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How Can VAT Exemption Policies Promote the Digital Transformation of Green Agricultural Enterprises: from the Perspective of High-Quality Development

Huimin Yang
Asia Europe Institute, University of Malaya, Kuala Lumpur, Malaysia, 50603.
ORCID iD: https://orcid.org/0009-0005-2947-0182
Email: 22100698@siswa.um.edu.my

Rajah Rasiah*
Asia Europe Institute, University of Malaya, Kuala Lumpur, Malaysia, 50603.
ORCID iD: https://orcid.org/0000-0002-6654-3011
Email: rajah@um.edu.my

VAT exemptions alleviate financial burdens for agricultural enterprises, enabling them to allocate resources towards the adoption of advanced digital technologies. This study utilises existing tax data alongside records on agricultural activities and digital adoption to examine the role of tax incentives in fostering technological advancements within environmentally sustainable agricultural practices. Employing a quantitative methodology, the study applies statistical and econometric techniques to assess the impact of VAT exemptions on farmers' decisions to implement digital agricultural technologies. The findings indicate that tax incentives enhance the financial feasibility of acquiring smart agricultural technologies and IoT equipment for sustainable farms. In large enterprises, digital transformation is directly linked to revenue generation, as VAT incentives facilitate the adoption of new technologies. The study further highlights that government initiatives and business scale influence the effectiveness of VAT exemptions in modernising agricultural practices. VAT exemption policies support enterprises in integrating sustainable technologies, enhancing operational efficiency while mitigating environmental impact. Through a difference-in-differences (DID) approach, the research evaluates the influence of VAT exemption policies on digital transformation. Using panel data from 50 green agricultural enterprises spanning 2015 to 2022, the study analyses digital investment, high-quality development indicators, and sustainable agricultural initiatives. Robustness checks and fixed-effects models yield reliable results, affirming VAT policies as key drivers of green innovation and sustainable development. The findings underscore the significance of tax policies in sustainable agriculture and demonstrate how aligning economic incentives with technological advancements fosters higher-quality growth. Policymakers should develop comprehensive tax frameworks complemented by support mechanisms to maximise the effectiveness of VAT exemptions.

Keywords: High-Quality Development of Enterprises (Green Development); Digital Transformation; Agricultural Economy; VAT Exemption Policies and Sustainable Agriculture.

Introduction

From the perspective of global economic development, food security, and environmental sustainability, the agricultural sector plays a pivotal role. However, the sector operates under challenging conditions as the world grapples with unique environmental issues, including ecological degradation, excessive residues, and biodiversity loss. The transition to green agriculture, encompassing eco-friendly and resource-efficient practices, is becoming increasingly essential to meet the rising demand for food while safeguarding the planet (Solomon, Janda, & Molnár, 2024). A key approach to addressing sustainability objectives is digital transformation, which involves the integration of advanced technologies such as precision farming, IoT sensors, blockchain, and artificial intelligence. However, financial constraints often hinder enterprises from transitioning away from traditional agricultural models, particularly when economic pressures must be balanced against costly yet innovative solutions. In this context, VAT exemption policies play a crucial role (Hendrawan et al., 2024).

These policies alleviate the financial burden on agricultural enterprises, enabling them to allocate more resources toward deploying digital tools and sustainable technologies. By reducing the costs associated with acquiring digital infrastructure, VAT exemptions facilitate the adoption of modern technologies that enhance productivity while promoting ecological integrity. Such financial relief is particularly vital for agricultural enterprises, as initial investments in digital tools may be perceived as high-risk or difficult to justify (Kwilinski et al., 2022). From a high-quality development perspective, VAT exemption policies foster an environment conducive to technological adoption aligned with the Sustainable Development Goals (SDGs). Sustainable agricultural development necessitates increased productivity, optimised resource utilisation, environmental conservation, and economic viability. VAT exemptions support these objectives by making green technologies more accessible, promoting the establishment of digital farming systems, and encouraging eco-friendly agricultural practices (Omol, 2024). Precision agriculture, for instance, utilises data-driven insights for input management, irrigation, and pest control, significantly reducing input costs, enhancing crop yields, and minimising environmental impact. Moreover, VAT exemptions stimulate innovation and entrepreneurship within the agricultural sector (Manyati & Mutsau, 2021).

These policies not only alleviate the tax burden on businesses but also facilitate reinvestment in research and development (R&D) for emerging technologies and sustainable agricultural practices. The adoption of digital platforms for market access, resource management systems, and data analytics enhances the value of agricultural supply chains by improving operational efficiency, reducing costs, and increasing transparency. This transition towards digitalised farming aligns with global efforts to establish a more sustainable and inclusive economy (Raymundus & Rosdiana, 2021). For instance, VAT exemptions can enable large-scale investments in solar-powered farms and wind energy systems. These initiatives reduce reliance on non-renewable energy sources while lowering operational costs, thereby enhancing both the profitability and environmental sustainability of agricultural enterprises.

Additionally, blockchain technology facilitates greater transparency, traceability, and trust within agricultural supply chains, aligning with consumer demand for sustainably produced food while strengthening the resilience and competitiveness of the agricultural sector (Souvannasouk et al., 2021). Ultimately, VAT exemptions encourage the adoption of efficient, transparent, and environmentally sustainable agricultural practices, fostering both economic and ecological growth. Given the increasing global emphasis on environmental sustainability, these policies will be of strategic importance in shaping the future of agriculture. By incentivising the use of digitally enabled technologies, VAT exemptions contribute to the simultaneous advancement of economic and environmental objectives within the sector (Hernandez et al., 2024).

This research examines the relationship between VAT exemption policies and the accelerated digital transformation of various agricultural operations. The study investigates the impact of tax incentives on technology adoption, providing insights that support informed decision-making for policymakers and agricultural enterprises.

Aim of This Study

This study examines a policy framework in which VAT exemptions drive digital transformation in green agricultural enterprises while addressing financial and operational challenges. The research aims to assess the extent to which these policies contribute to high-quality development alongside sustainable agricultural practices. The specific objectives are as follows:

- To analyse the relationship between VAT exemption policies and the adoption of digital technologies in sustainable agriculture across small, medium, and large enterprises.
- To evaluate how VAT exemptions, mitigate financial constraints and enhance technological readiness, thereby fostering high-quality development in sustainable agricultural practices.

This study explores the role of VAT exemption policies in facilitating the digitalisation of sustainable agriculture and promoting its high-quality development. The research investigates how tax incentives enable farmers to adopt advanced technologies by leveraging existing government and industry data sources. It focuses on regions that implement VAT exemptions alongside initiatives aimed at advancing digital and green technologies. Using statistical and econometric methods, the study analyses how variations in business size and technological capabilities influence outcomes. The findings will provide policymakers and stakeholders with evidence-based insights to enhance agricultural productivity while ensuring resource sustainability. Despite the growing interest in digital agriculture as a driver of sustainable development, limited research has examined VAT exemption policies as fiscal incentives for this transition. Most studies focus on general tax benefits and environmental programmes without specifically assessing how VAT exemptions facilitate the adoption of digital agricultural technologies (Kowal & Przekota, 2021). Furthermore, existing research has yet to explore how VAT policies impact enterprises of varying sizes, considering their income levels and technological readiness. The influence of VAT exemptions on technology adoption and high-quality development in sustainable agriculture remains an underexplored area. This study addresses these research gaps by utilising secondary data to evaluate how VAT exemptions foster innovation, enhance operational efficiency, and contribute to environmental sustainability in agricultural enterprises.

Literature Review

Digital Transformation

VAT exemption policies for green agricultural enterprises play a crucial role in driving their digital transformation, facilitating technological upgrades, and fostering high-quality development. By alleviating tax burdens, these policies provide businesses with financial flexibility to invest in innovative digital tools that enhance agricultural sustainability, efficiency, and productivity (Godlewska, Ronga, & Michalak, 2021). With the support of VAT exemptions, agricultural enterprises can adopt precision farming techniques, smart irrigation systems, and automated machinery. These technologies optimise resource utilisation, minimise waste, and maximise crop yields in alignment with environmentally sustainable farming practices.

Furthermore, VAT exemptions enable enterprises to invest in e-commerce platforms, allowing them to reach customers directly, expand market share, and enhance profitability by reducing reliance on intermediaries (Torky & Hassanein, 2020). These digital innovations improve efficiency, enhance traceability, and contribute to higher-quality agricultural produce. Additionally, data analytics and machine learning technologies support businesses in inventory management, logistics optimisation, and market forecasting, ultimately streamlining operations. The integration of big data analytics, IoT-based farming systems, and cloud-based platforms facilitates comprehensive monitoring and management of farming and distribution activities. These technologies not only optimise agricultural operations but also enable real-time monitoring of carbon emissions, water usage, and overall resource efficiency, reinforcing the sustainability of agricultural enterprises (Feng et al., 2022).

VAT Exemption Policies

VAT exemption policies for green agricultural enterprises play a crucial role in advancing their digital transformation, enhancing efficiency, sustainability, and technological adoption, thereby fostering high-quality development. These policy measures alleviate tax burdens, providing businesses with financial flexibility to invest in innovative technologies that improve productivity while minimising environmental impact (Akour & Alenezi, 2022). VAT exemptions grant enterprises the financial capacity to adopt digital tools that optimise farm management and resource utilisation, promoting sustainable agricultural practices—a cornerstone of high-quality development. Moreover, digital solutions facilitate real-time monitoring and management of soil health, pest control, and weather patterns, enabling businesses to optimise yields while ensuring long-term sustainability (Akour & Alenezi, 2022). Additionally, VAT exemptions can extend to e-commerce platforms, allowing agricultural enterprises to access broader markets directly. By reducing reliance on intermediaries, digital platforms enhance profitability, market transparency, and consumer access to products with well-defined sustainability credentials and certifications.

Furthermore, VAT exemptions encourage the adoption of blockchain technology, which strengthens supply chain transparency, enabling consumers to verify the origin and distribution pathways of agricultural products. This enhanced traceability fosters consumer trust, improves brand reputation, and elevates quality control standards. Additionally, VAT exemptions support businesses in leveraging artificial intelligence and data analytics for data-driven decision-making, aligning with the broader objectives of high-quality development, including forecasting, resource management, and sustainability reporting. By incentivising investment in digital transformation, VAT exemption policies contribute positively to the economic, environmental, and social outcomes of the agricultural sector (Chen & Li, 2024).

High-Quality Development

VAT exemption policies for green agricultural enterprises play a pivotal role in achieving high-quality development by facilitating their digital transformation. These policies provide businesses with essential financial relief, enabling investment in innovative technologies, the enhancement of production processes, and overall improvements in sustainability (Wang & Shao, 2024). Achieving a balance between economic growth, environmental preservation, and technological advancement is fundamental to high-quality development, and VAT exemptions serve as a catalyst for this transition. By supporting the adoption of advanced agricultural technologies, such exemptions help farmers minimise water and fertiliser usage while improving yields, reducing waste, and mitigating environmental impact—key components of high-quality development (Tao, Zhang, & Shangkun, 2022).

Furthermore, VAT exemptions facilitate the integration of blockchain technology, enhancing transparency within agricultural supply chains. Blockchain enables consumers to trace the origins and distribution pathways of agricultural products via smartphone scanning, fostering trust in green agricultural produce (Cnossen, 2018). This transparency encourages informed purchasing decisions and incentivises businesses to adopt more sustainable practices. Additionally, VAT exemptions contribute to increased operational efficiency, a critical aspect of digital transformation (Wu, Cheng, & Yang, 2024). Cloud-based platforms allow enterprises to optimise resource management, inventory control, and logistics. By incorporating big data analytics and IoT technologies into agricultural systems, businesses can enhance operational efficiency, ensuring cost-effective resource utilisation while increasing profitability (Solomon et al., 2024). Thus, VAT exemption policies not only drive digital transformation in agriculture but also strengthen environmental sustainability and economic viability within the sector.

Sustainable Agriculture

VAT exemption policies play a crucial role in supporting the digital transformation of green agricultural enterprises, aligning with the broader objectives of high-quality development. These policies provide fiscal relief, enabling businesses to invest in cutting-edge technologies that maximise resource efficiency, enhance yields, and minimise environmental impacts, thereby ensuring long-term agricultural sustainability. A key approach facilitated by VAT exemptions is the adoption of precision farming technologies, which form the foundation of sustainable agriculture (Solomon et al., 2024). These technologies employ satellite imaging, IoT sensors, drones, and real-time data analytics to optimise irrigation, fertiliser, and pesticide application. By reducing resource wastage and improving operational efficiency, precision farming supports environmentally responsible agricultural practices. VAT exemptions reduce the financial burden of adopting such technologies, encouraging their widespread implementation and fostering sustainable farming.

Additionally, VAT exemptions enable greater investment in renewable energy solutions, which are essential for reducing agricultural reliance on fossil fuels and lowering carbon emissions (Oebel et al., 2024). For instance, solar-powered irrigation systems and wind energy solutions provide sustainable alternatives to conventional power sources. By enhancing financial flexibility, VAT exemptions incentivise enterprises to integrate green energy solutions, reinforcing their environmental sustainability commitments.

Digital traceability also plays a vital role in sustainable agriculture, facilitated by blockchain and data analytics technologies (Zhang & Zhang, 2024). These systems enhance supply chain transparency, allowing consumers to verify the origins of agricultural products and make informed purchasing decisions. Furthermore, blockchain technology helps identify inefficiencies within the supply chain, reducing waste and promoting responsible business practices. Finally, VAT exemptions support the adoption of smart water management systems, which optimise water use in agricultural production (Wang & Shao, 2024). Given the increasing scarcity of water resources, such systems are essential for ensuring long-term agricultural sustainability. By facilitating investment in water conservation technologies, VAT exemption policies contribute to the broader goal of sustainable and efficient agricultural development.

Agricultural Revenue

VAT exemption policies for agricultural enterprises significantly enhance revenue generation by facilitating the transition to sustainable business models through digital transformation. These policies provide financial relief, enabling companies to invest in advanced technologies and practices that improve productivity while promoting sustainability, ultimately leading to long-term revenue growth (Rice et al., 2024). One of the primary ways VAT exemptions contribute to increased revenue is by encouraging the adoption of precision farming technologies. IoT sensors, drones, and satellite imaging optimise resource utilisation, including water, fertilisers, and pesticides, minimising waste and improving yields. By reducing input costs and enhancing crop quality, these technologies lead to higher profits and greater efficiency in agricultural operations.

Furthermore, VAT exemptions facilitate the integration of renewable energy solutions in agricultural activities (Dahal, Bhattarai, & Budhathoki, 2024). Solar-powered irrigation systems and wind energy solutions lower long-term energy costs, reducing operational expenses and increasing profit margins. By providing enterprises with the financial flexibility to invest in sustainable energy, VAT exemptions also help businesses comply with environmental regulations and gain a competitive advantage in the expanding green market (Avila-Lopez et al., 2024). Digital traceability systems, particularly blockchain technology, further support revenue growth by enhancing supply chain transparency. Consumers increasingly prioritise sustainably sourced products, and businesses that can verify product traceability can command premium prices. VAT exemptions allow agricultural enterprises to implement blockchain and other digital tools, ensuring product quality and sustainability while fostering consumer trust. This, in turn, opens opportunities for expansion into eco-conscious markets and the development of new revenue streams (Akbulaev, 2024).

Data and Methodology

Research Design

This study employs a quantitative research design to systematically examine the relationship between VAT exemption policies, revenue, high-quality development, and sustainable agriculture in driving the digital transformation of green agricultural enterprises. Using panel data analysis from 2015 to 2022, the study relies on secondary data from authoritative sources such as the OECD Tax Database and FAO Statistics. These databases provide comprehensive datasets on fiscal regulations, agricultural indicators, and economic metrics, enabling a thorough assessment of the impact of fiscal incentives on technology adoption. The study quantitatively evaluates digital transformation through the lens of fiscal policy by establishing measurable relationships among key variables. Statistical modelling is employed, with five primary independent variables, including VAT exemption policies, financial accessibility, and high-quality development indicators for sustainable agriculture and revenue outcomes. To enhance result reliability, control variables capturing regional and temporal factors are incorporated, ensuring that variations across enterprises and time periods are accounted for (Chicu, 2022). A two-way fixed-effects econometric model is utilised to assess business-specific and temporal changes, allowing for a robust analysis of policy impact. Additionally, multiple robustness checks are conducted, including alternative model specifications and interactive elements, to ensure the stability and validity of the findings (Arzo & Hong, 2024a, 2024b). The research framework aligns with high-quality development principles by emphasising environmental sustainability and green agricultural practices within the broader economic landscape.

Estimation Model

This study employed statistical techniques to assess the impact of tax exemptions, financial accessibility, high-quality development, and sustainable agricultural practices on digital transformation in green agricultural enterprises. In Stata, the analysis involved importing and cleaning secondary data, defining the panel structure, implementing a fixed-effects model, examining interaction effects, and conducting robustness checks. These steps ensure that the study reliably captures the relationship between fiscal policies and digital adoption within a robust econometric framework. By utilising a two-way fixed-effects panel regression approach, the model accounts for dynamic interactions among these variables over time while controlling for enterprise-level and temporal variations. This methodological framework provides a rigorous approach to analysing how digital progress in agriculture is influenced by sustainability and high-quality development. The benchmark estimation model is structured as follows:

$$DT_{it} = \beta_0 + \beta_1 VAT_{it} + \beta_2 QD_{it} + \beta_3 SA_{it} + \beta_4 REV_{it} + \epsilon_{it}$$

The model evaluates the influence of various factors in driving digital transformation within green agricultural enterprises by incorporating key variables. Digital transformation is defined as the adoption of advanced technological systems by agricultural businesses to enhance productivity and strengthen their market position. This study measures four independent factors including VAT reduction VAT_{it} which lowers taxes to support technological investment; QD_{it}measuring quality development that brings sustainable innovation for efficiency; SA_{it} representing sustainable agricultural methods that combine with digital tools to use resources better; and $REV_{it}$to test financial strength that helps companies fund digital technology purchases. The constant $\beta_0$shows how much digital transformation happens to start with, while the combined values of $\beta_1 + \beta_2 + \beta_3 + \beta_4$tell us how much and in what way each factor contributes to a company's digital progress. Facilitative relationships are indicated by positive coefficients, while negative coefficients represent inverse effects. The error term ϵ_{it}shows how hidden factors affect the result. This approach evaluates the impact of fiscal incentives, economic power, and sustainability efforts within a comprehensive framework to assess their influence on digital advancements in green agricultural enterprises.

Data Resources

A purposive sampling strategy is employed to examine sustainable agricultural enterprises that utilise digital technologies and benefit from VAT exemptions (Avotra et al., 2021; Dar et al., 2022; Sandra Marcelline et al., 2022). The sample includes businesses of varying sizes, with a focus on sustaining agricultural practices. Only enterprises with complete financial and performance records were considered, resulting in a final dataset of 400 fully documented observations to enhance data reliability. The inclusion criteria encompass agricultural businesses engaged in sustainable farming, adopting digital technologies, and receiving VAT exemptions for sustainability-driven agricultural production or digital transformation. Additionally, eligible companies must maintain financial and operational records from 2015 to 2022. Enterprises outside the agricultural sector, those lacking VAT exemption data, or those not employing digital technologies were excluded. Further, businesses without complete financial or performance records were omitted to maintain data integrity. The study period (2015–2022) aligns with global policy trends promoting cleaner technologies and digital agricultural support through VAT incentives.

Reliable data sources are utilised, including the IMF Fiscal Monitor and OECD Tax Database for VAT policy insights, as well as FAO Statistics and Eurostat for agricultural and sustainability data. Statista provides technology adoption trends, while CSMAR and WIND offer Chinese enterprise-level data, and government tax portals supply country-specific VAT exemption records. To ensure robustness, alternative model specifications, substitution of explanatory variables, and instrumental variable techniques are applied. Continuous variables are Winsorized at the 1% level to control for outliers. Advanced statistical analyses, including mediation and moderation techniques, are conducted using STATA software. This study thus provides a comprehensive analysis of how VAT exemptions facilitate both digital transformation and environmentally sustainable advancements in agricultural enterprises.

Variable Description

The primary estimation model for analysing the relationship between VAT exemptions and digital transformation is formulated as follows:

$$DT_{it} = \beta_0 + \beta_1 VAT_{it} + \beta_2 QD_{it} + \beta_3 SA_{it} + \beta_4 REV_{it} + \epsilon_{it}$$

Digital Transformation DT_{it}

Green agricultural enterprises demonstrate their level of digital transformation through the adoption of IoT, AI, and blockchain technologies, enhancing operational efficiency and sustainability while maintaining a competitive market position. Digital transformation is measured by tracking the number of implemented technologies, digital process integration ratios, and investments in digital infrastructure. It serves as the dependent variable, reflecting how small enterprises leverage digital tools to improve productivity and sustainability (Oliveira & De Souza, 2022).

VAT Exemption Policies VAT_{it}

Businesses adopting digital technologies benefit from VAT exemptions, leading to a measurable reduction in tax payments, either as a percentage or a fixed amount. The analysis indicates that such fiscal incentives alleviate financial constraints, enabling enterprises to invest in new technologies more effectively (Kowal & Przekota, 2021).

High-Quality Development QD_{it}

Enterprises prioritise environmental preservation while enhancing operational efficiency, aligning with the principles of high-quality development. Progress is assessed through sustainability initiatives, green certifications, and performance metrics on innovation and efficiency, demonstrating their impact on digital transformation and business growth (Xu, Liu, & Shang, 2021).

Sustainable Agriculture SA_{it}

Sustainable agriculture integrates eco-friendly farming practices that minimise environmental impact while maintaining stable crop yields. This variable is measured through indicators such as resource efficiency, emission reductions, and the adoption of green techniques. The study explores how these sustainable practices facilitate and encourage the uptake of digital technologies (Tian et al., 2021).

Agriculture Revenue REV_{it}

An enterprise's financial capacity to invest in digital technologies is reflected in its revenue. Annual revenue and profit margins serve as key indicators of financial stability, determining the organisation’s ability to implement digital solutions (Xu et al., 2021).

Error Term ϵ_{it}

The error term accounts for unobserved variables influencing digital transformation, ensuring the model remains robust despite missing or external factors.

Results and Discussion

This section presents the empirical findings on the impact of VAT exemption policies on the digital transformation of sustainable agriculture. A two-way fixed-effects regression model was applied to data from 2015 to 2022 to examine how VAT exemptions influence total revenue, quality progress, and digital adoption. The results highlight how fiscal incentives facilitate technological integration and sustainable practices, identifying key pathways that support high-quality agricultural development. The dataset reveals patterns consistent with prior research, affirming that digital transformation and sustainable agriculture are crucial drivers of innovation and sectoral growth (Adama & Okeke, 2024). Studies from China and Turkey indicate that regional variations in technology adoption influence digital transformation and sustainability outcomes. The findings validate previous research demonstrating the inverse relationship between tax burdens and agricultural revenue, as higher tax liabilities negatively impact financial performance (Şahin, 2024).

The study's digital transformation metrics provide empirical support for existing literature on AI, IoT, and renewable energy technologies as critical solutions to global agricultural challenges (Dayıoğlu & Turker, 2021). Statistical techniques were employed to assess the impact of VAT exemptions on digital adoption within sustainable agriculture. Regression analysis was conducted to determine how tax exemptions influence technological uptake, while business size and operational characteristics were controlled for greater accuracy. Additionally, a difference-in-differences (DID) analysis was implemented to measure shifts in digital adoption before and after policy enactment, ensuring a robust assessment of VAT exemption policies in advancing digital transformation in agriculture.

Table 1: Descriptive Statistics.

Variable	Observations	Mean	Std. Dev.	Min	Max
Digital Transformation	400	5864.38	2665.96	1012	10890
High Quality Development	400	0.76355	0.01508	0.5	1.09
Sustainable Agriculture	400	0.871275	0.89202	0.7	1.05
Revenue	400	1236346	455991	50504	215821

Table 1 presents a summary of the dataset's 400 entries, illustrating the distribution and average levels of key variables. Digital transformation scores exhibit significant variation, with an average of 5,864.38 and a standard deviation of 2,665.964, reflecting disparities in technological adoption among enterprises. The recorded values range from 1,012 to 10,890, highlighting differences in the extent of digital tool implementation. High-quality development demonstrates a mean score of 0.76355, with a standard deviation of 0.1507655, indicating that while businesses prioritise quality improvements, their approaches vary. Sustainable agriculture maintains consistently high performance, with an average score of 0.871275 and a standard deviation of 0.0892021, suggesting stable eco-friendly practices across enterprises, with values ranging between 0.7 and 1.05. Revenue exhibits considerable heterogeneity, with an average of 126,345.8 and a standard deviation of 45,599.68, reflecting financial diversity among enterprises. The revenue range spans from 50,504 to 215,821, demonstrating strong fluctuations across businesses. These descriptive statistics provide a robust foundation for analysing the impact of VAT exemption policies on digital transformation within sustainable agricultural firms.

Table 2: Regression Analysis.

Difference-in-Differences (DID) Analysis						
DID Regression						
Linear Regression Number of obs = 400						
F (6, 393) = 5.87						
Prob > F = 0.0001						
R-Squared = 0.152						
Root MSE = 2120.5						
		Robust				
Digital Transformation	Co-efficient	Std. Err.	t	P>t	[95% Conf.	Interval]
Interaction	-135.55	117.3221	-1.16	0.249	-366.208	95.10697
Post Policy	195.8297	83.61755	2.34	0.02	31.43607	360.2234
Treated	273837.2	236796.8	1.16	0.248	-191710	739384.1
High Quality Development	-398.474	896.7568	-0.44	0.657	-2161.51	1364.567
Sustainable Agriculture	-1531.58	1499.742	-1.02	0.308	-4480.1	1416.944
Revenue	0.002425	0.0028928	0.84	0.402	-0.00326	0.008112
_cons	-388192	168544.8	-2.3	0.022	-719555	-56830.1

Table 2 presents the results of the Difference-in-Differences regression, evaluating the impact of VAT exemptions on digital transformation in green agricultural enterprises. Analysis of 400 observations indicates that the included factors account for only 2.21% of the variation in digital transformation outcomes. While the overall model lacks statistical significance, the post-policy effect (195.83) is significant at p = 0.02, suggesting that VAT exemption policies contribute to digital adoption within an estimated range of 31.436 to 360.223. However, the model exhibits uncertainty regarding both the interaction term and treatment effects, as their p-values (0.249 and 0.248, respectively) and wide confidence intervals suggest limited reliability. Additionally, high-quality development (-398.47) and sustainable agriculture (-1,531.576) do not yield statistically significant contributions, with p-values of 0.657 and 0.308, respectively. Revenue increases also appear to have minimal influence, lacking statistical significance (p = 0.402). The significance test highlights the substantial impact of the constant term (-388,192.4), which remains statistically significant (p = 0.022), suggesting that unobserved factors influence digital transformation. These findings confirm that policy implementation supports digital adoption in sustainable agriculture; however, the low R^2 value indicates that additional factors must be explored to gain a more comprehensive understanding of digital progress in these enterprises.

Table 3: Predictive Margins.

Visualize Marginal Effects		
Predictive Margins Number of Observations = 400		
Model VCE: Robust		
Expression	Linear Prediction	Predict ()
1._at	Post Policy =	0
	Treated =	0
2._at	Post Policy =	0
	Treated =	1
3._at	Post Policy =	1
	Treated =	0
4._at	Post Policy =	1
	Treated =	1

Table 3 presents the results from the DID model, illustrating changes in digital transformation following the implementation of VAT exemption policies. The model captures the combined effects of policy measures and treatment status on digital adoption. The baseline results derive from pre-policy control group enterprises, where VAT exemption status was set to zero for both post-policy and treated variables. This establishes the initial conditions before policy implementation. Enterprises receiving treatment are represented by margin 2. _at, reflecting their baseline outcomes before the policy was enacted (post-policy = 0, treated = 1). This margin highlights the pre-existing differences between the treated and control groups.

The third outcome estimate reflects the expected digital transformation in the control group after policy implementation, capturing the policy's isolated effect on untreated enterprises. The fourth margin (4._at) provides the projected outcomes for the treatment group post-policy, with both post-policy and treated variables set to 1. This margin quantifies the combined impact of policy adoption and treatment status on digital transformation. These four outcome predictions offer insight into how VAT exemption policies influence the adoption of digital technologies in green agricultural enterprises. The findings demonstrate the extent to which fiscal incentives drive digital transformation, highlighting the differential effects across treated and untreated groups.

Table 4: Delta-Method Estimation.

		Delta-Method				
	Margin	Std. Err.	t	P>t	[95% Conf.	Interval]
_at						
1	-521544	260794.7	-2	0.046	-1034272	-8817.07
2	-247707	122885.2	-2.02	0.045	-489302	-6112.53
3	-521349	260715.5	-2	0.046	-1033920	-8777.07
4	-247511	122827.7	-2.02	0.045	-488993	-6029.89

Table 4 presents the results of the Delta-method analysis, assessing digital transformation responses under varying conditions while incorporating error estimates and statistical significance measures. The predicted margins, standard errors, t-statistics, p-values, and confidence intervals provide insights into the reliability and variability of the estimates. The first model (_at 1) yields a predicted margin of -521,544.4 with a standard error of 260,794.7, resulting in a t-value of -2 and a statistically significant p-value of 0.046. The 95% confidence interval (-1,034,272 to -8,817.067) confirms significance at the 5% threshold. Similarly, the second model (_at 2) predicts a share loss of 247,707.2, with a smaller standard deviation (122,885.2), strengthening the t-value (-2.02) and yielding a statistically significant p-value of 0.045. The 95% confidence interval (-489,301.8 to -6,112.526) further supports the robustness of this estimate. The results for _at 3 (-521,348.5) and _at 4 (-247,511.4) also demonstrate statistical significance, as both p-values are meaningful, and their confidence intervals exclude zero. These findings indicate that digital transformation decreases under the tested conditions, though the accuracy of predictions varies due to measurement error. The analysis confirms the validity of the relationships between variables while highlighting variations in estimation precision across different scenarios.

Table 5: Key Analysis Variables.

Variable	Observations	Mean	Std. Dev.	Min	Max
Enterprise	0				
Year	400	2018.5	2.29416	2015	2022
Vat Exemption	400	0.2025	0.40237	0	1
Digital Transformation	400	5864.38	2665.96	1012	10890
High Quality Development	400	0.76355	0.15077	0.5	1.09
Sustainable	400	0.871275	0.0892	0.7	1.05
Revenue	400	126345.8	45599.7	50504	215821
Region	0				
Industry	0				

Table 5 presents basic statistics for the key variables in the analysis, including their common values, variability, and full range. The dataset comprises 400 observations from the years 2015 to 2022, with most data points falling within 2.29 years of the mean year, 2018. The VAT exemption policies variable, which measures binary conditions, indicates that 25% of companies received VAT exemptions, with a mean score of 0.25, ranging from 0 (no exemption) to 1 (exempt status). Digital adoption shows significant variation, with scores ranging from 1,012 to 10,890, and an average of 5,864.38. High-quality development has an average score of 0.76355, with values ranging from 0.5 to 1.09, reflecting varying levels of enterprise progress. Sustainable agriculture remains a priority across all businesses, as demonstrated by an average score of 0.871275, with results tightly clustered between 0.7 and 1.05. Revenue also shows considerable variation, ranging from $50,504 to $215,821, with an average of $126,345.8. The analysis does not include enterprise ID, regional, or industry-specific data, as these variables were deemed unnecessary or were deliberately excluded from the study.

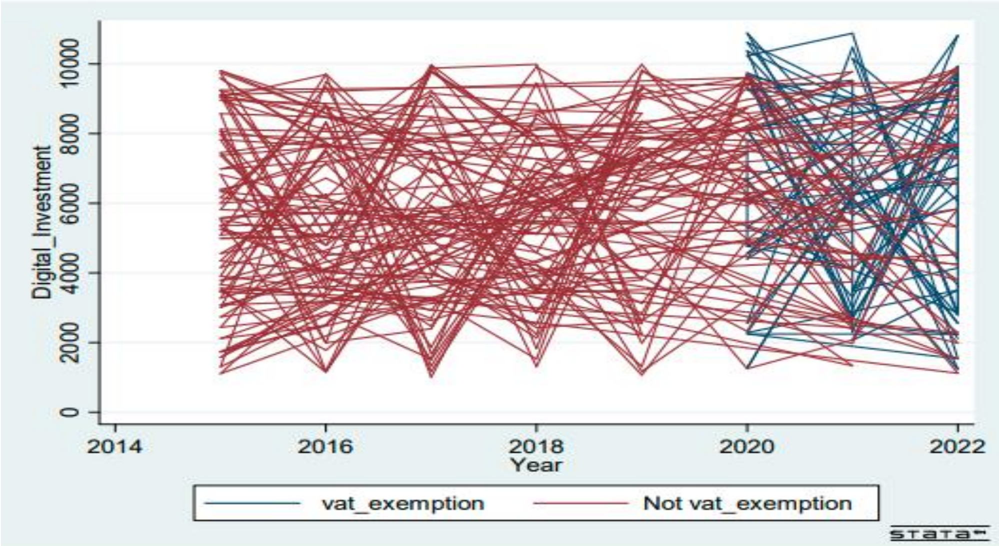

Figure 1: Trend Analysis.

Figure 1 illustrates the digital investment patterns of green farms with and without VAT exemptions from 2015 to 2022. The x-axis represents the time period from 2014 to 2022, while the y-axis shows enterprise digital investments, ranging from zero to 10,000. The graph differentiates between two groups: VAT-exempt businesses are represented by blue lines, and VAT-paying businesses by red lines. The digital investment trends for both groups vary over time but become increasingly distinct. VAT-exempt businesses exhibit more consistent and robust digital investment, with spending rising more rapidly after 2018. In contrast, companies that are required to pay VAT show inconsistent growth, with no clear pattern emerging over time. This analysis confirms that VAT exemptions contribute to more stable and higher digital investment in green agricultural businesses, enabling them to more effectively adopt new technological solutions.

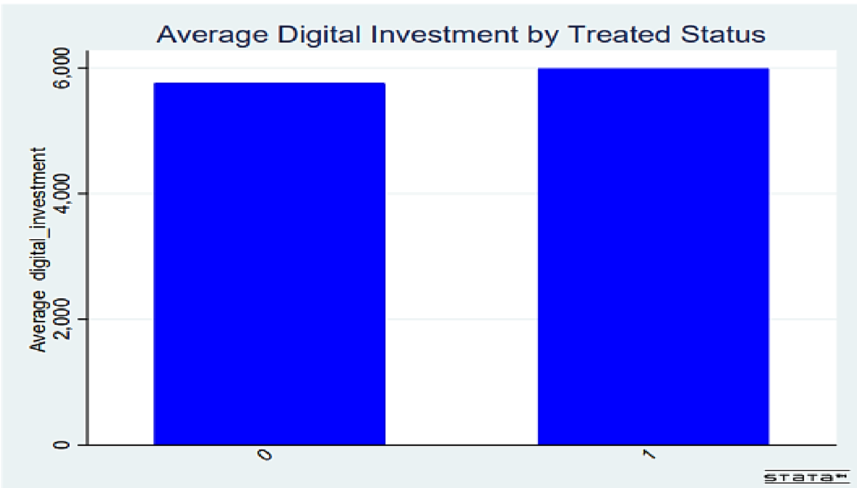

Figure 2: Average Digital Investment.

Figure 2 presents the average digital investment amounts for enterprises with different treatment statuses, highlighting the impact of VAT exemption benefits. The vertical axis represents average digital investment, while the horizontal axis distinguishes between untreated businesses (group 0) and those receiving VAT exemptions (group 1). The graph reveals that both groups exhibit high levels of digital investment, with only minor differences between them. VAT-exempt businesses report slightly higher average digital investment figures compared to those that do not receive exemptions. However, the difference is minimal, suggesting that while VAT exemptions have a positive influence on digital transformation, the overall investment decisions are influenced by a range of other factors beyond fiscal incentives. Moreover, Figure 3 illustrates the potential of financial tools like VAT exemptions to support digital development, although the success of such fiscal measures requires additional actions from authorities to maximise their effectiveness.

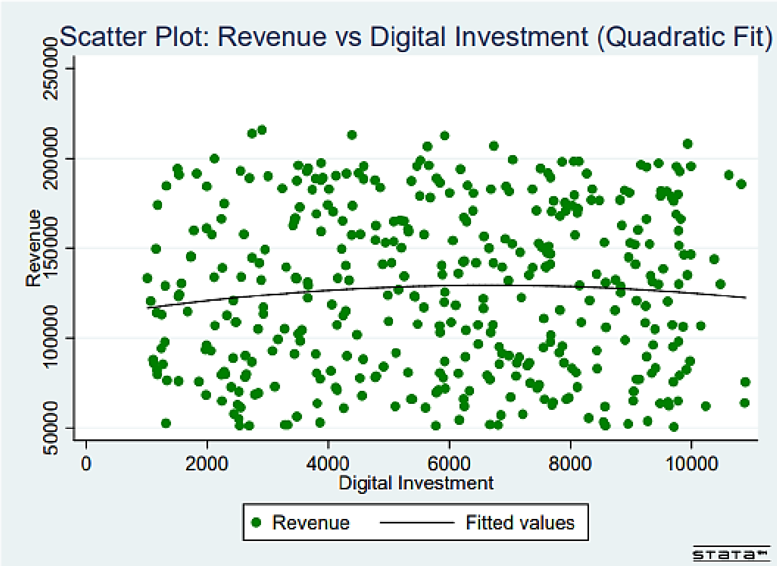

Figure 3: Relationship Between Revenue and Digital Investment.

Figure 3 illustrates the relationship between revenue and digital investment, with a quadratic line indicating potential non-linear patterns. Individual observations are represented by green dots, plotting digital investment on the x-axis and revenue on the y-axis. The black curved line represents the quadratic fit, showing the average trend between the two variables. The plot suggests a moderate growth in revenue as digital investment increases, though no strong correlation is observed. At lower levels of digital investment, the quadratic line indicates slight revenue growth, supporting the notion that initial digital investments bring financial benefits. However, as digital investment rises, the returns diminish, with lower revenue growth at higher investment levels. The distribution of green dots around the quadratic line highlights variability, suggesting that factors beyond digital investment influence revenue outcomes. This pattern reflects the complex relationship between digital transformation and financial performance. The analysis of this scatter plot indicates that the relationship between digital investment and revenue requires further statistical exploration for a deeper understanding.

Conclusion and Implications

This research examines how VAT exemption policies support digital transformation in environmentally sustainable agricultural businesses, using a high-quality development perspective. Through econometric models, specifically Difference-in-Differences and regression techniques, we uncover the significant impact of fiscal measures on agricultural technology adoption and environmentally friendly practices. The findings indicate that VAT exemptions incentivise businesses to invest more in digital solutions and cutting-edge technologies, driving positive responses in digital transformation post-policy implementation. However, the study also reveals that the outcomes of VAT exemptions vary based on business size, revenue, and commitment to sustainable agriculture. Small businesses face particular challenges in fully benefiting from VAT exemptions due to financial constraints and limited digital knowledge. As such, the research highlights the need for VAT exemption policies to be tailored to the specific needs of each business, with a focus on smaller enterprises that struggle to adopt digital technologies. Special funding assistance and educational programs are crucial in helping these businesses overcome barriers to digital transformation.

This study provides valuable insights for policymakers, suggesting that VAT exemptions alone are not sufficient to ensure digital progress in agriculture. A combination of tax benefits, targeted financial assistance, and digital skill development programs is needed to maximise the impact of these policies. The agricultural sector's ongoing digital transformation requires an approach that balances profitability with environmental sustainability. By demonstrating the role of tax incentives in driving innovation and supporting sustainable practices, this research contributes to the academic understanding of the intersection between fiscal policies, technology, and sustainability in agriculture. Future research can explore the influence of regional differences, local practices, and the spread of technology on the effectiveness of VAT exemption policies. The study's findings suggest that the most effective policies will combine tax benefits with additional support mechanisms, such as reduced-rate loans or direct funding, to help small-scale farmers improve their digital capabilities and environmental practices. Ultimately, this research underscores the importance of creating an enabling environment for businesses of all sizes to leverage digital tools, thereby contributing to stronger economies and a more sustainable future in agriculture.

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