargaining game. While our study is rooted in theoretical modeling with simplifying assumptions, empirical research can validate and enhance our understanding of the mechanisms and outcomes discussed. Future investigations may delve into empirical testing to strengthen the validity of the study's claims.

The findings from this study cater to three key audiences. Researchers can leverage them as a foundational reference for subsequent analysis. Managers gain valuable insights for evaluating the effectiveness of diverse strategies in markets featuring multiple channel types. Social planners find utility in understanding the implications of dual sourcing and direct procurement by platforms from farmers on the farmer and consumer welfare. Moreover, these results contribute to informed decision-making in shaping regulatory legislation.

Appendix A: Proofs For Propositions

A Benchmark setting

The profit function of the trader and the platform is given by $\pi_t^B = (P_{tp}^B - P_{ft}^B)(Q_{tp}^B) + (P_{tc}^B - P_{ft}^B)(Q_{tc}^B)$ and $\pi_p^B = n(P_{pc}^B - P_{tp}^B)(Q_{tp}^B)$, respectively. We solve the game using backward induction to arrive at the SPNE. First, we find the optimal Q_{tp}^B by the first order condition which is $\frac{-nP_{tp}^B+\theta-1}{n(n+1)(\theta-1)}$. Substituting the optimal Q_{tp}^B in the platform's profit function, we find that the platform profit is concave in P_{tp}^B. From the first order condition, we find that $P_{tp}^B = \frac{(1-\theta)\left(n^2-2n-1\right)}{2n(2n+1)}$.

Proof for Lemma 1.

$\partial w_f^B/\partial t = \frac{1}{4n} > 0$ and $\partial \pi_t^B/\partial t = -\frac{1}{2n^2} < 0$.

Proof for Lemma 2.

$\partial \pi_p^B/\partial\theta = -\frac{(n+1)^2}{4n(2n+1)} < 0$, $\partial \pi_t^B/\partial\theta = -\frac{(n+1)\left(4n^2-n-1\right)}{4n^2(2n+1)^2}$. Since, $n > 1$, we conclude that $\partial \pi_t^B/\partial\theta < 0$. Finally, we find that $\partial C^B/\partial\theta = \frac{(n+1)(2n-1)(3n+1)}{4n^2(2n+1)^2} > 0$ for $n > 1$.

B Dual Sourcing Model

In this model, we consider the setting where the platform can purchase directly from the farmers in addition to purchasing from the traders. The platform's and the trader's profit functions are given by π_p^D and π_t^D, respectively. As the trader's profit function is concave in Q_{tc}^D, we find optimal Q_{tc}^D from the first order condition. Solving $\frac{\partial \Pi_t^D}{\partial Q_{tc}^D} = 0$ for Q_{tc}^D, reveals that the optimal $Q_{tc}^D = -\left[n^3(-2\theta+4\mu+2)+2n^2(-2\theta+3\mu+7t+2)+n(-2\theta+2\mu+9t+2)+t\right] \div \left[2n\left(2(\theta-1)n^3-4n^2(-\theta+3t+1)-2n(-\theta+6t+1)-3t\right)\right]$.

Substituting the optimal Q_{tc}^D in the platform's profit function, we find that the platform's profit function is concave in P_{tp}^D. Thereby, from the first order condition, we find that the optimal $P_{tp}^D = \left[(1-\theta)\left(2n^4(\theta+2\mu-1)+2n^3(\theta+5\mu-5t-1)+n^2(-2\theta+8\mu-t+2)+2n(-\theta+\mu+2t+1)+t\right)\right] \div \left[2n\left(2(\theta-1)n^3-4n^2(-\theta+3t+1)-2n(-\theta+6t+1)-3t\right)\right]$.

Substituting the optimal Q_{tc}^D and P_{tp}^D in the platform's and trader's profit functions, from the first order condition, we find that prices offered by the platform and trader to farmers are P_{fp}^D and P_{ft}^D, respectively, where

$$
\begin{aligned}
P_{fp}^D = \Bigg[& -2(\theta-1)n^4(\theta+2\mu-1) - 2n^3(\mu(5\theta+4t-5)-(\theta-1)(-\theta+4t+1)) \\
& + n^2\left(2(\theta-1)^2+8t^2-8\mu(\theta+t-1)-\theta t+t\right) + 2n\left((\theta-1)^2+4t^2-\mu(\theta+t-1)-2(\theta-1)t\right) \\
& + t(-\theta+2t+1)\Bigg] \div \Bigg[(2n\left(2(\theta-1)n^3-4n^2(-\theta+3t+1)-2n(-\theta+6t+1)-3t\right))\Bigg]
\end{aligned}
$$

and

$$
\begin{aligned}
P_{ft}^D = \Bigg[& -2(\theta-1)n^4(\theta+4\mu-1) + 2n^3(\mu(-9\theta+4t+9)+(\theta-1)(-\theta+4t+1)) \\
& + n^2\left(2(\theta-1)^2+4t^2+4\mu(-3\theta+2t+3)+(\theta-1)t\right) + 2n\left((\theta-1)^2+2t^2+\mu(-\theta+t+1)-\theta t+t\right) \\
& + t(-\theta+t+1)\Bigg] \div \Bigg[2n\left(2(\theta-1)n^3-4n^2(-\theta+3t+1)-2n(-\theta+6t+1)-3t\right)\Bigg]
\end{aligned}
$$

Proof for Lemma 3.

We solve

$$
\begin{aligned}
Q_{tp} &= \Big[-2n^3(\theta+6\mu-1) + n^2(6t-10\mu) + n(2\theta-2\mu+t-2) - t \Big] \\
&\quad \div \Big[2n\left(2(\theta-1)n^3 - 4n^2(-\theta+3t+1) - 2n(-\theta+6t+1) - 3t\right) \Big] \\
&= 0
\end{aligned}
$$

for μ to reveal that $Q_{tp}^D > 0$ only if $\mu > \frac{-2n^3(\theta-1)+6n^2t+n(t+2\theta-2)-t}{2n(6n^2+5n+1)} = \mu^L$.

Proof for Proposition 1. When $\mu < \mu^L$, then $Q_{tp} = 0$. Solving the game using backward induction, given that $P_{fp} > \mu$ and $P_{ft} > x * t$, we find that $\frac{\partial^2 \Pi_t}{\partial P_{ft}^2} < 0$, hence Π_t is concave in P_{ft}. Similarly, we find that $\frac{\partial^2 \Pi_p}{\partial P_{fp}^2} < 0$, hence Π_p is concave in P_{fp}. On Solving through first order condition, we find that optimal P_{ft} and P_{fp} are:

$P_{fp} = \frac{2\mu n(4n(\theta-1)-t)+8n^2 P_{ft}(\theta-1)-2nt(P_{ft}+\theta-1)+t^2}{4n(2n(\theta-1)-t)} = P_{fp}^o$ and

$P_{ft} = \frac{\mu(t-4n(\theta-1))+4nP_{fp}(\theta-1)+t(-P_{fp}+\theta-1)}{4n(\theta-1)-2t} = P_{ft}^o$.

However, $P_{fp} > \mu$ (else farmers will never sell to the platform) and $P_{ft} > xt$ (else, farmers will never sell to the trader). Hence, optimal $P_{ft} = \max\{P_{ft}, xt\}$ and optimal $P_{fp} = \max\{P_{fp}, \mu\}$. Solving with these constraints we find that optimal $P_{ft} = \mu$. Substituting optimal P_{fs} in the traders optimal buying price, we find that the traders optimal buying price is $P_{ft} = \frac{t(\theta-a)}{4n(\theta-1)-2t}$. When $P_{fs} = \mu$, we find that $\frac{\partial \Pi_t}{\partial P_{ft}} = 0$ at $P_{ft} = \frac{t(\theta-a)}{4n(\theta-1)-2t}$. Further, we find that when $P_{ft} = \frac{t(\theta-a)}{4n(\theta-1)-2t}$, $\frac{\partial \Pi_p}{\partial P_{fs}} < 0$ at $P_{ft} = \mu$. Hence, we conclude that the found value is the Nash Equilibrium. We find that the equilibrium value Q_{ft}^D when $\mu < \mu^L$ and $P_{ft} = \mu$ is $\frac{1-\theta}{2n(1-\theta)+t}$ which is >0 for all $t > 0$ and $1 > \theta > 0$. Also, when $\mu > \mu^L$ in dual sourcing when $Q_{tp} > 0$ and $Q_{fp} > 0$, we find that the equilibrium $Q_{ft} > 0$ for all $t > 0$ and $1 > \theta > 0$. Thus, farmers will continue to sell to traders even in the dual-sourcing scenario.

Proof for Lemma 4.

We find that $P_{tp}^D - P_{fp}^D =$

$\Big[2\mu n\left(2n^3(1-\theta)+4n^2(t+(1-\theta))+n(4t+2(1-\theta))+t\right)+t\left(2n(1-\theta)(n^2-1)+4n^2t+4nt+t\right)\Big] \div \Big[2n\left(2n^3(1-\theta)+4n^2(3t+1-\theta)+2n(6t+1-\theta)+3t\right)\Big]$. Since, $n > 3$ and $0 < \theta < 1$, we conclude that $P_{tp}^D - P_{fp}^D =$

$\Big[2\mu n\left(2n^3(1-\theta)+4n^2(t+(1-\theta))+n(4t+2(1-\theta))+t\right)+t\left(2n(1-\theta)(n^2-1)+4n^2t+4nt+t\right)\Big] \div \Big[2n\left(2n^3(1-\theta)+4n^2(3t+1-\theta)+2n(6t+1-\theta)+3t\right)\Big] > 0$

Proof for Proposition 2.

$$\begin{aligned}\partial\pi_t^D/\partial\mu = \Big[&\big(4n^3(1-\theta)+n^2(8t+9(1-\theta))+n(8t+6(1-\theta))+2t \\ &+1-\theta\big)\big(8\mu n^3+n^2(8\mu+4t+2(1-\theta))+2n(\mu+2t+1-\theta)+t\big)\Big] \\ &\div\Big[n\big(2n^3(1-\theta)+4n^2(3t+1-\theta)+2n(6t+1-\theta)+3t\big)^2\Big]>0\end{aligned}$$

$$\begin{aligned}\partial\pi_t^D/\partial\mu = \Big[&2(2n+1)\big(n^2(\theta-1)+2n(2t+\theta-1)+2t+\theta-1\big)\big(\mu(2n+1)^2n+n^3(\theta-1) \\ &+n^2(-4t+\theta-1)-4nt-t\big)\Big]\div\Big[\big(-2n^3(\theta-1)+4n^2(3t-\theta+1)+2n(6t-\theta+1)+3t\big)^2\Big]\end{aligned}$$

Solving for $\partial\pi_t^D/\partial\mu=0$ for μ, we find that $\partial\pi_t^D/\partial\mu>0$ when $\mu<\frac{n^3(-(\theta-1))+n^2(4t-\theta+1)+4nt+t}{n(2n+1)^2}=\mu_t$. However, we find that $\mu_t>\mu^U$. Hence, we conclude that when $\mu^L<\mu<\mu^U$, $\partial\pi_t^D/\partial\mu>0$.

Proof for Lemma 5. Solving $P_{ft}^D-P_{ft}^B=0$ for μ reveals that

$$\begin{aligned}P_{ft}^D-P_{ft}^B=\Big[&-2n^4(\theta-1)(4\mu+\theta-1)+2n^3(\mu(4t-9\theta+9)+(\theta-1)(3t-\theta+1)) \\ &+n^2\big(4\mu(2t-3\theta+3)+16t^2-3t(\theta-1)+2(\theta-1)^2\big) \\ &+2n\big(\mu(t-\theta+1)+8t^2-2t(\theta-1)+(\theta-1)^2\big)+t(4t-\theta+1)\Big] \\ &\div\Big[2n\big(2n^3(\theta-1)-4n^2(3t-\theta+1)-2n(6t-\theta+1)-3t\big)\Big] \\ =0,&\end{aligned}$$

when

$$\begin{aligned}\mu=\Big[&-2n^4(\theta-1)^2+2n^3(\theta-1)(3t-\theta+1)+n^2\big(16t^2-3t(\theta-1)+2(\theta-1)^2\big) \\ &+2n\big(8t^2-2t(\theta-1)+(\theta-1)^2\big)+t(4t-\theta+1)\Big] \\ &\div\Big[2n\big(4n^3(\theta-1)+n^2(-4t+9\theta-9)+n(-4t+6\theta-6)-t+\theta-1\big)\Big] \\ =\mu^e.&\end{aligned}$$

such that, $P_{ft}^D<P_{ft}^B$ when $\mu>\mu^e$. Otherwise $P_{ft}^D\geq P_{ft}^B$

Solving $P_{tp}^D-P_{tp}^B=0$ for μ reveals that

$$\begin{aligned}P_{tp}^D-P_{tp}^B=-&\Big[(n+1)^2(\theta-1)\big(\mu(2n+1)^2n+n^3(\theta-1)+n^2(-4t+\theta-1)-4nt-t\big)\Big] \\ &\div\Big[n(2n+1)\big(2n^3(\theta-1)-4n^2(3t-\theta+1)-2n(6t-\theta+1)-3t\big)\Big] \\ =0&\end{aligned}$$

when $\mu = \frac{n^3(-(\theta-1))+n^2(4t-\theta+1)+4nt+t}{n(2n+1)^2} = \mu_{tp}$ Such that $P_{tp}^D > P_{tp}^B$ when $\mu < \mu_{tp}$; otherwise, $P_{tp}^D \leq P_{tp}^B$. However, $\mu_{tp} > \mu^U$. Hence, we conclude that $P_{tp}^D > P_{tp}^B$ when $\mu^L < \mu < \mu^U$.

Solving $P_{tc}^D - P_{tc}^B = 0$ for μ reveals that

$$\begin{aligned} P_{tc}^D - P_{tc}^B = &-\Big[(n+1)(\theta-1)\left(\mu(2n+1)^2 n + n^3(\theta-1) + n^2(-4t+\theta-1) - 4nt - t\right)\Big] \\ &\div \Big[(2n+1)\left(2n^3(\theta-1) - 4n^2(3t-\theta+1) - 2n(6t-\theta+1) - 3t\right)\Big] \\ = &\ 0 \end{aligned}$$

when $\mu = \frac{n^3(-(\theta-1))+n^2(4t-\theta+1)+4nt+t}{n(2n+1)^2} = \mu_{tc}$, such that $P_{tc}^D > P_{tc}^B$ when $\mu < \mu_{tc}$; otherwise $P_{tc}^D \leq P_{tc}^B$. However, we find that $\mu_{tc} > \mu^U$. Hence, we conclude that $P_{tc}^D > P_{tc}^B$ when $\mu^L < \mu < \mu^U$.

Solving $P_{pc}^D - P_{pc}^B = 0$ for μ reveals that

$$\begin{aligned} P_{pc}^D - P_{pc}^B = &\left[(n+1)(\theta-1)\left(\mu(2n+1)^2 n + n^3(\theta-1) + n^2(-4t+\theta-1) - 4nt - t\right)\right] \\ &\div \left[(2n+1)\left(2n^3(\theta-1) - 4n^2(3t-\theta+1) - 2n(6t-\theta+1) - 3t\right)\right] \\ = &\ 0 \end{aligned}$$

when $\mu = \frac{n^3(-(\theta-1))+n^2(4t-\theta+1)+4nt+t}{n(2n+1)^2} = \mu_{pc}$, such that $P_{pc}^D < P_{pc}^B$ when $\mu < \mu^e$; otherwise, $P_{pc}^D \geq P_{pc}^B$. However, $\mu_{pc} > \mu^U$. Hence, we conclude that $P_{pc}^D < P_{pc}^B$, when $\mu^L < \mu < \mu^U$.

Proof for Proposition 3.

$$\begin{aligned} \Pi_p^D - \Pi_p^B = &\Big[8n^9(\theta-1)\left((\theta-1)^2 - 16\mu^2\right) \\ &+ 2n^8\left(16\mu^2(8t-17\theta+17) - 32\mu(\theta-1)(2t-\theta+1) - 5(\theta-1)^2(8t-3\theta+3)\right) \\ &+ 4n^7\left(48\mu^2(4t-5\theta+5) + 4\mu\left(16t^2 - 42t(\theta-1) + 17(\theta-1)^2\right)\right. \\ &\left.+ (\theta-1)\left(16t^2 - 38t(\theta-1) + 7(\theta-1)^2\right)\right) + 4n^6\left(12\mu^2(20t-19\theta+19)\right. \\ &\left.+ 4\mu\left(48t^2 - 84t(\theta-1) + 29(\theta-1)^2\right) + 160t^3 - 116t^2(\theta-1) + 31t(\theta-1)^2 - 8(\theta-1)^3\right) \\ &+ 2n^5\left(4\mu^2(80t-63\theta+63) + \mu\left(480t^2 - 680t(\theta-1) + 202(\theta-1)^2\right) + 960t^3\right. \\ &\left.- 768t^2(\theta-1) + 279t(\theta-1)^2 - 44(\theta-1)^3\right) + 2n^4\left(3\mu^2(40t-27\theta+27) + 320\mu t^2\right. \\ &\left.- 380\mu t(\theta-1) + 94\mu(\theta-1)^2 + 1200t^3 - 916t^2(\theta-1) + 299t(\theta-1)^2 - 37(\theta-1)^3\right) \\ &+ 2n^3\left(2\mu^2(12t-7\theta+7) + \mu\left(120t^2 - 117t(\theta-1) + 22(\theta-1)^2\right) + 800t^3\right. \\ &\left.- 562t^2(\theta-1) + 153t(\theta-1)^2 - 14(\theta-1)^3\right) + n^2\left(\mu^2(4t-2\theta+2)\right. \\ &\left.+ 4\mu\left(12t^2 - 9t(\theta-1) + (\theta-1)^2\right) + 600t^3 - 381t^2(\theta-1) + 78t(\theta-1)^2 - 4(\theta-1)^3\right) \\ &+ 2nt\left(\mu(2t-\theta+1) + 60t^2 - 34t(\theta-1) + 4(\theta-1)^2\right) + 5t^2(2t-\theta+1)\Big] \\ &\div \Big[2n^2(2n+1)^2\left(-2n^3(\theta-1) + 4n^2(3t-\theta+1) + 2n(6t-\theta+1) + 3t\right)^2\Big]. \end{aligned}$$

Solving $\Pi_p^D - \Pi_p^B = 0$ for μ, we find that $\Pi_p^D - \Pi_p^B < 0$ if $\mu \in (\mu_1, \mu_2)$. Otherwise $\Pi_p^D - \Pi_p^B \geq 0$. Where

$$\begin{aligned}
\mu_1 = \Big[& -32n^8(\theta-1)(2t-\theta+1) + 8n^7\left(16t^2 - 42t(\theta-1) + 17(\theta-1)^2\right) \\
& + 8n^6\left(48t^2 - 84t(\theta-1) + 29(\theta-1)^2\right) + n^5\left(480t^2 - 680t(\theta-1) + 202(\theta-1)^2\right) \\
& + 2n^4\left(160t^2 - 190t(\theta-1) + 47(\theta-1)^2\right) + n^3\left(120t^2 - 117t(\theta-1) + 22(\theta-1)^2\right) \\
& + 2n^2\left(12t^2 - 9t(\theta-1) + (\theta-1)^2\right) + \sqrt{n^2(2n+1)^4ab} + nt(2t-\theta+1)\Big] \\
& \div \Big[2n^2(2n+1)^4\left(4n^3(\theta-1) + n^2(-8t+9\theta-9) + n(-8t+6\theta-6) - 2t+\theta-1\right)\Big]
\end{aligned}$$

where, $a = \left(-2n^3(\theta-1) + 4n^2(3t-\theta+1) + 2n(6t-\theta+1) + 3t\right)^2$

$$\begin{aligned}
b = \big(16n^6(\theta-1)^2 &+ 32n^5(\theta-1)^2 + n^4\left(-64t^2 + 80t(\theta-1) + 7(\theta-1)^2\right) \\
& - 8n^3\left(16t^2 - 18t(\theta-1) + 3(\theta-1)^2\right) - 2n^2\left(48t^2 - 50t(\theta-1) + 11(\theta-1)^2\right) \\
& - 8n(-2t+\theta-1)^2 - (-2t+\theta-1)^2\big)
\end{aligned}$$

and

$$\begin{aligned}
\mu_2 = \Big[& -32n^8(\theta-1)(2t-\theta+1) + 8n^7\left(16t^2 - 42t(\theta-1) + 17(\theta-1)^2\right) \\
& + 8n^6\left(48t^2 - 84t(\theta-1) + 29(\theta-1)^2\right) + n^5\left(480t^2 - 680t(\theta-1) + 202(\theta-1)^2\right) \\
& + 2n^4\left(160t^2 - 190t(\theta-1) + 47(\theta-1)^2\right) + n^3\left(120t^2 - 117t(\theta-1) + 22(\theta-1)^2\right) \\
& + 2n^2\left(12t^2 - 9t(\theta-1) + (\theta-1)^2\right) - \sqrt{n^2(2n+1)^4cd} + nt(2t-\theta+1)\Big] \\
& \div \Big[2n^2(2n+1)^4\left(4n^3(\theta-1) + n^2(-8t+9\theta-9) + n(-8t+6\theta-6) - 2t+\theta-1\right)\Big].
\end{aligned}$$

where, $c = \left(-2n^3(\theta-1) + 4n^2(3t-\theta+1) + 2n(6t-\theta+1) + 3t\right)^2$

$$\begin{aligned}
d = \big(16n^6(\theta-1)^2 &+ 32n^5(\theta-1)^2 + n^4\left(-64t^2 + 80t(\theta-1) + 7(\theta-1)^2\right) \\
& - 8n^3\left(16t^2 - 18t(\theta-1) + 3(\theta-1)^2\right) - 2n^2\left(48t^2 - 50t(\theta-1) + 11(\theta-1)^2\right) \\
& - 8n(-2t+\theta-1)^2 - (-2t+\theta-1)^2\big)
\end{aligned}$$

However, $\mu^U < \mu_1 < \mu_2$. Hence, we conclude that $\Pi_p^D - \Pi_p^B < 0$.

Solving

$$
\begin{aligned}
w_f^D - w_f^B = \Big[&- 2n^6 \left(16a(\theta-1)(3t-\theta+1) - 16\mu^2 t - 2\mu(\theta-1)(32t-17\theta+17)\right.\\
&\left.+ (\theta-1)\left(-19t\theta - 29t + 6\theta^2 + 4\theta - 10\right)\right)\\
&+ 2n^5 \left(24a\left(6t^2 - 6t(\theta-1) + (\theta-1)^2\right) + 32\mu^2 t - 4\mu\left(20t^2 - 49t(\theta-1) + 14(\theta-1)^2\right)\right.\\
&\left.- 28t^2\theta - 116t^2 + 35t\theta^2 + 74t\theta - 109t - 4\theta^3 - 12\theta^2 + 36\theta - 20\right)\\
&+ 4n^4 \left(2a\left(72t^2 - 39t(\theta-1) + 4(\theta-1)^2\right) + 12\mu^2 t - 2\mu\left(40t^2 - 57t(\theta-1) + 11(\theta-1)^2\right)\right.\\
&\left.- 40t^3 + 7t^2\theta - 151t^2 + 78t\theta - 78t + 2\theta^3 - 14\theta^2 + 22\theta - 10\right)\\
&+ 2n^3 \left(4a\left(54t^2 - 18t(\theta-1) + (\theta-1)^2\right) + 8\mu^2 t - 120\mu t^2 + 125\mu t(\theta-1) - 16\mu(\theta-1)^2\right.\\
&\left.- 160t^3 + 75t^2\theta - 291t^2 - 33t\theta^2 + 138t\theta - 105t + 6\theta^3 - 22\theta^2 + 26\theta - 10\right)\\
&+ n^2 \left(t^2(144a + 113\theta - 257) - 6t(\theta-1)(4a + 7\theta - 11) + 2\mu^2 t\right.\\
&\left.- 4\mu\left(20t^2 - 16t(\theta-1) + (\theta-1)^2\right) - 240t^3 + 4(\theta-1)^3\right) + 4n^7(\theta-1)^2(2a - 4\mu - \theta - 1)\\
&- 2nt\left(t(-9a - 16\theta + 25) + \mu(5t - 3\theta + 3) + 40t^2 + 4(\theta-1)^2\right) + t^2(-10t + 3\theta - 3)\Big]\\
&\div \left[2n\left(-2n^3(\theta-1) + 4n^2(3t-\theta+1) + 2n(6t-\theta+1) + 3t\right)^2\right]\\
= 0 \;&
\end{aligned}
$$

for μ, we find that $w_f^D > w_f^B$ when $\overline{\mu_1} < \mu < \overline{\mu_2}$. Where

$$
\begin{aligned}
\overline{\mu_2} = \Big[&- \sqrt{-n^2(2n+1)^4 efg} - 32n^8(\theta-1)(2t-\theta+1) + 8n^7\left(16t^2 - 42t(\theta-1) + 17(\theta-1)^2\right)\\
&+ 8n^6\left(48t^2 - 84t(\theta-1) + 29(\theta-1)^2\right) + n^5\left(480t^2 - 680t(\theta-1) + 202(\theta-1)^2\right)\\
&+ 2n^4\left(160t^2 - 190t(\theta-1) + 47(\theta-1)^2\right) + n^3\left(120t^2 - 117t(\theta-1) + 22(\theta-1)^2\right)\\
&+ 2n^2\left(12t^2 - 9t(\theta-1) + (\theta-1)^2\right) + nt(2t-\theta+1)\Big]\\
&\div \left[2n^2(2n+1)^4\left(4n^3(\theta-1) + n^2(-8t+9\theta-9) + n(-8t+6\theta-6) - 2t + \theta - 1\right)\right]
\end{aligned}
$$

where $e = \left(-2n^3(\theta-1) + 4n^2(3t-\theta+1) + 2n(6t-\theta+1) + 3t\right)^2$,

$f = \left(4n^3(\theta-1) + n^2(-8t+9\theta-9) + n(-8t+6\theta-6) - 2t + \theta - 1\right)$ and

$g = \left(4n^3(4a-\theta-3) + n^2(16a-8t+\theta-17) + 2n(2a-4t+\theta-3) - 2t + \theta - 1\right)$ and

$$
\begin{aligned}
\overline{\mu_1} = \Big[&- 32n^8(\theta-1)(2t-\theta+1) + 8n^7\left(16t^2 - 42t(\theta-1) + 17(\theta-1)^2\right)\\
&+ 8n^6\left(48t^2 - 84t(\theta-1) + 29(\theta-1)^2\right) + n^5\left(480t^2 - 680t(\theta-1) + 202(\theta-1)^2\right)\\
&+ 2n^4\left(160t^2 - 190t(\theta-1) + 47(\theta-1)^2\right) + n^3\left(120t^2 - 117t(\theta-1) + 22(\theta-1)^2\right)\\
&+ 2n^2\left(12t^2 - 9t(\theta-1) + (\theta-1)^2\right) + \sqrt{n^2(2n+1)^4 hk} + nt(2t-\theta+1)\Big]\\
&\div \left[2n^2(2n+1)^4\left(4n^3(\theta-1) + n^2(-8t+9\theta-9) + n(-8t+6\theta-6) - 2t + \theta - 1\right)\right]
\end{aligned}
$$

where $h = \left(-2n^3(\theta-1) + 4n^2(3t-\theta+1) + 2n(6t-\theta+1) + 3t\right)^2$,

$$\begin{aligned} k = \big(&16n^6(\theta-1)^2 + 32n^5(\theta-1)^2 + n^4\left(-64t^2 + 80t(\theta-1) + 7(\theta-1)^2\right) \\ &- 8n^3\left(16t^2 - 18t(\theta-1) + 3(\theta-1)^2\right) - 2n^2\left(48t^2 - 50t(\theta-1) + 11(\theta-1)^2\right) \\ &- 8n(-2t+\theta-1)^2 - (-2t+\theta-1)^2\big) \end{aligned}$$

However, $\overline{\mu_1} < \mu^L$. Hence, we conclude that when $\mu < \overline{\mu_2}$, $w_f^D > w_f^B$; otherwise, $w_f^D < w_f^B$.
We Solve

$$\begin{aligned} \Pi_t^D - \Pi_t^B =\ & 8n^9(\theta-1)\left((\theta-1)^2 - 16\mu^2\right) \\ &+ 2n^8\left(16\mu^2(8t-17\theta+17) - 32\mu(\theta-1)(2t-\theta+1) - 5(\theta-1)^2(8t-3\theta+3)\right) \\ &+ 4n^7\left(48\mu^2(4t-5\theta+5) + 4\mu\left(16t^2 - 42t(\theta-1) + 17(\theta-1)^2\right)\right. \\ &\left.+ (\theta-1)\left(16t^2 - 38t(\theta-1) + 7(\theta-1)^2\right)\right) + 4n^6\left(12\mu^2(20t-19\theta+19)\right. \\ &\left.+ 4\mu\left(48t^2 - 84t(\theta-1) + 29(\theta-1)^2\right) + 160t^3 - 116t^2(\theta-1) + 31t(\theta-1)^2 - 8(\theta-1)^3\right) \\ &+ 2n^5\left(4\mu^2(80t-63\theta+63) + \mu\left(480t^2 - 680t(\theta-1) + 202(\theta-1)^2\right) + 960t^3\right. \\ &\left.- 768t^2(\theta-1) + 279t(\theta-1)^2 - 44(\theta-1)^3\right) + 2n^4\left(3\mu^2(40t-27\theta+27) + 320\mu t^2\right. \\ &\left.- 380\mu t(\theta-1) + 94\mu(\theta-1)^2 + 1200t^3 - 916t^2(\theta-1) + 299t(\theta-1)^2 - 37(\theta-1)^3\right) \\ &+ 2n^3\left(2\mu^2(12t-7\theta+7) + \mu\left(120t^2 - 117t(\theta-1) + 22(\theta-1)^2\right) + 800t^3\right. \\ &\left.- 562t^2(\theta-1) + 153t(\theta-1)^2 - 14(\theta-1)^3\right) + n^2\left(\mu^2(4t-2\theta+2)\right. \\ &\left.+ 4\mu\left(12t^2 - 9t(\theta-1) + (\theta-1)^2\right) + 600t^3 - 381t^2(\theta-1) + 78t(\theta-1)^2 - 4(\theta-1)^3\right) \\ &+ 2nt\left(\mu(2t-\theta+1) + 60t^2 - 34t(\theta-1) + 4(\theta-1)^2\right) \\ &+ 5t^2(2t-\theta+1)\big) / 2n^2(2n+1)^2\left(-2n^3(\theta-1) + 4n^2(3t-\theta+1) + 2n(6t-\theta+1) + 3t\right)^2 \\ =\ & 0 \end{aligned}$$

for μ, to reveal that $\Pi_t^D - \Pi_t^B < 0$ when $\mu \in (\underline{\mu_1}, \underline{\mu_2})$. However, $\underline{\mu_1} < \mu^L$. Hence, we conclude that $\Pi_t^D - \Pi_t^B < 0$ when $\mu < \underline{\mu_2}$; otherwise $\Pi_t^D - \Pi_t^B > 0$. Where

$$\begin{aligned} \underline{\mu_1} = \Big[&-32n^8(\theta-1)(2t-\theta+1) + 8n^7\left(16t^2 - 42t(\theta-1) + 17(\theta-1)^2\right) \\ &+ 8n^6\left(48t^2 - 84t(\theta-1) + 29(\theta-1)^2\right) + n^5\left(480t^2 - 680t(\theta-1) + 202(\theta-1)^2\right) \\ &+ 2n^4\left(160t^2 - 190t(\theta-1) + 47(\theta-1)^2\right) + n^3\left(120t^2 - 117t(\theta-1) + 22(\theta-1)^2\right) \\ &+ 2n^2\left(12t^2 - 9t(\theta-1) + (\theta-1)^2\right) + \sqrt{n^2(2n+1)^4uv} + nt(2t-\theta+1)\Big] \\ &\div \left[2n^2(2n+1)^4\left(4n^3(\theta-1) + n^2(-8t+9\theta-9) + n(-8t+6\theta-6) - 2t + \theta - 1\right)\right] \end{aligned}$$

where, $u = \left(-2n^3(\theta-1) + 4n^2(3t-\theta+1) + 2n(6t-\theta+1) + 3t\right)^2$,

$$\begin{aligned} v = \big(&16n^6(\theta-1)^2 + 32n^5(\theta-1)^2 + n^4\left(-64t^2 + 80t(\theta-1) + 7(\theta-1)^2\right) \\ &- 8n^3\left(16t^2 - 18t(\theta-1) + 3(\theta-1)^2\right) - 2n^2\left(48t^2 - 50t(\theta-1) + 11(\theta-1)^2\right) \\ &- 8n(-2t+\theta-1)^2 - (-2t+\theta-1)^2\big) \end{aligned}$$

and

$$
\begin{aligned}
\underline{\mu_2} = \Big[& -32n^8(\theta-1)(2t-\theta+1) + 8n^7\left(16t^2 - 42t(\theta-1) + 17(\theta-1)^2\right) \\
& + 8n^6\left(48t^2 - 84t(\theta-1) + 29(\theta-1)^2\right) + n^5\left(480t^2 - 680t(\theta-1) + 202(\theta-1)^2\right) \\
& + 2n^4\left(160t^2 - 190t(\theta-1) + 47(\theta-1)^2\right) + n^3\left(120t^2 - 117t(\theta-1) + 22(\theta-1)^2\right) \\
& + 2n^2\left(12t^2 - 9t(\theta-1) + (\theta-1)^2\right) - \sqrt{n^2(2n+1)^4 yz} + nt(2t-\theta+1)\Big] \\
& \div \Big[2n^2(2n+1)^4\left(4n^3(\theta-1) + n^2(-8t+9\theta-9) + n(-8t+6\theta-6) - 2t+\theta-1\right)\Big]
\end{aligned}
$$

where, $y = \left(-2n^3(\theta-1) + 4n^2(3t-\theta+1) + 2n(6t-\theta+1) + 3t\right)^2$

$$
\begin{aligned}
z = \big(& 16n^6(\theta-1)^2 + 32n^5(\theta-1)^2 + n^4\left(-64t^2 + 80t(\theta-1) + 7(\theta-1)^2\right) \\
& - 8n^3\left(16t^2 - 18t(\theta-1) + 3(\theta-1)^2\right) - 2n^2\left(48t^2 - 50t(\theta-1) + 11(\theta-1)^2\right) \\
& - 8n(-2t+\theta-1)^2 - (-2t+\theta-1)^2\big)
\end{aligned}
$$

Proof for Proposition 4.

Solving

$$
\begin{aligned}
\Pi_p^D - \Pi_p^B = \Big[& \left(n^2(\theta-1) + 2n(2t+\theta-1) + 2t+\theta-1\right)\big(\mu(2n+1)^2 n + n^3(\theta-1) + n^2(-4t+\theta-1) \\
& - 4nt - t\big)^2\Big] \div \Big[n(2n+1)\left(-2n^3(\theta-1) + 4n^2(3t-\theta+1) + 2n(6t-\theta+1) + 3t\right)^2\Big] \\
= 0 &
\end{aligned}
$$

for θ reveals that $\Pi_p^D - \Pi_p^B < 0$ when $\theta < \frac{n^2+n(2-4t)-2t+1}{(n+1)^2}$; otherwise $\Pi_p^D - \Pi_p^B > 0$. Combining the results form Propositions 3 and 4, we conclude that $\Pi_t^D > \Pi_t^B$, $\Pi_p^D > \Pi_p^B$, and $w_f^D > w_f^B$ when $\theta > \frac{n^2+n(2-4t)-2t+1}{(n+1)^2}$ and $\mu \in (\underline{\mu}, \overline{\mu})$.

Appendix B: Additional Tables and Graphs

Appendix Table 2.a: Equilibrium Prices and Quantities in Dual Sourcing Model

	Equilibrium Solution in Dual Sourcing Model
P_{ft}^{D*}	$\Big[-2(\theta-1)n^4(\theta+4\mu-1)+2n^3(\mu(-9\theta+4t+9)+(\theta-1)(-\theta+4t+1))+ n^2\left(2(\theta-1)^2+4t^2+4\mu(-3\theta+2t+3)+(\theta-1)t\right)+2n\left((\theta-1)^2+2t^2+\mu(-\theta+t+1)-\theta t+t\right)+t(-\theta+t+1)\Big]\div\Big[2n\left(2(\theta-1)n^3-4n^2(-\theta+3t+1)-2n(-\theta+6t+1)-3t\right)\Big]$
P_{fp}^{D*}	$\Big[-2(\theta-1)n^4(\theta+2\mu-1)-2n^3(\mu(5\theta+4t-5)-(\theta-1)(-\theta+4t+1))+ n^2\left(2(\theta-1)^2+8t^2-8\mu(\theta+t-1)-\theta t+t\right)+2n\left((\theta-1)^2+4t^2-\mu(\theta+t-1)-2(\theta-1)t\right)+t(-\theta+2t+1)\Big]\div\Big[(2n\left(2(\theta-1)n^3-4n^2(-\theta+3t+1)-2n(-\theta+6t+1)-3t\right))\Big]$
P_{tp}^{D*}	$\Big[(1-\theta)\left(2n^4(\theta+2\mu-1)+2n^3(\theta+5\mu-5t-1)+n^2(-2\theta+8\mu-t+2)+2n(-\theta+\mu+2t+1)+t\right)\Big]\div \Big[2n\left(2(\theta-1)n^3-4n^2(-\theta+3t+1)-2n(-\theta+6t+1)-3t\right)\Big]$
Q_{ft}^{D*}	$-\Big[8\mu n^3+n^2(-2\theta+8\mu+4t+2)+2n(-\theta+\mu+2t+1)+t\Big]\div\Big[n\left(2(\theta-1)n^3-4n^2(-\theta+3t+1)-2n(-\theta+6t+1)-3t\right)\Big]$
Q_{fp}^{D*}	$\Big[2\left((\theta-1)n^3+n^2(\theta-4t-1)+\mu(2n+1)^2n-4nt-t\right)\Big]\div\Big[n\left(2(\theta-1)n^3-4n^2(-\theta+3t+1)-2n(-\theta+6t+1)-3t\right)\Big]$
Q_{tp}^{D*}	$\Big[-2n^3(\theta+6\mu-1)+n^2(6t-10\mu)+n(2\theta-2\mu+t-2)-t\Big]\div\Big[2n\left(2(\theta-1)n^3-4n^2(-\theta+3t+1)-2n(-\theta+6t+1)-3t\right)\Big]$
Q_{tc}^{D*}	$-\Big[n^3(-2\theta+4\mu+2)+2n^2(-2\theta+3\mu+7t+2)+n(-2\theta+2\mu+9t+2)+t\Big]\div\Big[2n\left(2(\theta-1)n^3-4n^2(-\theta+3t+1)-2n(-\theta+6t+1)-3t\right)\Big]$
P_{tc}^{D*}	$-\Big[(\theta-1)(n+1)\left(2n(\theta+\mu-5t-1)+2n^2(\theta+2\mu-1)-5t\right)\Big]\div\Big[4(\theta-1)n^3-8n^2(-\theta+3t+1)-4n(-\theta+6t+1)-6t\Big]$
Q_{pc}^{D*}	$\Big[(n+1)\left(2n^2(\theta+2\mu-1)+2n(\theta+\mu-5t-1)-5t\right)\Big]\div\Big[2n\left(2(\theta-1)n^3-4n^2(-\theta+3t+1)-2n(-\theta+6t+1)-3t\right)\Big]$
P_{pc}^{D*}	$\Big[(\theta-1)\left(n^3(-2\theta+4\mu+2)+2n^2(-2\theta+3\mu+7t+2)+n(-2\theta+2\mu+9t+2)+t\right)\Big]\div\Big[4(\theta-1)n^3-8n^2(-\theta+3t+1)-4n(-\theta+6t+1)-6t\Big]$

Appendix Table 2.b: Equilibrium Welfare and Profits in Dual Sourcing Model (Welfare and Profits

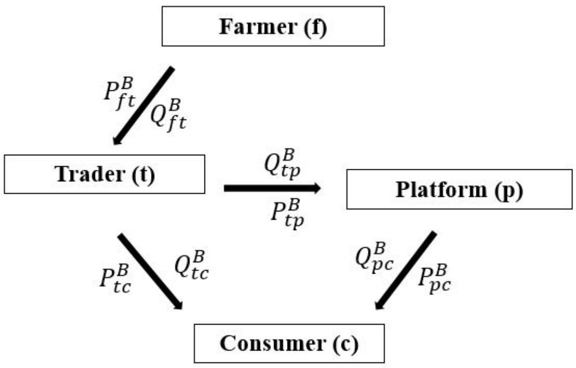
	Equilibrium Solution in Dual Sourcing Model
w_f^{D*}	$\Big[-8(\theta-1)^2n^7(\theta+4\mu-1)+8n^6\left((\theta-1)\mu(-17\theta+32t+17)+(\theta-1)^2(-3\theta+10t+3)+8\mu^2t\right)+$ $4n^5\left(-4\mu\left(14(\theta-1)^2+20t^2-49(\theta-1)t\right)-(\theta-1)\left(4(\theta-1)^2+40t^2-39(\theta-1)t\right)+32\mu^2t\right)+$ $8n^4\left(2(\theta-1)^3-22t^3-2\mu\left(11(\theta-1)^2+40t^2-57(\theta-1)t\right)-11(\theta-1)t^2+3(\theta-1)^2t+12\mu^2t\right)+$ $4n^3\left(-16(\theta-1)^2\mu+6(\theta-1)^3-88t^3+36(\theta-1)t^2-120\mu t^2+125(\theta-1)\mu t-29(\theta-1)^2t+8\mu^2t\right)+$ $2n^2\left(4(\theta-1)^3-132t^3-4\mu\left((\theta-1)^2+20t^2-16(\theta-1)t\right)+77(\theta-1)t^2-40(\theta-1)^2t+2\mu^2t\right)-$ $4nt\left(4(\theta-1)^2+22t^2+\mu(-3\theta+5t+3)-13(\theta-1)t\right)+t^2(6\theta-11t-6)\Big]$ $\div\Big[4n\left(-2(\theta-1)n^3+4n^2(-\theta+3t+1)+2n(-\theta+6t+1)+3t\right)^2\Big]$
π_t^{D*}	$\Big[-64(\theta-1)\mu^2n^7+4n^6\left(-(\theta-1)^3+4\mu^2(-13\theta+8t+13)-8(\theta-1)\mu(-\theta+2t+1)\right)+$ $8n^5\left(\mu\left(13(\theta-1)^2+16t^2-34(\theta-1)t\right)-2(\theta-1)\left((\theta-1)^2+t^2-4(\theta-1)t\right)+32\mu^2(-\theta+t+1)\right)+$ $4n^4\left(-6(\theta-1)^3+8t^3+\mu\left(30(\theta-1)^2+64t^2-96(\theta-1)t\right)-57(\theta-1)t^2+\mu^2(-37\theta+48t+37)+39(\theta-1)^2t\right)+$ $4n^3\left(-4(\theta-1)^3+16t^3+\mu\left(14(\theta-1)^2+48t^2-57(\theta-1)t\right)-68(\theta-1)t^2+2\mu^2(-5\theta+8t+5)+31(\theta-1)^2t\right)+$ $n^2\left(-4(\theta-1)^3+48t^3+8\mu\left((\theta-1)^2+8t^2-7(\theta-1)t\right)-113(\theta-1)t^2+\mu^2(-4\theta+8t+4)+36(\theta-1)^2t\right)+$ $2nt\left(2(\theta-1)^2+8t^2+\mu(-2\theta+4t+2)-9(\theta-1)t\right)+t^2(-\theta+2t+1)\Big]$ $\div\Big[4n^2\left(-2(\theta-1)n^3+4n^2(-\theta+3t+1)+2n(-\theta+6t+1)+3t\right)^2\Big]$
π_p^{D*}	$\Big[16(\theta-1)\mu n^7(\theta+2\mu-1)+4n^6\left(14(\theta-1)^2\mu+4\mu^2(7\theta+8t-7)+(\theta-1)^2(-\theta+4t+1)\right)+$ $4n^5\left(-2\mu\left(-9(\theta-1)^2+32t^2+12(\theta-1)t\right)-(\theta-1)\left(4(\theta-1)^2+26t^2-17(\theta-1)t\right)+\mu^2(38(\theta-1)+64t)\right)+$ $4n^4\left(-6(\theta-1)^3+32t^3-2\mu\left(-5(\theta-1)^2+64t^2+28(\theta-1)t\right)-67(\theta-1)t^2+\mu^2(25(\theta-1)+48t)+32(\theta-1)^2t\right)+$ $2n^3\left(-8(\theta-1)^3+128t^3+4\mu\left((\theta-1)^2-48t^2-23(\theta-1)t\right)-135(\theta-1)t^2+16\mu^2(\theta+2t-1)+64(\theta-1)^2t\right)+$ $n^2\left(-4(\theta-1)^3+192t^3-141(\theta-1)t^2+4\mu^2(\theta+2t-1)-64\mu t(\theta+2t-1)+64(\theta-1)^2t\right)+$ $4nt\left(3(\theta-1)^2+16t^2-2\mu(\theta+2t-1)-10(\theta-1)t\right)+t^2(-5\theta+8t+5)\Big]$ $\div\Big[4n\left(-2(\theta-1)n^3+4n^2(-\theta+3t+1)+2n(-\theta+6t+1)+3t\right)^2\Big]$

Appendix Table 3: Equilibrium Solution in Benchmark Model and when direct selling cost is very low

	Equilibrium Solution for low direct selling cost ($\mu < \mu^L$)	Equilibrium Solution in Benchmark Model ($Q_{fp} = 0$)
P_{ft}^*	$\frac{t(\theta-1)}{4n(\theta-1)-2t}$	$\frac{t}{2n}$
Q_{ft}^*	$\frac{1-\theta}{-2n\theta+2n+t}$	$\frac{1}{n}$
P_{tp}^*	0	$\frac{(1-\theta)\left(n^2-2n-1\right)}{2n(2n+1)}$
Q_{tp}^*	0	$\frac{n+1}{4n^2+2n}$
P_{fp}^*	μ	0
Q_{fp}^*	$\frac{\theta-1}{t-2n(\theta-1)} + \frac{1}{n}$	0
P_{tc}^*	$-\frac{(\theta-1)(n(-\theta)+n+t)}{t-2n(\theta-1)}$	$\frac{(1-\theta)(n+1)}{4n+2}$
Q_{tc}^*	$\frac{1-\theta}{-2n\theta+2n+t}$	$\frac{3n+1}{4n^2+2n}$
P_{pc}^*	$-\frac{n(\theta-1)^2}{2n(\theta-1)-t}$	$\frac{(1-\theta)(3n+1)}{4n+2}$
Q_{pc}^*	$\frac{\theta-1}{t-2n(\theta-1)} + \frac{1}{n}$	$\frac{n+1}{4n^2+2n}$
π_t^*	$-\frac{(\theta-1)^2}{4n(\theta-1)-2t}$	$\frac{\theta-4(\theta-1)n^3+n^2(-3\theta-8t+3)+n(2\theta-8t-2)-2t-1}{4n^2(2n+1)^2}$
π_p^*	$-\frac{(n(-\theta)+n+t)(\mu t-n(\theta-1)(2\mu+\theta-1))}{(t-2n(\theta-1))^2}$	$\frac{(1-\theta)(n+1)^2}{4n(2n+1)}$
w_f^*	$\frac{nt(\theta-1)^2}{(2t-4n(\theta-1))^2}$	$\frac{t}{4n}$

Appendix Table 4: Effect of market competition θ and transportation cost t on prices and quantities for both models with dual sourcing and single sourcing.

Dual Sourcing	$\partial P/\partial\theta$	$\partial P/\partial t$	Benchmark	$\partial P/\partial\theta$	$\partial P/\partial t$
∂P_{ft}^D	<0	>0	∂P_{ft}^B	$=0$	>0
∂P_{tp}^D	<0	>0	∂P_{tp}^B	<0	$=0$
∂P_{tc}^D	<0	>0	∂P_{tc}^B	<0	$=0$
∂P_{pc}^D	<0	<0	∂P_{pc}^B	<0	$=0$
Dual Sourcing	$\partial Q/\partial\theta$	$\partial Q/\partial t$	Benchmark	$\partial Q/\partial\theta$	$\partial Q/\partial t$
∂Q_{ft}^D	>0	<0	∂Q_{ft}^B	$=0$	$=0$
∂Q_{tp}^D	>0	<0	∂Q_{tp}^B	$=0$	$=0$
∂Q_{tc}^D	>0	<0	∂Q_{tc}^B	$=0$	$=0$
∂Q_{pc}^D	<0	>0	∂Q_{pc}^B	$=0$	$=0$

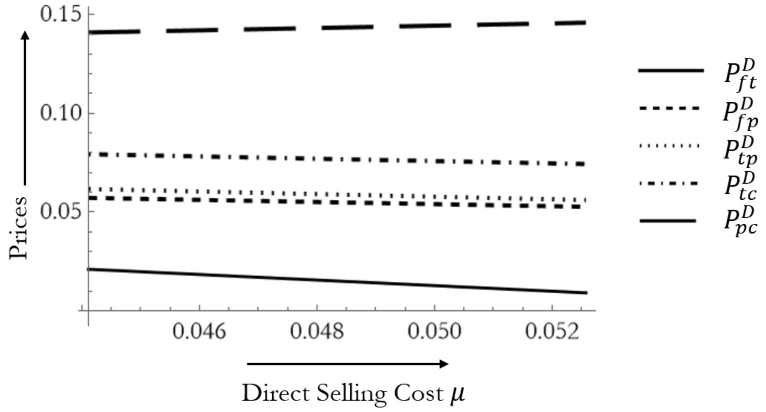


((a)) Benchmark Model with single sourcing ((b)) Model with dual sourcing by platform

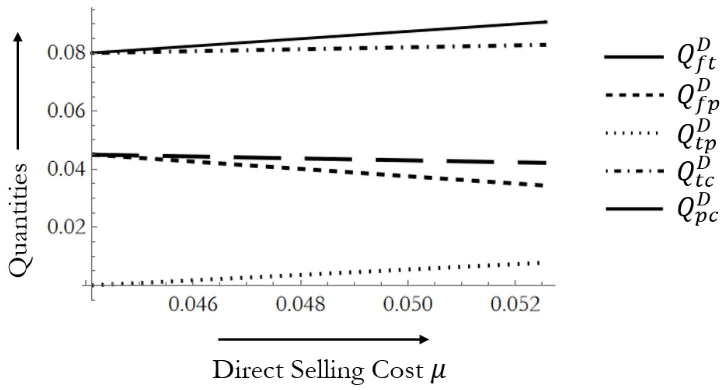
Figure 7: Channels of trading from farmers to consumers

Appendix Table 5: Effect of direct selling cost μ on prices, quantities, and profits for the dual sourcing model

Price	Quantity	Profits
$\partial P^D_{ft}/\partial\mu < 0$	$\partial Q^D_{ft}/\partial\mu > 0$	$\partial f^D_t/\partial\mu < 0$
$\partial P^D_{fp}/\partial\mu < 0$	$\partial Q^D_{fp}/\partial\mu < 0$	$\partial f^D_p/\partial\mu < 0$
$\partial P^D_{tp}/\partial\mu < 0$	$\partial Q^D_{tp}/\partial\mu > 0$	$\partial \pi^D_t/\partial\mu > 0$
$\partial P^D_{pc}/\partial\mu > 0$	$\partial Q^D_{pc}/\partial\mu < 0$	$\partial \pi^D_p/\partial\mu > 0$
$\partial P^D_{tc}/\partial\mu < 0$	$\partial Q^D_{tc}/\partial\mu > 0$	$\partial C^D_s/\partial\mu > 0$



((a)) Changes in prices with μ



((b)) Changes in quantities with μ

Figure 8: Change in Prices and Quantities with change in Direct Selling cost μ for Dual sourcing

Note: As direct selling cost μ increases, the farmer sells less quantity to the platform at a lower price, and the platform sells less quantity to consumers at a higher price. The above figure have been drawn for : $t = 0.2, n = 10, \theta = 0.8$ for plotting against μ. For any value of t, n has to be greater than n', which is $\frac{1}{2}\left(\sqrt{16t^2 + 16t + 1} + 4t + 1\right)$ and θ has to be less than θ^U which is $\frac{-n^2+4nt+n+2t}{n-n^2}$ for model to be valid. Thus, for t=0.2, n has to be greater than 2, and θ has to be less than $\theta^U = 0.906$. Also, μ on the X axis ranges from μ^L to μ^U, whereas θ on the X axis ranges from 0 to θ^U.

References

Abdulai, A. (2000). Spatial price transmission and asymmetry in the ghanaian maize market. *Journal of Development Economics*, *63*(2), 327–349. https://doi.org/10.1016/S0304-3878(00)00115-2

Balasubramanian, S. (1998). Mail versus mall: A strategic analysis of competition between direct marketers and conventional retailers. *Marketing Science*, *17*(3), 181–195.

Banerji, A., & Meenakshi, J. V. (2004). Buyer collusion and efficiency of government intervention in wheat markets in northern india: An asymmetric structural auctions analysis [Publisher: [Agricultural & Applied Economics Association, Oxford University Press]]. *American Journal of Agricultural Economics*, *86*(1), 236–253. Retrieved October 28, 2022, from https://www.jstor.org/stable/3697887

Bardhan, P. K. (1980). Interlocking factor markets and agrarian development: A review of issues. *Oxford Economic Papers*, *32*(1), 82–98.

Barrett, C. B. (1997). Liberalization and food price distributions: ARCH-m evidence from madagascar. *Food Policy*, *22*(2), 155–173. https://doi.org/10.1016/S0306-9192(96)00033-4

Basu, K. (1983). The emergence of isolation and interlinkage in rural markets. *Oxford Economic Papers*, *35*(2), 262–280.

Bhaduri, A. (1986). Forced commerce and agrarian growth. *World Development*, *14*(2), 267–272.

Bhanot, D., Kathuria, V., & Das, D. (2021). Can institutional innovations in agri-marketing channels alleviate distress selling? evidence from india. *World Development*, *137*, 105202. https://doi.org/10.1016/j.worlddev.2020.105202

Chen, J., & Guo, Z. (2014). Strategic sourcing in the presence of uncertain supply and retail competition. *Production and Operations Management*, *23*(10), 1748–1760.

Chintapalli, P., & Tang, C. (2021). The value and cost of crop minimum support price: Farmer and consumer welfare and implementation cost. *Management Science*, *67*(11), 6839–6861.

Chirwa, E. W. (2009). *Determinants of marketing channels among smallholder maize farmers in malawi*. Chancellor College, University of Malawi.

Coulter, J., & Golob, P. (1992). Cereal marketing liberalization in tanzania. *Food Policy*, *17*(6), 420–430. https://doi.org/10.1016/0306-9192(92)90074-8

Dani, S. (2015). *Food supply chain management and logistics: From farm to fork*. Kogan Page Publishers.

Detre, J. D., Mark, T. B., Mishra, A. K., & Adhikari, A. (2011). Linkage between direct marketing and farm income: A double-hurdle approach [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.100 *Agribusiness*, *27*(1), 19–33. https://doi.org/10.1002/agr.20248

Dong, B., Tang, W., Zhou, C., & Ren, Y. (2021). Is dual sourcing a better choice? the impact of reliability improvement and contract manufacturer encroachment. *Transportation Research Part E: Logistics and Transportation Review*, *149*, 102275.

Donkor, E. A., Garnevska, E., Siddique, M. I., & Donkor, E. (2021). Determinants of rice farmer participation in the direct marketing channel in ghana. *Sustainability*, *13*(9), 5047. https://doi.org/10.3390/su13095047

Ezealaji, N. L. O., & Adenegan, K. O. (2014). The role of agricultural market reform in enhancing farmers income in nigeria. *African Journal of Marketing Management*, *6*(3). https://doi.org/10.5897/ajmm2011.025

Fafchamps, M., & Hill, R. V. (2005). Selling at the farmgate or traveling to market [Publisher: Wiley Online Library]. *American journal of agricultural economics*, *87*(3), 717–734.

Govindasamy, R., Hossain, F., & Adelaja, A. (1999). Income of farmers who use direct marketing [Publisher: Cambridge University Press]. *Agricultural and Resource Economics Review*, *28*(1), 76–83.

Hardesty, S. D., & Leff, P. (2010). Determining marketing costs and returns in alternative marketing channels. *Renewable Agriculture and Food Systems*, *25*(1), 24–34. https://doi.org/10.1017/S1742170509990196

Hari, M., TN ; Subramanian. (2019). *Saying no to jugaad: The making of bigbasket*. Bloomsbury.

Hernández, R., Reardon, T., & Berdegué, J. (2007). Supermarkets, wholesalers, and tomato growers in guatemala [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1574-0862.2007.00206.x]. *Agricultural Economics*, *36*(3), 281–290. https://doi.org/10.1111/j.1574-0862.2007.00206.x

Jayne, T. S., Mangisoni, J., & Sitko, N. (2014). Social analysis of malawi's maize marketing reforms. . *World Bank Report*.

Lee, B., Liu, J.-Y., & Chang, H.-H. (2020). The choice of marketing channel and farm profitability: Empirical evidence from small farmers. *Agribusiness*, *36*(3), 402–421. https://doi.org/10.1002/agr.21640

Leng, M., Parlar, M., & Zhang, D. (2013). The retail space-exchange problem with pricing and space allocation decisions. *Production and Operations Management*, *22*(1), 189–202.

Li, T., Sethi, S., & Zhang, J. (2013). Supply diversification with responsive pricing. *Production and Operations Management*, *22*(2), 447–458.

Liao, C., & Chen, Y. (2017). Farmers' information management in developing countries—a highly asymmetric information structure. *Production and Operations Management*, *26*(6), 1207–1220.

Michelson, H., Reardon, T., & Perez, F. (2012). Small farmers and big retail: Trade-offs of supplying supermarkets in nicaragua. *World Development*, *40*(2), 342–354. https://doi.org/10.1016/j.worlddev.2011.07.013

Negi, D. S., Birthal, P. S., Roy, D., & Khan, M. T. (2018). Farmers' choice of market channels and producer prices in india: Role of transportation and communication networks. *Food Policy*, *81*, 106–121.

Niu, B., Li, J., Zhang, J., Cheng, H., & Tan, Y. (2019). Strategic analysis of dual sourcing and dual channel with an unreliable alternative supplier. *Production and Operations Management*, *28*(3), 570–587.

Rao, E. J. O., & Qaim, M. (2011). Supermarkets, farm household income, and poverty: Insights from kenya. *World Development*, *39*(5), 784–796. https://doi.org/10.1016/j.worlddev.2010.09.005

Salop, S. C. (1979). Monopolistic competition with outside goods. *The Bell Journal of Economics*, 141–156.

Santorum, A., & Tabaijuka, A. (1992). Trading responses to food market liberalization in tanzania [Publisher: Elsevier]. *Food Policy*, *17*(6), 431–442.

Sartwelle, J., O'Brien, D., Tierney, W., & Eggers, T. (2000). The effect of personal and farm characteristics upon grain marketing practices [Publisher: Cambridge University Press]. *Journal of Agricultural and Applied Economics*, *32*(1), 95–111. https://doi.org/10.1017/S1074070800027851

Schipmann, C., & Qaim, M. (2011). Supply chain differentiation, contract agriculture, and farmers' marketing preferences: The case of sweet pepper in thailand. *Food Policy*, *36*(5), 667–677. https://doi.org/10.1016/j.foodpol.2011.07.004

Shiimi, T., Taljaard, P., & Jordaan, H. (2012). Transaction costs and cattle farmers' choice of marketing channel in north-central namibia. *Agrekon*, *51*(1), 42–58. https://doi.org/10.1080/03031853.2012.649543

Singh, N., & Vives, X. (1984). Price and quantity competition in a differentiated duopoly. *The Rand journal of economics*, 546–554.

Singh, S. (2018). Reforming agricultural markets in india. *Economic and Political Weekly*, *53*(51), 15–18.

Smith, L. D. (1995). Malawi: Reforming the state's role in agricultural marketing. *Food Policy*, *20*(6), 561–571. https://doi.org/10.1016/0306-9192(95)00049-6

Tang, S., Gurnani, H., & Gupta, D. (2014). Managing disruptions in decentralized supply chains with endogenous supply process reliability. *Production and Operations Management*, *23*(7), 1198–1211.

Xaba, B. G., & Masuku, M. B. (2012). Factors affecting the choice of marketing channel by vegetable farmers in swaziland. *Sustainable Agriculture Research*, *2*(1), 112. https://doi.org/10.5539/sar.v2n1p112

Zhou, J., & Fan, T. (2015). Research on the competition strategy of the fresh agricultural products based on hotelling model. *International Conference on Logistics Engineering, Management and Computer Science. doi: https://doi. org/10.2991/lemcs-15.2015*, *249.*