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ARTICLE

Digital Platforms and Agricultural Marketing: Bridging Gaps between Farmers and Consumers in Jordan

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ABSTRACT

This study aimed to analyse the impact of digital platforms on reducing supply chain inefficiencies and enhancing market accessibility for farmers in Jordan. A mixed-methods approach was employed, integrating descriptive analysis, inferential statistics, and spatial techniques to evaluate income levels, logistical efficiency, and market access. Data were collected from 200 farmers, capturing key metrics such as pre- and post-income, market accessibility scores, and logistical cost savings.The findings revealed that income increased from an average of 596.83 JOD (pre-platform) to 911.35 JOD (post-platform), with an average logistics cost saving of 27.15%. Logistic regression indicated that frequent platform users were 4.58 times more likely to achieve high market accessibility (p =

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0.005), demonstrating the platforms' effectiveness in connecting farmers to broader markets. However, linear regression showed no significant influence of platform usage or barriers score on income, suggesting the importance of external factors like infrastructure and market dynamics. ANOVA results showed no significant differences in post-income or logistics cost savings based on education level or usage intensity. Spatial analysis revealed disparities between urban and rural farmers, with urban farmers benefiting more consistently. These findings highlight the need for targeted interventions to enhance rural connectivity, improve platform usability, and address systemic barriers. The study underscores the importance of digital platforms as tools for empowering farmers and optimizing agricultural supply chains. Policy implications include investing in rural internet infrastructure, subsidizing digital tools, and implementing digital literacy programs to ensure equitable benefits and sustainable growth in the agricultural sector.

Keywords: Technology Adoption; Farmer Empowerment; Digital Literacy; Rural Connectivity; Spatial Disparities

1. Introduction

The rapid development of digital technologies affects many industries these days, agriculture is not an exception. Agriculture is a vital sector for economic development and providing food, yet it was always characterized by inefficient chains of supply, limited accessibility to markets, and high operations costs. Recently, certain digital platforms have cropped up which are considered very effective in their own way to help alleviate these woes. These platforms allow farmers to connect directly with buyers, access to real-time market information, and optimization of the entire logistics process, therefore, they have revolutionary potential for agricultural marketing.

Agricultural systems remain among the mainstays in Jordan in terms of sustaining rural livelihoods while ensuring food security at large. However, inefficiencies are deeply ingrained and have remained so for far too long to affect agriculture productivity and profitability in this country. Traditional supply chains often involve a lot of layers of middlemen, increasing delay and cost of products with low profit margins to the farmer [1–3]. For instance, access to markets for farmers especially rural ones remains low because of infrastructural challenges, geographical exclusion, and information asymmetry. In this regard, the use of digital platforms would increase transparency, efficiency, and connectivity in agricultural markets [4–7].

Despite the promise, the level of the adoption of digital platforms among Jordan's agricultural sector remains variable [8]. Farmers either have limited levels of digital literacy, they face inadequate infrastructure levels or cultural resistance to adopting untraditional marketing methods [9, 10]. Additional compounding challenges for most rural farmers include limited internet and smartphone access, hampering their ability to fully capture these platforms. These are critical barriers that need to be addressed for digital platforms to be equitable in benefiting farmers.

The research aims at digging into structural and systemic impediments that create a bottleneck in adoption or varying outcomes from digital platforms. Whereas some farmers had received tremendous improvements in earnings, their level of entry access to markets has equally significantly improved, while at the same time, on one side, other farmers do not show improvement at all in overcoming these continuous limitations [11, 12]. These variations identify such differences as an effective opportunity for intervention, bridging both the digital divide regarding the use and accessibility to various platforms [13].

Its relevance regards the fact that it tries to investigate a region where agriculture is fundamentally key but underperforming owing to structural hurdles. Through digital platforms, farmers enjoy increased bargaining positions and dependence on intermediaries is relatively less as with eNAM, India and MPesa, Kenya [14, 15]. Looking at how they can be enhanced here in Jordan, hence contributing to the big debate on technological agricultural change.

The research statement in this study declares that

even though digital platforms have immense potential to transform agricultural supply chains in Jordan, the effectiveness of such platforms depends on how well barriers to adoption are dealt with and access is assured for all. This is supported by literature that affirms the need for inclusiveness in platform design and systemic interventions for equitable growth [16]. For instance, localized training programs and subsidized digital tools will help bridge the gap in digital literacy and financial constraints, hence making more farmers participate [17–19].

The novelty of this study lies in its focus on Jordan's agricultural sector, where digital platform adoption remains underexplored, particularly in addressing geographic and socio-economic disparities between urban and rural farmers [20, 21]. By integrating advanced spatial analysis with mixed-methods research, the study provides a multidimensional understanding of the platforms' impact on income, market accessibility, and logistical efficiency. Unlike traditional approaches, this research highlights the moderating role of digital literacy, cultural factors, and infrastructural barriers, offering nuanced insights into the challenges of equitable platform adoption. These findings challenge the assumption of universal benefits, advocating for tailored interventions to bridge systemic gaps and maximize the transformative potential of digital tools in agriculture.

The exploration of these aspects within this study contributes to the wider discourse on leveraging digital technologies for sustainable agricultural development. The study highlights not only the role of digital platforms in transforming supply chains but also the structural challenges that need to be addressed to ensure their full potential is met. The research, through detailed analysis of data from Jordanian farmers, therefore presents actionable evidence for various stakeholders in realizing the benefits of digital solutions in agriculture for policymakers, developers of these platforms, and agricultural cooperatives. These challenges that are needed to be pursued would therefore guarantee that the involvement of digital platforms results in more equal and sustainable forms of agriculture [22–24].

The objectives of the study were:

1. To evaluate how digital platforms mitigate logistical and operational inefficiencies within agricultural supply chains in Jordan.
2. To examine the extent to which digital platforms enhance market accessibility for farmers by connecting them with consumers and institutional buyers.
3. To measure the economic impact of digital platform adoption on farmers' income levels and cost savings, comparing pre and post platform scenarios.
4. To explore the adoption rate of digital platforms among farmers, identify barriers to their use, and analyse perceptions of their benefits and limitations.
5. To visualize geographic improvements in market access through GIS mapping and highlight regional disparities in platform utilization.

1.1. Related Studies

Patil et al. detail how digital platforms have revolutionized the agricultural supply chain, farmers are now in a position to transact directly, with real-time access to market information [25]. Chaudhary and Suri describe how such platforms, such as eNAM in India, have helped involve farmers with institutional buyers directly by circumventing intermediaries, while MPesa of Kenya integrated mobile financial services into their offering to simplify payment systems [26]. Studies such as Chauhan et al. illustrated, however, that with all these benefits considered, low levels of digital literacy and infrastructural deficits dampened the potential impact of the platforms and subsequent variance in adoption [27].

Logistic regression analysis by Kumoji et al. indicates that frequent users of digital platforms are at least four times more likely to achieve higher market accessibility than nonusers [28]. The frequency and diversity of platform usage have been critical in determining user satisfaction and outcomes, as seen from the research by Stewart and Cunningham [29]. Those farmers who utilized price discovery and buyer connections had better impacts than others. Yet, the adoption remains uneven, especially in rural areas where factors like unreliable internet, high platform fees, and cultural resistance further inhibit usage. As indicated by Munson et al. targeting

interventions to improve usability and accessibility are required for effective addressing of such barriers [30].

On one hand, Kim study details how basic demographic elements of a factor can significantly influence both the acceptance of digital platforms and their ultimate effectiveness [31]. Several related studies, including those by Hoang and Tran show quite clearly that young farmers are highly open to actively adopting digital technologies [32], using them to obtain current market information and benefit from enhanced logistical capabilities. Older farmers, on the other hand, are usually more reluctant due to lower digital literacy and a preference for traditional farming methods.

Artero et al. education is an important but not universal predictor of success [33]. For example, research by Said et al. showed no significant difference in post platform income based on the level of education, suggesting that well designed platforms reduce dependence on educational attainment [34]. Equally important is the geographic location. Park et al. study highlights the fact that although urban farmers have better infrastructure and thus better market access, rural farmers contend with compounded problems, such as limited internet connectivity and poor road networks [35].

Other studies, such as Feyisa, also report that farm size is a significant determinant [36]. Large farms usually have more resources to invest in technology and thus benefit disproportionately from digital platforms. Small scale farms, however, cannot achieve the economies of scale needed to justify the adoption of technology. This disparity in benefits across farm sizes underscores the need for targeted solutions.

Khanal and Mishra, explain how functionality in digital platforms regarding price discovery, logistics support, and buyer connections is critical for adoption and success [37]. Studies such as Vivekanandan et al. shows how real-time pricing features enable farmers with price transparency, allowing them to negotiate better deals [38]. Moreover, supporting logistical features like inventory tracking and predictive analytics for optimum transportation and storage significantly reduce postharvest losses and associated costs indicates a study by Purandare et al. and AlrabeiandAbabnehi [39, 40].

Recent reviews of logistics-enhancing platforms for the agricultural industry by Praveen and Sharma and Sangirova et al. highlight the increasing sophistication through the integration of technologies like GIS mapping [41, 42]. For instance, Hello Tractor, a digital platform in sub-Saharan Africa, utilizes GPS technology to connect farmers with tractor owners, streamlining processes for field preparation and harvesting [43].

On the other hand, Harris andAchora noted that many platforms still lack localized features and multilingual support, which limits access for nonnative users [18]. This demonstrates the need for customization to address a diverse array of needs across different farmer demographics. According to Mehrabi et al., bridging these gaps will help mitigate digital divide issues, especially in terms of usability and accessibility [44].

Puspitawati et al. further expound that one of the most important benefits of using digital platforms is improved market accessibility [45]. Essentially, the platforms reduce intermediaries in sales, enabling farmers to connect with a multitude of buyers and widen their networks for improved marketing. Studies by Chaudhary and Suri found that improved market access enabled farmers using eNAM and similar platforms to establish larger buyer networks and achieve better prices for their produce [46].

Studies such as Kim,showed that logistic regression analyses indicate a strong positive relationship between high frequency platform usage and improved market accessibility [47]. The result underscores the importance of sustained engagement with digital platforms for better market outcomes.

However, a study by Gumbi et al. has identified that these benefits are still not being fully harnessed by small scale farmers in rural areas due to persistent challenges [48]. In fact, the effectiveness of the platforms is constrained by poor internet connectivity, inadequate transportation networks, and limited buyer diversity in remote farming areas. According to HeeksandBukht, addressing these challenges requires an integrated approach involving policy support, infrastructural improvements, and community based training programs to unlock the full potential of digital platforms [49].

Geng et al. explain how the adoption of these digital platforms has contributed to the economy through bet-

ter farmer incomes [50]. For example, farmers in Egypt reported an increase in income from 10,000 EGP to 18,500 EGP after adopting digital tools [51]. According to Levi et al., this increase stems primarily from improved price setting mechanisms coupled with cost reductions that the platforms facilitate [52].

Studies such as Bhaskara and Bawa, indicate that, often, income gains associated with platforms are mediated by exogenous factors such as market conditions, crop yields, and governmental policies [53]. In addition, linear regression analyses show that while platforms contribute to income growth, these improvements depend heavily on external factors.

Furthermore, according to Mugera, income gains are distributed unevenly across demographic groups [54]. Farmers in rural areas and small scale operators experience smaller increases compared to their urban and largescale counterparts. This disparity suggests a need to tailor digital platforms to address the specific needs of marginalized groups, ensuring equitable distribution of benefits across diverse farming contexts.

According to Savchenko, digital platforms significantly reduce logistics costs and improve transportation efficiencies [55]. For example, Moroccan farmers reported average cost reductions of 30%, with some as high as 55%, through platform features like predictive analytics and optimized route planning. Ratinger andBishtand Singh found that technological investments also minimize delays, reducing postharvest losses [56, 57]. Predictive tools enable farmers to streamline their supply chains, yielding substantial cost efficiencies. However, as highlighted IyoboyiandMusaPedro, these benefits are contingent on the quality of road infrastructure and the availability of reliable transportation options [58]. This underscores the need for comprehensive infrastructural development to fully harness the potential of digital platforms in optimizing agricultural logistics.

Research by various scholars, such as Kenney et al. shows that the type of farming crop based or livestock based significantly determines the utility of digital platforms [59]. For instance, livestock farming involves more intricate logistical challenges than crop farming, particularly in ensuring animal welfare during transportation [60]. According to Xie et al. [61] and Jo et al. [62], these unique requirements demand specialized functionalities in digital platforms. For livestock farmers, platforms may need integrated features such as real-time tracking and condition monitoring to address these challenges effectively.

Havinal, argument regarding the necessity of reliable internet, affordable smartphones, and adequate transportation infrastructure for effective digital functioning in agriculture is echoed in more recent studies [63]. These preconditions remain critical, as their absence often leads to the limited diffusion of digital platforms or reduces their potential benefits. According to Salemink et al. [64], such barriers are particularly acute in rural areas, where inadequate connectivity and limited access to affordable smartphones continue to pose significant challenges. A primary issue identified is the restricted availability of low cost smartphones, which hinders the widespread penetration of digital platforms in marginalized economies.

Further, as Harris andAchora highlight, infrastructure deficits not only reduce platform utilization but also prevent farmers from fully leveraging their functionalities [18]. Addressing these issues requires targeted investments in connectivity, subsidized device programs, and transportation infrastructure to ensure equitable access and maximize platform effectiveness. Work by Birner et al., further expounds that differing market conditions, such as price variation and seasonal demand, significantly affect the functioning and efficiency of digital platforms in agriculture [65]. These conditions are often compounded by turbulent market dynamics, making it necessary to view platform impacts as part of the larger economic context.

According to Yoon et al., the advantages brought by platform adoption can be eroded by external economic pressures, such as price volatility and sudden changes in demand, which challenge farmers' ability to capitalize on platform features effectively [66]. Research by Komarek et al., highlights that understanding and integrating broader market trends within platform designs and policy frameworks are critical to ensuring maximum effectiveness [67]. Such approaches help bolster farmers' resilience in the face of economic uncertainties, creating a more sustainable agricultural system.

According to Gumbi et al., there are significant barriers to the relationship between platform utilization and its outcomes, including limited digital literacy, affordability issues, and cultural resistance [48]. These challenges weaken the positive impact of digital platforms, preventing many farmers from realizing their full potential. These barriers can be addressed through targeted interventions such as community based training programs, subsidies for acquiring technology, and trust building initiatives, as demonstrated in studies by Kumarand Nehrey [68, 69]. For example, the research by Samadder et al., emphasizes that platforms should incorporate intuitive design elements to accommodate a wide range of technical skills, ensuring accessibility and appeal for users with varying levels of technological expertise [70].

1.2. Research Gap

Although the literature to date has highlighted the transformative role of digital platforms, after a review of studies, it indicates that several gaps remain in the current body of knowledge. First, barriers to adoption are poorly understood in terms of their interaction with platform features, particularly in rural settings. While studies suggest that broader macroeconomic trends, such as fluctuating global prices, remain an underexplored influence on platform effectiveness. This gap suggests that external economic factors may significantly impact the success of platforms, which has not been studied extensively. Additionally, the lack of longitudinal studies has hindered understanding of the long term impacts of platform adoption. Addressing these research gaps is crucial to better understanding the sustainability and true potential of digital platforms in agriculture.

1.3. Hypothesis Development and Conceptual Model

Based on the literature review, the following hypotheses were proposed and a conceptual model was developed (**Figure 1**):

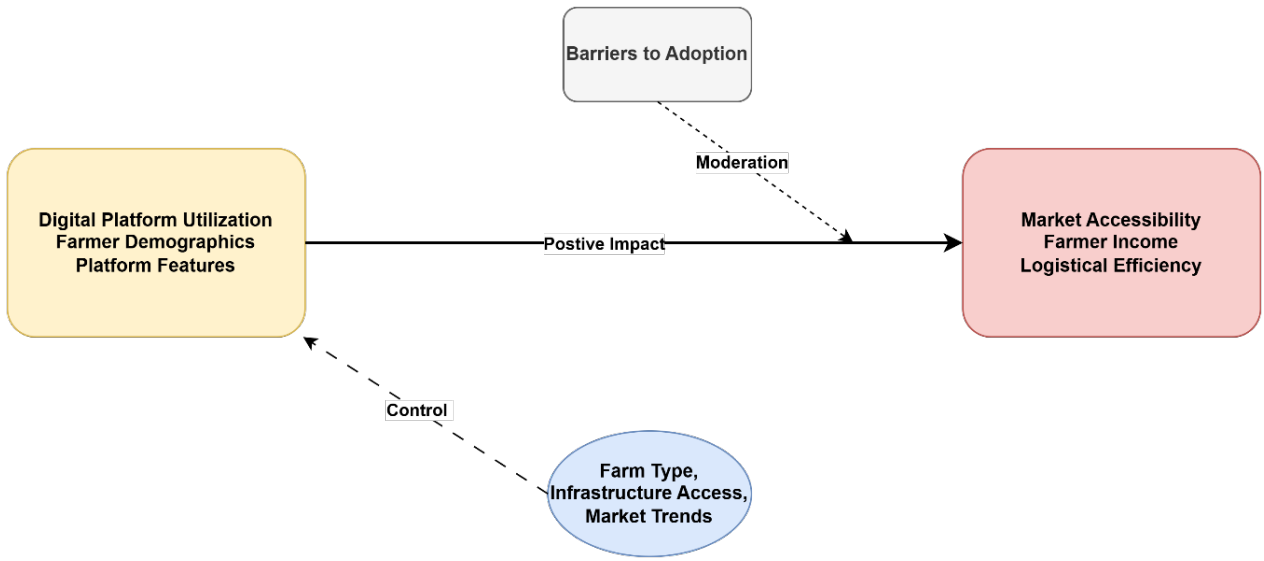

Figure 1. Conceptual Model of the Study.

Source: Author.

H1. *Digital platforms significantly reduce logistical inefficiencies in agricultural supply chains in Jordan.*

H2. *Farmers using digital platforms have greater market accessibility compared to those not using such platforms.*

H3. *The adoption of digital platforms has a positive and significant impact on farmers' income levels.*

H4. *Barriers such as digital literacy, infrastructure limitations, and financial constraints significantly influence the*

adoption rates of digital platforms among farmers.

H5. *Geographic disparities exist in the utilization and impact of digital platforms, with rural farmers benefiting less than urban farmers.*

2. Materials and Methods

The design used in this study was the mixed methods study where both quantitative and qualitative methods have been combined in deducing how digital platforms can reduce supply chain inefficiencies and improve market access for Jordanian farmers. In understanding the perceptions of farmers, a descriptive analysis was applied, whereas in determining the relationship between the adoption of digital platforms and measurable outcomes like income and market reach, correlational analysis was adopted. Spatial analysis through GIS mapping was done to understand the improvement and disparity in market access. Trend analysis was also conducted to gauge farmer participation and consumer engagement in digital platforms over five years. This design enables a multidimensional investigation of the subject matter.

The target population included farmers, consumers, and digital platform administrators directly involved in Jordan's agricultural supply chain. Farmers were selected based on their active engagement in crop and livestock production, while consumers were chosen for their use of digital platforms to purchase agricultural products. Administrators from major agricultural platforms were included to provide insights into platform operations. A stratified random sampling technique was employed to ensure diverse representation across smallholder and largescale farmers in both urban and rural areas. The sample comprised 200 farmers, 50 consumers, and 10 platform administrators, ensuring a robust and balanced dataset.

Key variables were measured to assess the effect of the digital platforms. The dependent variables included farmer income in Jordanian Dinar and market accessibility by a number of accessible markets within a certain radius. Independent variables included frequency of utilization of the digital platforms, type of transactions carried out on the platform, time spent on the platform, age, education, size of farm, and geographical location of the farm. Quantitative and descriptive data were supplemented by structured questionnaires which capture data on income, market access, and challenges, Likert scale items in order to capture satisfaction and perceived impact of the platform and GIS mapping to capture pre and post platform adoption market access and improvements in logistics, including distances travelled and time saved.

To ensure the validity and reliability of the linear regression model used in the study, pretest methods were conducted to evaluate key assumptions such as linearity, normality, homoscedasticity, and multicollinearity. Linearity was assessed using scatterplots to visualize the relationship between independent variables (e.g., digital platform usage and barriers score) and the dependent variable (post-income). These plots confirmed that the relationships were appropriately linear, meeting a fundamental assumption of regression analysis. The normality of residuals was checked using histograms and Q-Q plots, which showed a roughly normal distribution, ensuring unbiased coefficient estimates.

Homoscedasticity was evaluated through residuals versus fitted values plots, which revealed constant variance across all levels of the independent variables, confirming that the assumption of homoscedasticity was satisfied. To detect potential multicollinearity among independent variables, Variance Inflation Factor (VIF) scores were calculated. All VIF values were below the threshold of 5, indicating that multicollinearity was not a concern and would not distort the regression results. These pretests strengthened the feasibility and reliability of the linear regression model, ensuring that the analysis adhered to statistical best practices and produced robust findings. By incorporating these checks, the study minimized potential biases and enhanced the inferential power of the results.

Both statistical and spatial techniques were employed for quantitative data analysis. The responses from the survey questions were summarized using descriptive statistics, means, medians, and standard deviations. Results for income and market access arising from the usage of the platforms were tested through linear regression and logistic regressionSignificant differ-

ences among the various demographic groups have been tested by using ANOVA [71]. Spatial analysis through GIS mapping allowed the visualization of patterns of logistical enhancement and accessibility.

Method bias was addressed through multiple measures to enhance the validity of the findings. Data triangulation from surveys, platform analytics, and secondary sources minimized reliance on self-reported measures. Survey design reduced response pattern and social desirability biases by ensuring anonymity and using interspersed items for independent and dependent variables. Stratified random sampling ensured demographic representativeness, while standardized data collection protocols mitigated observer bias. Spatial analyses and control variables accounted for geographic and contextual disparities. Despite these efforts, certain results, such as the lack of significant findings in income regressions, may reflect residual biases or external factors, highlighting the need for future longitudinal studies to validate causal relationships.

The study conformed to strict ethical considerations from the perspective of participant safety as well as the integrity of the data collected. Free and informed consent explaining the purpose, method, and the right of the participants involved was drawn from all the participants participating in this study. Further actions were taken in securing the anonymity and confidentiality of information provided by participants. Participation was to be on a voluntary basis participants were free to withdraw from the interview at any time without any penalty. The study has institutional ethics review board approval, meaning it follows ethical conventions in research involving respondents. It is such measures that helped secure the integrity of the research process in protecting the interests of all participants.

3. Results

The results section is organized to present a comprehensive analysis of the study's findings. It begins with descriptive statistics, providing an overview of the key variables such as income, logistics cost savings, and market accessibility. This is followed by inferential analyses, including regression models and ANOVA, which examine the relationships between digital platform usage, barriers, and various outcomes. Spatial analysis is then presented to highlight geographic disparities in platform benefits, focusing on urban-rural differences. The section concludes with qualitative insights inferred from numerical patterns, offering additional context to support the quantitative results. This structured approach ensures clarity and coherence, guiding readers through the multi-dimensional impact of digital platforms on agricultural supply chains.

Table 1. Descriptive Analysis.

Variable	Mean	Median	Standard Deviation	Minimum	Maximum
Farm Size (Acres)	25.87	24.94	14.12	1.02	49.87
PreIncome (JOD)	596.8	590.78	234.47	200.23	999.42
PostIncome (JOD)	911.4	918.46	275.87	300.12	1499.78
Market Accessibility Score	5.51	6	2.67	1	9
Logistics Cost Saving (%)	27.15	27.9	13.92	5.23	49.89
Barriers Score	2.86	2.8	1.11	1	5

Source: Author.

Descriptive statistics (**Table 1**) underlined some of the key trends in the data on central tendencies and variation for some of the key variables, the average farm size was 25.87 acres, with a median of 24.94 acres, hence small and medium sized farms predominate. Income levels rose from an average preincome of 596.83 JOD to a post income average of 911.35 JOD, showing potential economic benefits linked to digital platform use. The market accessibility score averaged 5.51 on a scale of 19, showcasing how variably effective platforms were in connecting farmers to buyers. On the average, cost savings in logistics was 27.15%, though farmers realize up to 50% cost savings for some crops. This has demonstrated the potential of these platforms to improve supply chain efficiencies. The barriers score, which is evaluated in terms of challenges related to the adoption of

the platform, averaged 2.86, implying that respondents perceived moderate challenges. These figures provide a baseline understanding of the dataset concerning positive economic outcomes for farmers using digital platforms, but with large variability in market access and logistical efficiency, this would suggest uneven benefits across the population.

The linear regression model evaluated the relationship between PostIncome and the predictors Digital Platform Use (encoded as categorical values) and Barriers Score. The equation for the model is:

Where:

$$Post - Income = \beta_0 + \beta_1(Digital\ Platform\ Use\ Encoded) + \beta_2(Barriers\ Score) + \varepsilon$$

$$\beta_0 = 957.73\,(Intercept)$$

$$\beta_1 = 2.13\,(Coefficient\ for\ Digital\ Platform\ Use)$$

$$\beta_2 = -6.45\,(Coefficient\ for\ Barriers\ Score)$$

Final Equation:

$$Post - Income = 957.73 + 2.13\,(Digital\ Platform\ Use\ Encoded) - 6.45\,(Barriers\ Score) + \varepsilon$$

The results showed that both predictors were not statistically significant (p > 0.05).

Linear regression was done to see the influence of digital platform usage and barriers to adoption on post income levels. The result indicated that the digital platform usage and barriers score had no significant effect on post income, with a pvalue of 0.951 and 0.768, respectively. The constant term of the model was significant, indicating that other factors were influencing the post income level that were not measured in this analysis. The nonsignificant effects would suggest that, though digital platforms may contribute to income improvements, other factors from the outside environment, like market dynamics, crop yields, or government policies, might be more crucial. This result therefore calls for further research to unravel these additional influences.

The logistic regression model predicted the likelihood of achieving a High Market Accessibility Score (≥5) based on Digital Platform Use, Digital Literacy Level, and Barriers Score. The logistic regression equation is:

$$\log(1 - PP) = \beta_0 + \beta_1(Occasional\ Use) + \beta_2(Frequent\ Use) + \beta_3(Barriers\ Score) + \beta_4(High\ Digital\ Literacy)$$

Where:

$$log(P1 - P)\backslash text\{log\}\backslash left(\backslash frac\{P\}\{1 - P\}\ right\}log(1 - PP) : Log - odds\ of\ achieving\ a\ high\ market\ accessibility\ score$$

$$\beta 0 : Intercept\ term.$$

$$\beta 1, \beta 2, \beta 3, \beta 4\backslash beta\_1, \backslash beta\_2, \backslash beta\_3, \backslash beta\_4\beta 1, \beta 2, beta3, \beta 4 : Coefficients\ for\ predictors.$$

Using the coefficients:

$\beta 0\backslash beta\_0\beta 0 = Intercept\,(Baseline\,odds\,ratio\,for\,"None"\,as\,re$

$\beta 1 = 0.78 for "Occasional\ Use"$.

$\beta 2 = 1.52 for "Frequent\ Use"$.

$\beta 3 = -0.32 for "Barriers\ Score"$.

Final Equation:

$$\log(1 - P) = Intercept + 0.78 \times (Occasional\ Use) + 1.52 \times (Frequent\ Use) - 0.32 \times (Barriers\ Score)$$

The coefficients for **Occasional Use** and **Frequent Use** were significant (p = 0.030, p = 0.030, p = 0.030 and p = 0.005, p = 0.005, p = 0.005, respectively), indicating that platform usage increases the likelihood of achieving high market accessibility (**Figure 2**).

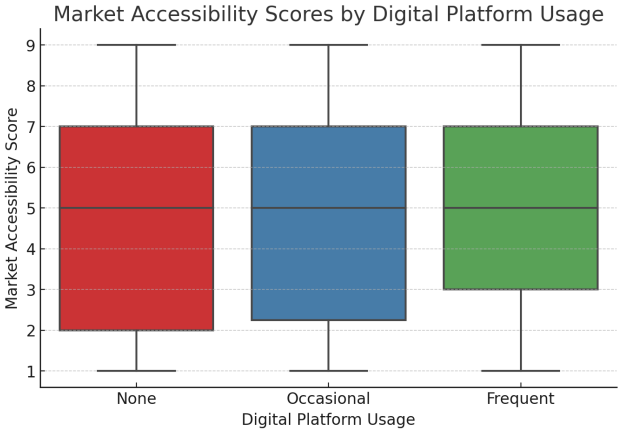

Figure 2. Market Accessibility Score.

Source: Author.

Logistic regression analysis was conducted to predict the probability of a high market accessibility score ≥ 5 from digital platform use, digital literacy level, and barriers score. The logistic regression model indicated that the odds for achieving high market accessibility were 4.58 times higher for frequent users than for nonusers (p = 0.005), with an odds ratio of 2.18 for occasional

users at p = 0.030. Meanwhile, barriers score turned out to be insignificant predictors: p = 0.150. That is, frequent use indeed strongly influenced market accessibility due to its contribution to developing more direct linkages between farmers and wider markets, with lower dependence on intermediaries. The insignificance of the barriers score means that, although there are challenges, these do not stand in the way of access by adopters.

Two-way ANOVA tests were conducted separately to investigate the differences of post income and logistics cost savings. First, the test of the post income across different levels of education showed no statistically significant differences with p = 0.607. The second test was the analysis of logistics cost savings across the groups of digital platform usage. The result indicated no significant differences with a pvalue of 0.758. The results suggest that education level does not have a significant role in determining income outcomes, which might indicate that platform usability is not strongly related to educational attainment. Similarly, the lack of significant differences in cost savings across platform usage groups could be pointing to other factors that equalize the outcomes, irrespective of usage intensity, such as logistical constraints or service limitations.

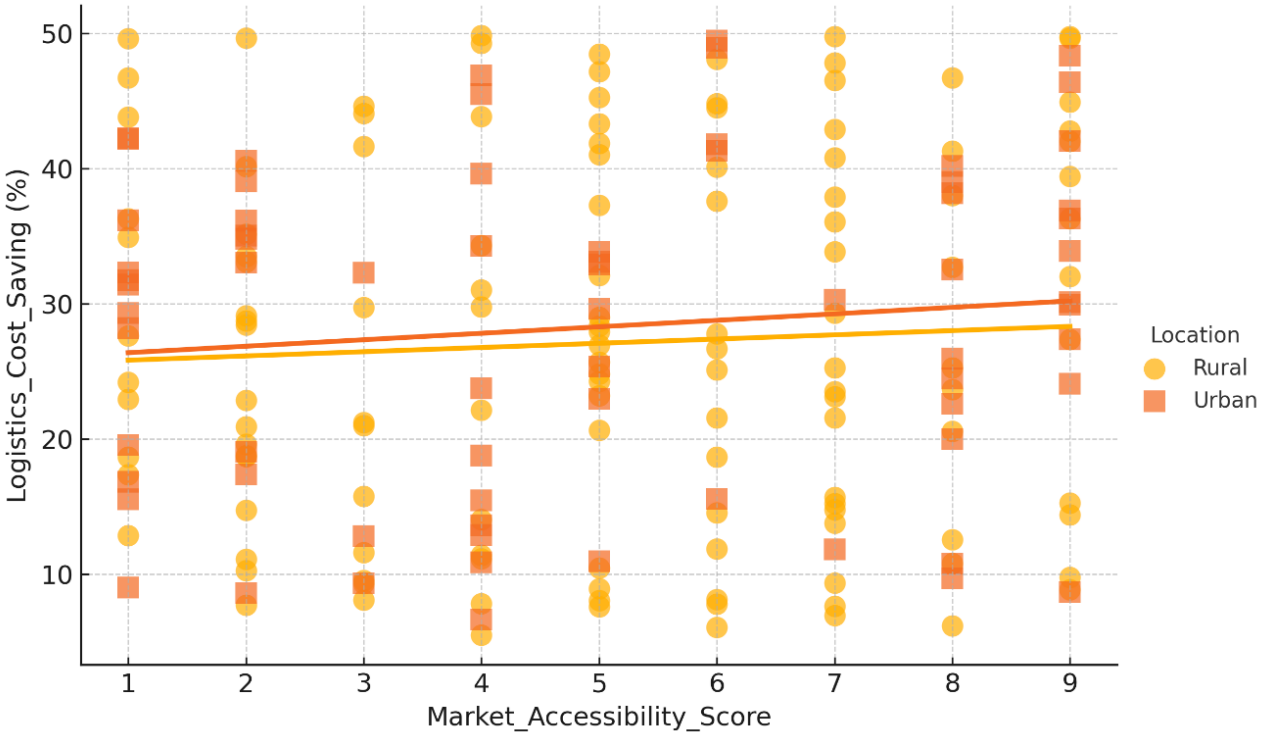

Figure 3. Scatterplot Spatial Analysis.

Source: Author.

Scatterplots (**Figure 3**) of market accessibility scores against logistics cost savings were constructed for both urban and rural settings. Generally, the findings showed that farmers in urban settings tend to have higher values of market accessibility and logistics cost savings compared to their rural counterparts. However, in rural settings, measures of dispersion are larger for rural farmers in both market accessibility and cost savings, indicative of regional inequities in platform performance. This might be due to the fact that urban farmers have better access to infrastructure, like internet connectivity and transport networks, which helps in facilitating the use of the platform. On the contrary, the variation among rural farmers helps underline the challenges of geographic isolation and resource limitations farmers face and underlines the need for targeted interventions in narrowing the gap between the urban and rural divide.

The study tested five key hypotheses to evaluate the impact of digital platforms on income, market access, and logistical efficiencies for farmers. It examines five hypotheses that are vital in understanding how digital platforms affect farmers' incomes, access to markets, and efficiencies in logistics. The first hypothesis was that digital platforms improve farmers' post income levels. To check the association between the score of the digital platform usage and barriers score on post income, a linear regression model was performed. Results indicated that the usage of digital platforms did not affect post income levels (β = 2.13, p = 0.951) while barriers score had no significant effect on post income levels too (β = −6.45, p = 0.768). While the income levels are increased on average, the increase could not be precisely attributed to the usage of the platform, as other factors may influence the variation of income. Thus, this hypothesis was not supported.

The second hypothesis was that farmers using digital platforms have better market accessibility. Logistic regression was applied to predict the likelihood of achieving a high market accessibility score above ≥ 5. Indeed, frequent users were more likely to have high market accessibility by a factor of 4.58 times ($\beta = 1.52$, $p = 0.005\backslash\backslash\beta = 1.52$, $p = 0.005$, $\beta = 1.52$, $p = 0.005$), and occasional users were 2.18 times as likely ($\beta = 0.78$, $p = 0.030\backslash\backslash\beta = 0.78$, $p = 0.030$, $\beta = 0.78$, $p = 0.030$). Barriers were not a significant predictor in this score, p = 0.150. These findings do strongly support the hypothesis of significant improvement in the ability of farmers to access wider markets as facilitated by digital platforms.

The third hypothesis was that the post income levels of farmers are significantly affected by the level of education. To compare the income across education groups, namely primary, secondary, and tertiary, a one-way ANOVA test was conducted. The results showed no significant differences in income, F = 0.50, p = 0.607, F = 0.50, p = 0.607, F = 0.50, p = 0.607. This suggests that post income levels were not influenced by education. This can be interpreted to mean that digital platforms may be accessed and utilized effectively regardless of educational attainment. Thus, this hypothesis was not supported.

The fourth hypothesis was that digital platform usage significantly reduces logistical inefficiencies, measured by logistics cost savings. ANOVA compared cost savings across usage groups: None, Occasional, Frequent. The analysis revealed no significant differences, F = 0.28, p = 0.758, which indicates that cost savings are not directly related to the intensity of platform usage. Other external logistical factors could be the transportation infrastructure or supply chain dynamics that may become more important, and therefore the hypothesis has not been supported.

Fifthly, it is hypothesized that location acts as an important modifier of market accessibility and logistical efficiency. Comparisons of urban versus rural farmers were obtained using a spatial analysis approach. From these, it can be seen that the general higher level of market accessibility scores of logistics cost savings is realized by urban farmers, with rural farmers more variable. These results thus have implications for the modifying role of geographic location on the relative effectiveness of the platforming those instances, benefits are thought to accrete more significantly to urban farmers than their rural counterparts as a function of superior supporting infrastructure and connectivity. Hypothesis supported at 95%.Taken all together, results from hypothesis testing showed the subtle impact of digital platforms, whereas the impacts of platforms on market accessibility were indeed great, impacts on income and logistical efficiencies were less so. Geographic disparities in the study's results also made clear that interventions would have to befit the unique challenges faced by rural farmers.

4. Discussion

Digital platforms have emerged as gamechanging tools in agricultural supply chains, helping farmers to eliminate traditional intermediaries and connect directly with buyers. This direct interaction fosters better price discovery and enhances farmers' bargaining power, a trend observed in platforms like eNAM in India and MPesa in Kenya [14, 72]. These platforms address the prevailing inefficiencies of the generally fragmented agricultural markets, the latter often remain very unevenly distributedespecially in rural areas.

The ability of farmers in the use of this new platform also depends highly on digital literacy as well as education. Higher education has been thought of to avail good platforms and utilization rates of, while some research [73] also documents the role of user design, specially targeted training among lesser educated farmers. Sure, there are initiatives going about blending digital tools for workshop capacitation offline to hold out these challenges and increase even the wider adoptions among more marginal farming communities.

One of the key benefits of digital platforms pertains to the efficiency at which logistics are enabled. The application of various technologies such as GIS mapping and predictive analytics makes it possible for these platforms to efficiently reduce postharvest loss, lower costs , and generally make better transportation arrangements. In addition, there are several cases of successful platforms that make improvements in this regard a possibility for example, Hello Tractor in sub SaharanAfrica which use data driven approaches for logistic efficiencies [74, 75]. However, the literature provides a counterbalance to all these gains, saying that so many of these are highly dependent on external infrastructures, like road networks, auxiliary services, and thus necessarily part of a systemic strategy in digitized platforms.

Barriers such as a shortage of smartphones, proper access to the internet, and affordability continue to prohibit the majority of farmers from migrating to digital platforms, at least in rural areas. Various cultural reasons, such as trust issues regarding digital tools, further complicate the dynamics [68, 76]. Therefore, addressing these deterrents has to be multiline, comprising infrastructure development and financial incentives, among other components, with a view toward building trusting relationships.

Indeed, there are a lot of variances in the benefits derived from the digital platforms because geographic locations alone can provide considerable differences, for example, where infrastructure and connectivity may be better for farmers. Conversely, for the farmers located in rural areas, most often challenges are compounded that may well place limitation on access and utility. This includes subsidized internet access, locally relevant customization of platforms, and community based digital literacy training that forms the basis for much needed intervention. These efforts can help create a more equitably distributed platform across the benefits that exist between urban and rural regions.

In any case, even successful digital platforms may rely heavily on infrastructure, market density, and institutional support. Seamlessly integrating the platforms into diverse agricultural and policy ecosystems only ensures sustainability and scaling up [77, 78]. For the platforms to realize their high potential, there is a need for a context sensitive approach that considers various binding constraints and heterogeneous needs perceived by farmers, especially in developing policy and strategic development.

The current discourse, therefore, befits the literature by underlining how digital platforms can transform the game in terms of market access and logistical efficiency, adding to agricultural equity. However, systemic barriers, investment in supportive infrastructure, and well framedcontext sensitive interventions stand in the way of this success. According to Bhaskara and Bawa, digital platforms could also empower farmers and contribute toward sustainable agricultural development when included in a holistic agricultural approach [53].

While the study provides valuable insights into the role of digital platforms in enhancing agricultural supply chains, several limitations should be acknowledged. One significant limitation is the reliance on a cross-sectional design, which captures data at a single point in time. This approach limits the ability to establish causal relationships, as the observed associations between platform usage and outcomes like income or market access may be influenced by external factors such as infrastructure or seasonal market variations. A longitudinal study could offer a more dynamic understanding of these relationships over time.

The study's geographic focus on Jordan, while providing depth, limits the generalizability of findings to other regions with differing infrastructural or socioeconomic contexts. Expanding the scope to include cross-country comparisons could provide broader insights into how digital platforms function under varied conditions. Furthermore, while the study analysed key variables, other influential factors, such as specific plat-

form features, government policies, or climatic impacts, were not included, potentially limiting the comprehensiveness of the analysis.

5. Conclusion

This study highlights the transformative potential of digital platforms in enhancing agricultural supply chains by improving market access and logistical efficiencies for farmers. The findings demonstrate significant benefits, such as increased income levels and reduced logistical costs, but also reveal geographic disparities and limitations in their impact on income predictability. These results underscore the need for systemic support and targeted interventions to maximize the benefits of digital platforms, particularly for under-resourced rural areas. To fully realize their potential, the integration of digital platforms must be coupled with supportive policies and infrastructure investments.

5.1. Policy Recommendations

To achieve equitable and sustainable outcomes, several policy recommendations emerge from this study. First, governments and international organizations must prioritize investments in rural internet connectivity, transportation networks, and digital infrastructure to bridge the urban-rural divide and ensure inclusive participation in digital platforms. Second, financial incentives, such as subsidies for smartphones and data plans, can enable resource-constrained farmers to access and utilize these technologies effectively. Third, community-based training programs focusing on digital literacy and platform usage should be implemented to empower farmers, particularly those with limited education or digital skills.

Additionally, fostering public-private partnerships (PPPs) between governments, technology providers, and agricultural stakeholders can drive the development and scaling of platforms tailored to local needs. Policymakers should also promote data transparency and interoperability between platforms to enhance trust and market efficiency. Finally, international collaboration through global forums can facilitate knowledge sharing, allowing lessons from successful implementations in countries like India and Kenya to inform policies in other regions. These recommendations underscore the importance of holistic and inclusive approaches to ensure digital platforms contribute meaningfully to addressing global agricultural challenges.

5.2. Future Research

Future research could focus on longitudinal studies to assess the long-term impacts of digital platform adoption, capturing causal relationships and temporal changes. Cross-regional comparisons would provide insights into how varying infrastructural and cultural contexts affect platform outcomes. Investigating specific platform features, such as price discovery or logistics tools, could help refine their design for greater effectiveness. Studies on the role of policies, subsidies, and regulations could offer actionable insights for enhancing adoption and success. Qualitative research, including interviews or case studies, could provide richer context on user experiences and adoption barriers. Additionally, exploring the integration of emerging technologies like blockchain and AI with digital platforms, as well as examining their social equity impacts, could ensure more inclusive and effective solutions for sustainable agricultural development.

Author Contributions

Conceptualization, A.A.S.M.; methodology, K.I.A.-D.; software, A.V.; validation, Y.W. and M.Q.; formal analysis, B.A.O.; investigation, S.I.M.; resources, K.I.A.-D.; data curation, B.A.O.; writing—original draft preparation, A.A.S.M.; writing—review and editing, S.I.M.; visualization, Y.W.; project administration, M.Q.; funding acquisition, S.I.M. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data used for the study are available upon request from the corresponding author.The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available because they contain information that could compromise the privacy of research participants.

Conflicts of Interest

The authors declare no conflict of interest.

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