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Sustainable Growth of Greenhouses: Investigating Key Enablers and Impacts

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Abstract

The main objective of this study was to identify the factors influencing greenhouse development in Uzbekistan. Supported by the literature, the conceptual model of the study hypothesized that economic viability, supportive infrastructure services, enablers, and competition impacts positively affect greenhouse development. Therefore, a questionnaire was administered among 200 individuals working in greenhouses across the Tashkent, Syrdarya, Jizzakh, and Bukhara regions. Quantitative empirical evidence using structural equation modeling revealed that enablers and competition impacts have a significant positive influence on greenhouse development. However, economic viability and supportive infrastructure services did not have a direct impact, although they indirectly contributed to the overall growth and functioning of the greenhouse industry. The study provides theoretical contributions by identifying key factors influencing greenhouse development and offers practical recommendations for policymakers and stakeholders to foster an enabling environment, manage competition effectively, enhance supportive infrastructure, promote international collaboration and investment, encourage research and development, and strengthen market linkages. This research contributes to the understanding of greenhouse development in Uzbekistan and provides insights for evidence-based decision-making and strategic planning in the industry.

Keywords:

Greenhouse Development;
Agricultural Sustainability;
Economic Viability;
Supportive Infrastructure;
Competitiveness;
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1- Introduction

Greenhouses play a vital role in modern agriculture, offering controlled environments for crop production and extending the growing season [1–3]. They provide a range of benefits that contribute to global food supply, economic development, and environmental sustainability. Greenhouses protect crops from adverse weather conditions, pests, and diseases, enabling year-round cultivation and higher yields [4, 5]. They offer opportunities for precision agriculture,

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allowing farmers to optimize resource utilization and minimize waste [6]. Moreover, greenhouses promote sustainable practices by reducing the need for excessive water usage [7], minimizing pesticide application, and mitigating soil erosion. By providing a stable and controlled environment, greenhouses enhance the quality, consistency, and availability of fresh produce, ensuring food security and meeting consumer demands [8]. As the world population continues to grow, greenhouses play a crucial role in meeting the rising demand for food, fostering agricultural resilience, and mitigating the challenges of climate change [9].

Greenhouse cultivation has experienced significant growth worldwide in recent years, with a substantial increase in the total area under greenhouse cultivation. The global area of greenhouses has reached 497.8 thousand hectares, growing by 24 percent. Plastic greenhouses cover 90 percent of this area, while glass greenhouses account for the remaining 10 percent. Experts project that the area of greenhouses will continue to expand at a rate of 11 percent per year, potentially reaching 750 thousand hectares by 2021. While Europe leads in greenhouse cultivation with 210 thousand hectares (42.2%), other regions also contribute significantly. Asia accounts for 180.5 thousand hectares (36.3%), Africa has 45.3 thousand hectares (9.1%), North America covers 31.8 thousand hectares (6.4%), the Middle East possesses 14.6 thousand hectares (2.9%), South America comprises 14 thousand hectares (2.8%), and Oceania accounts for 1.6 thousand hectares (0.3%).

Although the greenhouse area in developed countries surpasses that of Uzbekistan, the country ranks among the top ten in terms of greenhouse area. Uzbekistan has twice the greenhouse area of Israel but lags behind in export volume. The country has 0.243 hectares of greenhouse area per 1,000 people, with yields ranging from 3 to 10 kg/m², whereas developed countries achieve yields of 50–60 kg/m². To enhance productivity, it is crucial to introduce innovative developments into existing greenhouses. In 2020 alone, Uzbekistan established 334 new greenhouses, resulting in a total of 2,667 operational units—an increase of 2.3 times compared to 2017. Of these, 266 greenhouses (approximately 10 percent) are equipped with hydroponics. The Bukhara region accounts for the largest share of greenhouses, comprising 26.3 percent (702 units), followed by the Tashkent region with 19.6 percent (522 units), and the Navoi region with 9.8 percent (261 units). The Bukhara, Khorezm, and Samarkand regions predominantly feature hydroponic greenhouses.

Currently, Uzbekistan's greenhouse area exceeds 8,200 hectares, with an annual growth rate of 100–150 hectares across various greenhouse designs. The country possesses over 600 hectares of glass greenhouses and more than 5,000 hectares of heated and unheated film greenhouses (following Chinese technology). Additionally, small greenhouses utilizing two-layer film technology, heated with air, and incorporating modern Dutch and Israeli practices are also present. The construction cost for glass greenhouses is approximately 1.0–1.1 million USD per hectare, while that for film greenhouses ranges from 350–400 thousand USD per hectare. Chinese technology-based greenhouses cost around 80.0–100.0 thousand USD, and South Korean technology-based two-story film greenhouses range from 300–350 thousand USD per hectare. Modern small greenhouses and hydroponics have construction costs of 1.6-2 million USD.

While there has been some research on greenhouse development globally, there remains a lack of studies focused specifically on the key factors influencing greenhouse growth in Uzbekistan. For example, recent literature reviews such as Zhang et al. [10], Ariesen-Verschuur et al. [11], and Soussi et al. [12] on protected agriculture worldwide found very few studies examining the greenhouse industry in Central Asia, and none focused solely on Uzbekistan. They conclude that more country-specific research is needed to understand the unique opportunities and challenges for greenhouse development across different regions. This lack of Uzbekistan-focused research represents a gap in the literature.

The limited research on key factors affecting greenhouse development in Uzbekistan means there is insufficient understanding of the economic viability, infrastructure, enablers and competition dynamics influencing the industry's growth in the country [13, 14]. Without this understanding, it is difficult to formulate evidence-based policies and strategies to promote further expansion of the greenhouse sector in Uzbekistan sustainably. Therefore, the lack of research focused on the Uzbekistani context is a significant problem that needs to be addressed.

Filling this research gap has important practical and economic implications for Uzbekistan. Greenhouse agriculture has been identified as a priority industry for economic growth in the country. However, uncertainties around profitability, infrastructure gaps, and competitive pressures have constrained faster development of the sector. By examining the key factors influencing greenhouse investment decisions and operations, this research can provide insights to help optimize policies and incentives for the accelerated development of this strategic industry. Moreover, sustainable growth of the greenhouse industry can boost jobs, exports, and food security for Uzbekistan [15]. Therefore, addressing this knowledge gap through targeted research in the Uzbekistani context is crucial. This study aims to bridge this gap by identifying these factors and their impact on greenhouse development in Uzbekistan. By understanding these factors and their interrelationships, policymakers, practitioners, and stakeholders can make informed decisions to foster a conducive environment for greenhouse growth and enhance the sector's overall competitiveness and sustainability. Therefore, this study was conducted to answer the following questions:

Based on the information provided, the research questions that this study answers could be:

- What factors influence the development of greenhouses in Uzbekistan?
- How do these factors impact greenhouse development in Uzbekistan?
- What practical recommendations can be derived from the study findings to enhance greenhouse development in Uzbekistan?

This study makes several contributions to the understanding of greenhouse development in Uzbekistan. Firstly, it provides valuable insights into the factors influencing greenhouse development. By examining these factors, the study offers a comprehensive understanding of the key drivers and barriers to greenhouse development in the country. Secondly, the research contributes to the existing literature by empirically testing the relationships between these factors and greenhouse development using a quantitative approach. The findings provide evidence of the significant impact of enablers and competition on greenhouse development, highlighting the importance of these factors in shaping the industry. Lastly, the practical recommendations derived from the study findings can guide policymakers, entrepreneurs, and stakeholders in implementing targeted strategies to foster the growth and sustainability of the greenhouse sector in Uzbekistan.

This article follows a structured approach to examine the factors influencing greenhouse development in Uzbekistan. It begins by establishing a theoretical framework that encompasses the concepts of economic viability, supportive infrastructure services, enablers, and competition impact. These factors are hypothesized to have a significant influence on greenhouse development. The methodology section outlines the research design, the data collection process, and analysis techniques employed to test the hypotheses. The results section presents the empirical findings derived from the data analysis, providing insights into the relationships between the independent variables and greenhouse development. The subsequent section combines the findings and discussion, where the implications of the results are thoroughly examined and interpreted. Finally, the article concludes by summarizing the key findings and their significance, as well as presenting practical recommendations for stakeholders and future research directions in the field of greenhouse development in Uzbekistan.

2- Theoretical Framework

2-1- Economic Viability

Economic viability is a crucial factor in the development of greenhouses in Uzbekistan as it determines the financial sustainability and profitability of greenhouse operations. Economic viability refers to the ability of a project, business, or activity to generate sustainable economic benefits and maintain profitability over a given period [16, 17]. It involves assessing the financial aspects, cost-effectiveness, revenue generation, market conditions, and return on investment. Greenhouse businesses that are economically viable are more likely to thrive and contribute to the overall development of the industry.

A number of studies have highlighted the significance of economic viability in greenhouse development. For example, a study by Li & Stewart [17] demonstrates the link between economic viability and greenhouse development by applying a risk-cost-benefit framework to assess the economic feasibility of hazard mitigation strategies in response to potential wind damage caused by enhanced greenhouse conditions. By analyzing residential construction in North Queensland, Australia, the study evaluates the economic viability of retrofitting houses to adapt to changing wind hazard patterns associated with climate change. Through a risk-based cost-benefit analysis, the study highlights the importance of considering economic factors such as the cost of retrofitting, reduction in vulnerability, and discount rate in optimizing the timing and extent of retrofitting existing houses to mitigate the impact of enhanced greenhouse conditions. In another study by Andrews & Pearce [18] illustrates the relationship between economic viability and greenhouse development by examining the potential use of waste heat from industrial processes to operate greenhouses in northern climates. Through technical and economic methodology, the study assesses the viability of establishing waste heat greenhouses and compares them with traditional natural gas systems.

The findings reveal that the waste heat system proves to be significantly more economical to operate, highlighting the importance of considering economic factors in promoting sustainable and cost-effective greenhouse development. Furthermore, a study by Singh et al. [19] provides evidence of the relationship between economic viability and greenhouse development by investigating the utilization of waste heat from industrial processes for greenhouse operations in northern climates. This research employs a technical and economic approach to evaluate the feasibility of establishing waste heat greenhouses and compares them with conventional natural gas systems. The study findings demonstrate that the waste heat system offers superior economic viability, underscoring the significance of economic considerations in driving sustainable and efficient greenhouse development practices.

Based on the evidence from these studies, it can be hypothesized that economic viability has a positive significant impact on greenhouse development in Uzbekistan. It is expected that greenhouses that prioritize economic viability through efficient resource management, cost control, and market-oriented strategies will experience higher levels of development and contribute to the overall growth of the sector. Therefore, the first hypothesis of this study is written as follows:

H1: *Economic viability has a positive significant impact on greenhouse development in Uzbekistan.*

2-2- Supportive Infrastructure Services

Supportive Infrastructure Services in the context of greenhouse development refer to the essential physical and logistical elements that play a crucial role in facilitating the establishment and operation of greenhouses [20]. These services encompass a range of factors, including but not limited to communication networks, transportation systems, storage facilities, research centers, and other related services. The presence of robust supportive infrastructure services is vital in ensuring the smooth functioning and success of greenhouse operations.

Several studies highlight the significant impact of supportive infrastructure services on greenhouse development. For instance, Ghonji et al. [21] provide evidence of the relationship between supportive infrastructure services and greenhouse development. Through an analysis of promoter factors affecting horticultural greenhouse units in Iran, the findings highlight the significance of infrastructure as one of the determining factors in greenhouse development. The study emphasizes that factors such as climate diversification, availability of manpower, technical knowledge, and cheap energy contribute to the development of greenhouses, indicating the importance of supportive infrastructure services in creating a competitive and market-oriented agriculture sector.

In addition, Gutiérrez et al. [22] debated that the emergence of new technologies and the availability of hardware and software platforms enable the design and integration of communication monitoring and control systems, while the increasing demand for fresh and healthy foods and the trend of individuals growing their own food highlight the importance of supportive infrastructure services in greenhouse development. Furthermore, Barmpounakis et al. [23] introduced a novel Business-to-Business (B2B) collaboration platform designed for the agri-food sector. This platform aims to facilitate effective collaboration among stakeholders in associated business domains, providing swift deployment of cloud applications and enabling instant communication and complete "farm-to-fork" solutions for greenhouse management and control. By addressing the requirements of integrating diverse legacy systems and developing new services, the study demonstrates the importance of supportive infrastructure services in driving greenhouse development.

Considering the literature evidence, it is hypothesized that Supportive Infrastructure Services have a positive significant impact on greenhouse development in Uzbekistan. Adequate infrastructure and services that facilitate transportation, research support, storage, and other logistical aspects are expected to enhance the overall productivity, profitability, and sustainability of greenhouse operations in Uzbekistan, contributing to their successful development and growth. Hence, the second hypothesis of this study is formulated as follows:

H2: *Supportive infrastructure services have a positive significant impact on greenhouse development in Uzbekistan.*

2-3- Enablers

Enablers in the context of greenhouse development can be defined as a set of factors or conditions that play a crucial role in facilitating, supporting, and fostering the growth and success of greenhouse operations. This variable includes elements such as specialized training courses, partnerships, knowledge transfer, state support, availability of resources, business activity, traditional experience, and other enabling factors that contribute to the growth and success of greenhouses.

Several studies highlight the significant impact of enablers on greenhouse development. For instance, a study by Dorzhiev [24] identifies key roles played by higher education in agriculture development and highlights the importance of specialized training courses and knowledge transfer as enablers for greenhouse development. Dorzhiev [24] also discusses state support policies for the greenhouse industry, emphasizing the role of government assistance as an enabler. This aligns with the concept of enablers, as the availability of skilled professionals is crucial for the growth and the success of greenhouse operations. Another study by Ciplet et al. [25] highlights the importance of securing resources and governance mechanisms. These elements are essential enablers in creating a favorable environment for greenhouse development as they ensure the availability of necessary resources. The study suggests that addressing financial needs through enablers is crucial for greenhouse development. Based on the findings from these studies and the underlying principles of enablers, we can hypothesize that enablers have a positive significant impact on greenhouse development in Uzbekistan.

H3: *Enablers have a positive significant impact on greenhouse development in Uzbekistan.*

This hypothesis suggests that the presence of supportive factors, such as state support, financial assistance, and knowledge transfer, will contribute to the growth, productivity, and overall success of greenhouse operations in Uzbekistan.

2-4- Competition Impact

Competition Impact in the context of greenhouse development refers to the effects and influences that arise from the market competition on the growth and the progress of greenhouses. It encompasses various consequences and dynamics resulting from the presence of competing producers or businesses operating in the same market segment. Competition in an industry plays a crucial role in driving its development and growth. It creates incentives for businesses to innovate, improve the efficiency, and enhance their offerings to gain a competitive edge [26, 27]. In competitive markets, businesses strive to attract customers by offering better quality products, lower prices, and superior services. This drive for differentiation and improvement fosters technological advancements, research and development, and the adoption of best practices [28]. LaFary et al. [29], for instance, examined the competitive dynamics in the greenhouse industry and found that increased competition among producers led to improvements in product quality and cost reduction. This suggests that competition impact can drive innovation and efficiency, resulting in the advancement of greenhouse development. Based on the existing literature, we can hypothesize that competition impact has a positive significant impact on greenhouse development in Uzbekistan.

H4: *Competition Impact has a positive significant impact on greenhouse development in Uzbekistan.*

This hypothesis suggests that increased competition among greenhouse producers in Uzbekistan would lead to improved productivity, innovation, and sustainability, thereby contributing to the overall development and growth of the greenhouse industry in the country.

The conceptual framework of this study, as depicted in Figure 1, highlights four hypotheses regarding the factors influencing greenhouse development in Uzbekistan. The first hypothesis (H1) suggests that economic viability plays a positive and significant role in driving greenhouse development. This implies that the financial feasibility and profitability of greenhouse operations are crucial determinants of their growth and success. The second hypothesis (H2) focuses on supportive infrastructure services, positing that their presence and effectiveness have a positive and significant impact on greenhouse development. This underscores the importance of adequate infrastructure, such as transportation, irrigation, energy supply, and information and communication technologies, in facilitating the growth and efficiency of greenhouse operations. The third hypothesis (H3) emphasizes the positive and significant influence of enablers on greenhouse development. Enablers encompass factors such as specialized training, partnerships, knowledge transfer, state support, availability of resources, business activity, and traditional experience, which collectively contribute to the growth and sustainability of greenhouses. Finally, the fourth hypothesis (H4) suggests that competition impact positively affects greenhouse development. This implies that healthy competition among greenhouse producers and businesses in the market foster innovation, efficiency, and overall industry development.

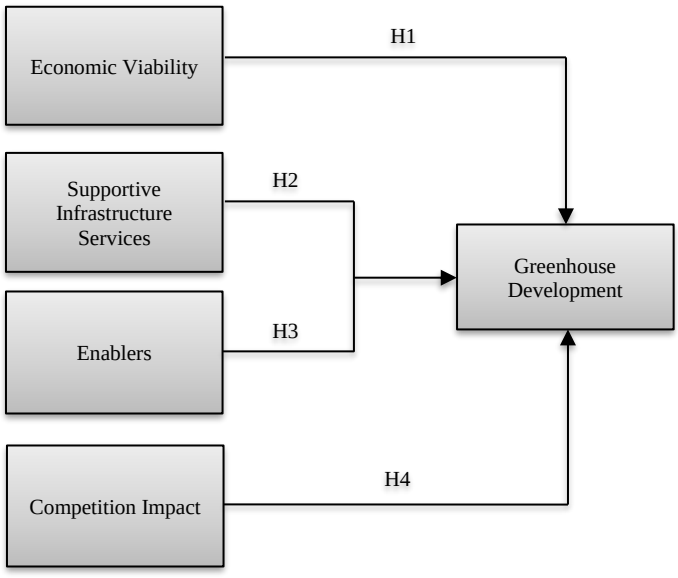


Figure 1. The proposed conceptual framework for this study

3- Research Methodology

To evaluate the proposed conceptual model of this study, a questionnaire was administered among 200 individuals working in greenhouses located in the Tashkent, Syrdarya, Jizzakh, and Bukhara regions of Uzbekistan. The questionnaire was designed by the authors of the study and utilized a Five-point Likert scale to gather responses from

the participants. The aim of the questionnaire was to collect data on the factors influencing greenhouse development and their impact on the dependent variables (Appendix I).

The study encompassed a total of 94 farms with varying greenhouse land areas. Specifically, 34.5% of the farms had a greenhouse land area ranging from 0.10 to 0.99 hectares, 34.5% had a land area of 1-5 hectares, 14% had a land area of 6-15 hectares, and 4.5% had a land area of 16 hectares. This diverse sample of greenhouse farms ensures a representative perspective on the factors influencing greenhouse development across different scales of operation.

The questionnaire administration involved participants who were directly involved in greenhouse activities, such as greenhouse operators, managers, and workers. Their firsthand experience and knowledge of the industry make them reliable sources of information for understanding the factors affecting greenhouse development in Uzbekistan. The data collection took place over a 3-month period starting from January 2023 to March 2023. The Five-Point Likert scale used in the questionnaire allows respondents to express their level of agreement or disagreement with specific statements related to the factors under investigation. This scale offers a balanced response format, capturing a range of opinions and perceptions regarding factors and their influence on greenhouse development. A copy of the questionnaire used in this study is provided in Table A-1 in the attachment section.

The administration of the questionnaire across multiple regions of Uzbekistan adds geographical diversity to the study. By including respondents from Tashkent, Syrdarya, Jizzakh, and Bukhara, the study captures a broader perspective on the factors influencing greenhouse development and ensures that the findings are not limited to a specific locality.

The data collected from the questionnaire responses will serve as the basis for analyzing the relationships between the independent variables (such as Economic Viability, Supportive Infrastructure Services, Enablers, and Competition Impact) and the dependent variable (Greenhouse Development). Through statistical analysis, such as structural equation modeling (SEM) using SmartPLS 4 software, the researchers will evaluate the proposed conceptual model and examine the significance and strength of the relationships between the variables. Figure 2 shows the methodology of this study to achieve the findings of this research.

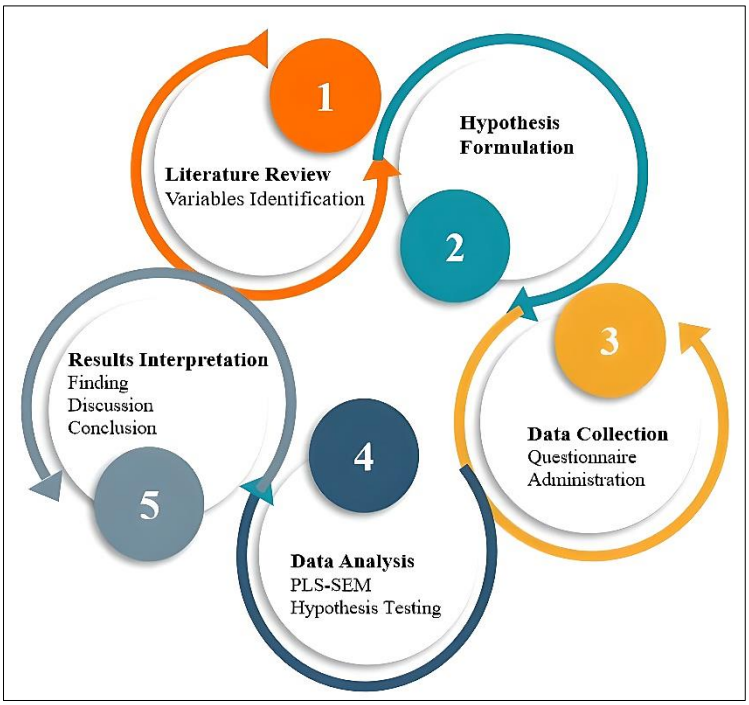


Figure 2. The current study research design for reaching the findings

4- Results

The results of the measurement model test, as summarized in Table 1, indicate positive findings for the variables in the study. Firstly, all the loading factors for the observed variables are above the threshold of 0.7, indicating a strong relationship with their respective latent variables. This suggests that the observed variables effectively measure the intended constructs and contribute to the overall understanding of the factors influencing greenhouse development in Uzbekistan. Additionally, all of the loading factors are statistically significant ($p < 0.05$), further confirming the reliability and validity of the measurement model.

Table 1. The result of the measurement model test

Question Codes	Loading Factor	Sample Mean	Standard Deviation	*p* Values	Cronbach's alpha	AVE
Economic Viability:					0.902	0.66
EV1	0.723	4.006	1.231	0.026		
EV2	0.720	3.875	1.052	0.029		
EV3	0.787	3.883	1.604	0.036		
EV4	0.865	4.587	1.079	0.043		
EV5	0.917	3.775	1.529	0.022		
EV6	0.722	4.189	0.903	0.019		
EV7	0.869	4.503	0.963	0.017		
EV8	0.867	4.178	0.930	0.018		
EV9	0.822	4.618	1.092	0.019		
EV10	0.738	3.943	1.093	0.013		
Supportive Infrastructure Services:					**0.89**	**0.75**
SIS1	0.806	4.459	1.071	0.012		
SIS2	0.857	3.836	0.919	0.031		
SIS3	0.773	4.742	1.495	0.023		
SIS4	0.754	4.007	1.268	0.025		
SIS5	0.732	4.360	0.811	0.029		
SIS6	0.928	4.632	1.399	0.040		
SIS7	0.749	3.724	0.915	0.043		
SIS8	0.707	4.532	1.399	0.036		
SIS9	0.800	4.043	0.853	0.037		
SIS10	0.721	3.343	0.869	0.039		
SIS11	0.744	3.819	1.248	0.022		
Enablers:					**0.855**	**0.73**
E1	0.828	4.594	1.735	0.040		
E2	0.778	4.691	1.441	0.033		
E3	0.743	4.261	1.725	0.024		
E4	0.784	3.302	1.251	0.038		
E5	0.791	3.716	1.504	0.023		
E6	0.775	4.136	1.489	0.038		
E7	0.929	3.478	1.483	0.022		
E8	0.812	3.335	1.569	0.025		
E9	0.792	3.979	1.405	0.014		
E10	0.883	4.422	0.834	0.041		
E11	0.889	4.435	1.027	0.022		
E12	0.836	4.239	0.966	0.040		
E13	0.842	4.698	1.742	0.028		
Competition Impact:					**0.833**	**0.77**
CI1	0.712	4.009	1.297	0.011		
CI2	0.759	3.970	1.085	0.012		
CI3	0.917	4.371	1.109	0.011		
CI4	0.751	4.034	0.987	0.040		
CI5	0.881	3.528	1.612	0.016		
CI6	0.926	4.511	1.570	0.040		
CI7	0.819	3.953	1.642	0.019		
CI8	0.715	3.504	0.832	0.030		
CI9	0.858	4.242	1.258	0.025		

Greenhouse Development:					**0.934**	**0.83**
GD1	0.905	3.410	1.271	0.037		
GD2	0.771	3.925	1.088	0.041		
GD3	0.726	3.799	1.277	0.019		
GD4	0.717	3.647	1.507	0.038		
GD5	0.900	4.505	0.942	0.013		
GD6	0.823	4.429	1.264	0.029		
GD7	0.845	3.608	1.493	0.027		
GD8	0.757	3.490	1.296	0.032		
GD9	0.760	4.079	1.317	0.032		
GD10	0.917	3.574	1.755	0.041		
GD11	0.890	3.522	1.457	0.015		
GD12	0.737	4.129	1.387	0.029		
GD13	0.780	4.482	1.018	0.042		
GD14	0.776	3.349	1.362	0.014		
GD15	0.913	4.172	0.834	0.029		
GD16	0.830	3.348	1.056	0.016		

The Cronbach's alpha values for all variables in the study are above the acceptable threshold of 0.7. This signifies good internal consistency reliability, indicating that the items within each construct consistently measure the same underlying concept. The high Cronbach's alpha values suggest that the items within each construct are reliable and consistent in measuring their respective constructs. This provides confidence in the reliability of the data collected for the study and strengthens the overall validity of the measurement model.

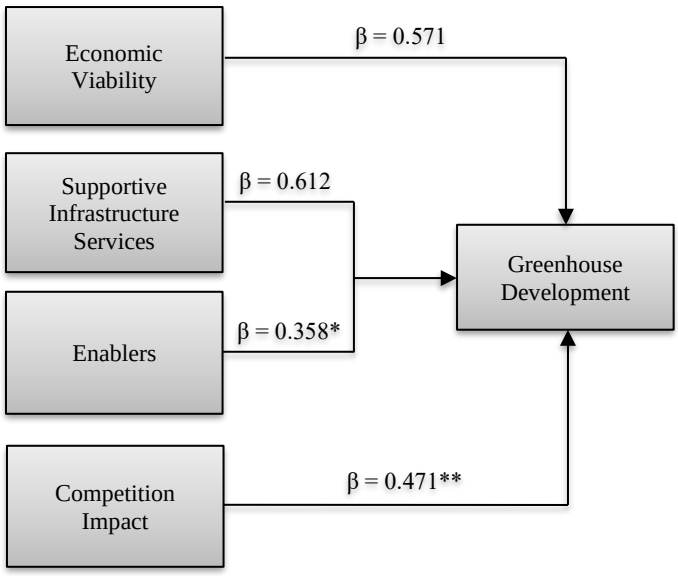
Furthermore, the Average Variance Extracted (AVE) values for all variables exceed the recommended threshold of 0.5. AVE represents the amount of variance captured by the latent variables in relation to the measurement error. The values above 0.5 indicate that a substantial proportion of variance in the observed variables is explained by their corresponding latent variables. This suggests that the constructs in the study have convergent validity and demonstrate a high degree of coherence, supporting the consistency and reliability of the measurement model. In conclusion, the results of the measurement model test provide strong evidence for the reliability, validity, and coherence of the measurement model used to assess the factors influencing greenhouse development in Uzbekistan.

The results of hypothesis testing, as presented in Table 2 and Figure 3, provide valuable insights into the relationships between the independent variables and the dependent variable, which is greenhouse development in Uzbekistan. Hypotheses 1 (H1) and 2 (H2) examined the potential impact of economic viability and supportive infrastructure services, respectively, on greenhouse development. However, statistical analysis does not confirm these hypotheses. The beta coefficients (β) for both H1 and H2 are positive, indicating a positive relationship between the independent variables (Economic Viability and Supportive Infrastructure Services) and the dependent variable (Greenhouse Development). Despite this positive relationship, the p-values associated with these coefficients are above the significance level ($p > 0.05$), suggesting that these relationships are not statistically significant.

Table 2. Results of hypotheses test

	Hypotheses	β	Standard Deviation	*p* Values	Result
H1	Economic Viability → Greenhouse Development	0.571	0.933	0.434	Not Confirmed
H2	Supportive Infrastructure Service → Greenhouse Development	0.612	0.841	0.657	Not Confirmed
H3	Enablers → Greenhouse Development	0.358	0.976	0.030	Confirmed
H4	Competition Impact → Greenhouse Development	0.741	1.223	0.000	Confirmed

The lack of statistical significance in the relationship between economic viability and greenhouse development implies that in the context of Uzbekistan, factors related to economic viability, such as financial resources, profitability, and cost-effectiveness, may not directly influence the growth and development of greenhouses. Similarly, the non-statistically significant relationship between Supportive Infrastructure Services and Greenhouse Development suggests that while access to infrastructure support, such as modern technology, communication systems, and transportation, is important, it may not have a direct and significant impact on the overall development of the greenhouse industry in Uzbekistan.



* The corresponding B is significant at 95% confidence interval; ** The corresponding B is significant at 99% confidence interval.

Figure 3. Results of testing the proposed conceptual framework of this study

It is essential to consider other potential factors and variables that may play a more prominent role in influencing greenhouse development in Uzbekistan. For instance, factors related to government policies, agricultural practices, technology adoption, and market demand might have a stronger influence on the growth and success of the greenhouse industry. Future research could explore these aspects in greater detail to gain a comprehensive understanding of the determinants of greenhouse development in Uzbekistan and inform policymakers and stakeholders on targeted interventions and strategies for sustainable growth in the sector.

On the other hand, the statistical analysis confirms the validity of Hypotheses 3 (H3) and 4 (H4), which postulated the relationships between Enablers and Competition Impact, respectively, with Greenhouse Development in Uzbekistan. The beta coefficients (β) for both H3 and H4 exhibit positive values, indicating a positive association between the independent variables (Enablers and Competition Impact) and the dependent variable (Greenhouse Development). Crucially, the p-values associated with these coefficients are found to be below the significance level ($p < 0.05$), signifying that these relationships are statistically significant, and their impact on greenhouse development is considered meaningful (see Figure 3).

The confirmed significance of Hypotheses 3 and 4 underscores the crucial role of Enablers and Competition Impact in driving and shaping the growth and advancement of the greenhouse industry in Uzbekistan. Enablers, encompassing factors such as specialized training, partnerships, knowledge transfer, state support and the availability of resources, create a conducive environment that supports and facilitates the development of greenhouses. Their positive impact on greenhouse development implies that interventions and policies aimed at bolstering these enabler elements can foster sustainable growth, enhance productivity, and improve the overall performance of the greenhouse sector in Uzbekistan.

Moreover, the confirmed positive relationship between competition impact and greenhouse development highlights the significance of the market competition in stimulating progress and innovation within the industry. The increased competition encourages growers and greenhouse operators to strive for efficiency and productivity and the adoption of advanced practices and technologies to gain a competitive edge. As a result, competition among producers fosters a dynamic and adaptive greenhouse landscape, potentially leading to improvements in product quality, cost-effectiveness, and market responsiveness. Acknowledging the impact of both Enablers and Competition Impact, policymakers and stakeholders can better strategize and design interventions that enhance the greenhouse industry's potential and foster its sustainable development in Uzbekistan.

The analysis reveals that economic viability and supportive infrastructure services do not have a statistically significant direct influence on greenhouse development in Uzbekistan. However, Enablers and Competition Impact demonstrate significant relationships with greenhouse development, suggesting that factors related to enabling conditions and market competition play a crucial role in driving the development and success of greenhouses in Uzbekistan. These findings provide valuable insights for policymakers, practitioners, and stakeholders in the greenhouse industry to focus on the factors that have a significant impact on the growth and sustainability of greenhouse operations in the country.

The R-square value of 0.67, derived from the regression analysis, indicates that around 67% of the variability in greenhouse development can be attributed to the joint influence of the independent variables considered in the model.

This relatively high R-square value suggests a moderately strong relationship between the independent variables and the dependent variables. This implies that the collective impact of Economic Viability, Supportive Infrastructure Services, Enablers, and Competition Impact plays a substantial role in influencing the level of greenhouse development in Uzbekistan. However, it is important to acknowledge that there may be other unaccounted factors contributing to the remaining 33% of the variance in greenhouse development. These unmeasured variables might include factors such as regional climatic conditions, government policies, technological advancements, and market demand fluctuations. While the current model captures a significant portion of greenhouse development determinants, further research and exploration of additional factors could enhance the comprehensiveness and accuracy of future models. Overall, the identified explanatory power of the independent variables underscores their importance in shaping the trajectory of greenhouse development in Uzbekistan, highlighting their potential value as critical targets for policy interventions and initiatives aimed at fostering a thriving and sustainable greenhouse sector in the country.

5- Findings and Discussion

The findings of this study shed light on the factors influencing greenhouse development in Uzbekistan. By examining the relationships between economic viability, supportive infrastructure services, enablers, and competition impact with greenhouse development, valuable insights have been obtained to inform policymakers, practitioners, and stakeholders in the greenhouse industry.

The measurement model results indicate that all observed variables demonstrate strong relationships with their respective latent variables as evidenced by loading factors above the threshold and statistical significance. Additionally, high Cronbach's alpha values for all variables indicate good internal consistency reliability, while the average variance extracted (AVE) values exceeding 0.5 demonstrate convergent validity, affirming the robustness and validity of the measurement model.

Regarding hypothesis testing, the results provide important insights into the relationships between the independent variables and greenhouse development. Hypotheses 1 and 2, which proposed the direct relationships of Economic Viability and Supportive Infrastructure Services, respectively, with Greenhouse Development, were not confirmed. This suggests that economic viability and supportive infrastructure services alone may not be significant drivers of greenhouse development in Uzbekistan. Other factors such as market conditions, government policies, and technological advancements may play a more prominent role.

On the other hand, Hypotheses 3 and 4, which proposed the relationships of Enablers and Competition Impact, respectively, with greenhouse development, were confirmed. These findings highlight the significance of factors related to enabling conditions and competition in driving the development and success of greenhouses in Uzbekistan. Enablers, including special training courses, partnerships, experience from developed countries, state support, and access to appropriate resources, play a crucial role in providing the necessary support and opportunities for greenhouse development. Additionally, competition impact, encompassing factors such as the presence of competitors, open field farming, share distribution instability, and price and quality effects, significantly influence greenhouse development in Uzbekistan.

The coefficient of determination (R-square) value of 0.67 indicates that approximately 67% of the variance in greenhouse development can be explained by the combined influence of the independent variables included in the model. This suggests a moderately strong relationship between the independent variables and greenhouse development. However, it is important to acknowledge that other unmeasured factors may contribute to the remaining variance.

The findings of this study contribute to the existing literature on greenhouse development in Uzbekistan and provide valuable insights for various stakeholders. The rejection of hypotheses related to economic viability and supportive infrastructure services underscores the need to consider broader factors beyond economic considerations and supportive infrastructure in driving greenhouse development. Policymakers should focus on creating an enabling environment, including training programs, partnerships, state support, and access to resources, to facilitate greenhouse development. Moreover, managing the competition and addressing market dynamics are crucial for ensuring sustainable greenhouse development.

However, it is essential to acknowledge the limitations of this study. The research design employed in this study is based on cross-sectional data, which limits the ability to establish causal relationships. Future research could employ longitudinal or experimental designs to gain a deeper understanding of the causal mechanisms at play. Additionally, the study focused on specific factors and may have overlooked other relevant variables that could influence greenhouse development.

5-1- Theoretical Contributions

This study makes several theoretical contributions to the field of greenhouse development in Uzbekistan. These contributions are outlined below:

- *Conceptualization of Factors:* This study contributes to the theoretical understanding by identifying and conceptualizing key factors that influence greenhouse development in Uzbekistan. Through an empirical examination of economic viability, supportive infrastructure services, enablers, and competition impact, the study provides a comprehensive framework for understanding the multifaceted nature of greenhouse development. This conceptualization helps to fill a gap in the existing literature by providing a holistic view of the factors influencing greenhouse development in the specific context of Uzbekistan.
- *Enriching the Literature:* The findings of this study enrich the existing literature on greenhouse development by providing empirical evidence from Uzbekistan. While previous studies have predominantly focused on developed countries, this study contributes to the literature by examining greenhouse development in an emerging economy. By highlighting the specific factors that shape greenhouse development in Uzbekistan, the study adds valuable insights to the global knowledge base on greenhouse industry dynamics and offers a unique perspective for comparison and further exploration.
- *Understanding the Role of Enablers and Competition:* The study contributes to the theoretical understanding of greenhouse development by emphasizing the role of Enablers and Competition Impact. Enablers, such as special training courses, partnerships, experience from developed countries, state support, and access to resources, are identified as crucial factors in facilitating greenhouse development. This highlights the significance of creating an enabling environment to foster the growth of greenhouse industry. Additionally, the study emphasizes the influence of competition on greenhouse development, including factors such as the presence of competitors, market dynamics, and price and quality effects. This deepens our understanding of the competitive dynamics within the greenhouse industry and provides insights into managing the competition to enhance development outcomes.
- *Contextualization of Findings:* By focusing on the specific context of Uzbekistan, this study contributes to the literature by providing insights into the unique factors that shape greenhouse development in this country. Uzbekistan has its own socio-economic, cultural, and regulatory characteristics, which may influence the dynamics of the greenhouse industry. The study contextualizes the findings within the Uzbekistani context, offering nuanced perspectives that can inform policymakers, practitioners, and stakeholders operating in this specific context.
- *Methodological Contributions:* The study employs structural equation modeling (SEM) to examine the relationships between these factors and greenhouse development. This methodological approach enhances the rigor of the analysis and contributes to the methodological toolkit available for studying greenhouse development. By employing SEM, the study provides a robust statistical analysis that strengthens the validity and reliability of the findings.

5-2- Practical Recommendations

Based on the findings of this study on the factors influencing greenhouse development in Uzbekistan, several practical recommendations can be made to policymakers, practitioners, and stakeholders in the greenhouse industry. These recommendations are as follows:

- *Foster an Enabling Environment:* Recognizing the importance of enablers in greenhouse development, policymakers should focus on creating an enabling environment that supports and encourages greenhouse operations. This can be achieved by offering specialized training courses to enhance the skills and knowledge of greenhouse operators. Additionally, facilitating partnerships and knowledge exchange with developed countries can provide valuable insights and best practices for greenhouse development. Furthermore, providing state support in the form of financial incentives, access to resources, and streamlined regulatory processes can significantly contribute to the growth of the greenhouse industry in Uzbekistan.
- *Manage Competition:* Given the significant impact of competition on greenhouse development, stakeholders should adopt strategies to effectively manage the competition and enhance market dynamics. Encouraging open-field vegetable farming and promoting fair share distribution mechanisms can help mitigate the instability associated with competition. Additionally, stakeholders should focus on improving product quality, differentiation, and branding to gain a competitive edge in the market. Regular market research and analysis can provide valuable insights into consumer preferences and trends, enabling greenhouse operators to adjust their strategies accordingly.
- *Enhance Supportive Infrastructure:* While Supportive Infrastructure Services did not directly influence greenhouse development in this study, it is still crucial to invest in and enhance supportive infrastructure to facilitate the growth of the greenhouse industry. This includes improving transportation services, ensuring reliable access to utilities such as water and electricity, and establishing vegetable storage warehouses that meet the specific needs of greenhouse products. Moreover, developing efficient payment systems and ensuring an adequate labor force can contribute to the overall competitiveness and efficiency of greenhouse operations.

- *Promote International Collaboration and Investment:* The findings suggest that international collaboration and foreign investment can significantly impact greenhouse development. Policymakers should actively promote opportunities for foreign businessmen to operate in Uzbekistan's greenhouse industry and create favorable conditions for foreign investors to enter the sector. This can be achieved through streamlined investment processes, offering attractive incentives, and establishing partnerships with international organizations and research centers to facilitate knowledge transfer and technology adoption.
- *Continuous Research and Development:* To ensure the sustainability and growth of the greenhouse industry, stakeholders should prioritize research and development activities. This includes investing in engineering research, technical tests, and analysis in the field, as well as fostering collaboration with genetic scientific research centers and breeding facilities. Continuous innovation and the adoption of advanced technologies can lead to improved productivity, product quality, and market competitiveness.
- *Strengthen Market Linkages:* To maximize the impact of greenhouse development, stakeholders should focus on strengthening market linkages. This involves establishing effective channels for the product distribution and ensuring timely and reliable transportation services. Collaborating with market intermediaries, wholesalers, and retailers can help create a seamless supply chain and ensure access to a large number of buyers. Additionally, efforts should be made to enhance consumer awareness and promote the natural safety and quality of greenhouse products to build trust and loyalty among consumers.

By implementing these practical recommendations, policymakers, practitioners, and stakeholders can contribute to the sustainable development of the greenhouse industry in Uzbekistan. These actions aim to create an enabling environment, manage competition, enhance supportive infrastructure, promote international collaboration and investment, foster research and development, and strengthen market linkages. Collectively, these measures can facilitate the growth, competitiveness, and long-term viability of the greenhouse sector, benefiting both the industry and the broader economy of Uzbekistan

6- Conclusion

This study aimed to identify and examine the factors influencing greenhouse development in Uzbekistan. Through the administration of a questionnaire among greenhouse workers in the Tashkent, Syrdarya, Jizzakh, and Bukhara regions, the study collected valuable data on the independent variables of Economic Viability, Supportive Infrastructure Services, Enablers, and Competition Impact and their impact on the dependent variable of Greenhouse Development.

The results of our research on the impact of Economic Viability (H1) on greenhouse development in Uzbekistan did not confirm the hypothesis, as the statistical analysis did not find a statistically significant relationship. However, studies by Li & Stewart [17], Andrews & Pearce [18], and Singh et al. [19] provided evidence supporting the positive link between economic viability and greenhouse development through their investigations into hazard mitigation strategies, waste heat utilization, and economic feasibility in greenhouse operations. While our study did not find sufficient evidence to directly support this relationship, these prior studies highlight the importance of economic viability in driving greenhouse development in different contexts. The disconfirmation of the first hypothesis may be attributed to several reasons. The specific context of greenhouse development in Uzbekistan, the complexity of the industry, and the interactions with other factors such as government policies and supportive infrastructure services could influence the relationship. Further research is needed to understand the multiple variables influencing greenhouse development in Uzbekistan and their interplay in shaping the industry's progress.

This study also failed to provide adequate evidence to confirm the positive impact of supportive infrastructure services (H2) on greenhouse development in Uzbekistan. This finding is not aligned with the literature such as Ghonji et al. [21], Gutiérrez et al. [22], and Barmpounakis et al. [23] that supported the relationship between supportive infrastructure services and greenhouse development, emphasizing the role of new technologies, communication monitoring, and collaboration platforms in facilitating growth in the greenhouse industry. One possible reason is the availability and effectiveness of existing infrastructure services in the region. It is possible that the level of the support provided by infrastructure services in the context of greenhouse development may not be sufficient to show a statistically significant impact. Further investigation and analysis are required to delve deeper into the specific dynamics of supportive infrastructure services and their influence on the growth and sustainability of greenhouses in Uzbekistan.

Furthermore, the research findings in our study support the positive impact of enablers (H3) on greenhouse development in Uzbekistan. This is consistent with the studies by Dorzhiev [24] and Ciplet et al. [25], which highlighted the importance of enablers such as higher education, specialized training, and resource governance in fostering greenhouse development. These enablers play a crucial role in providing the necessary skills, knowledge, and support for the growth and sustainability of greenhouses in Uzbekistan.

Lastly, our research results support the positive impact of competition impact (H4) on greenhouse development in Uzbekistan. This aligns with the concept of competition driving industry growth and improvement, as demonstrated by LaFary et al. [29], who found that increased competition among producers led to improvements in product quality and

cost reduction in the greenhouse industry. The literature supports the notion that competition incentivizes businesses to innovate and enhance efficiency, fostering technological advancements and the adoption of best practices, ultimately leading to the development and progress of the greenhouse sector in Uzbekistan.

The findings of the study revealed several important insights. Firstly, the factors of enablers and competition impact were found to have a significant positive influence on greenhouse development in Uzbekistan. This suggests that creating an enabling environment and effectively managing the competition are crucial for the growth and sustainability of the greenhouse industry. Policymakers and stakeholders should prioritize initiatives that foster an enabling environment, facilitate international collaboration and promote a fair competition to drive the development of the greenhouse sector. On the other hand, the study did not find a significant direct influence of Economic Viability and Supportive Infrastructure Services on greenhouse development. However, these factors should not be overlooked as they play indirect roles in supporting and facilitating the overall growth and functioning of the greenhouse industry. Policymakers and stakeholders should continue to invest in enhancing economic viability and supportive infrastructure services, as these factors contribute to the overall competitiveness and efficiency of greenhouse operations.

However, it is important to acknowledge some limitations of this study. Firstly, the research was conducted within specific regions of Uzbekistan, which may limit the generalizability of the findings to other areas. Future studies should include a more diverse sample from various regions to obtain a comprehensive understanding of the factors influencing greenhouse development across the country. Moreover, the study solely relied on self-reported data obtained through a questionnaire, which may be subjected to response biases and limitations inherent in survey-based research. Future research could consider employing mixed-method approaches, such as interviews or observational studies, to complement and validate the findings obtained through self-report measures.

In practical terms, this study provides valuable insights for policymakers, practitioners, and stakeholders in the greenhouse industry. The recommendations include fostering an enabling environment, managing competition effectively, enhancing supportive infrastructure, promoting international collaboration and investment, encouraging continuous research and development, and strengthening market linkages.

Overall, this study contributes to the understanding of the factors influencing greenhouse development in Uzbekistan. The findings can inform evidence-based decision-making, policy formulation, and strategic planning to support the growth, competitiveness, and sustainability of the greenhouse industry. Further research is encouraged to explore additional factors and investigate their interrelationships to enhance our knowledge in this area.

7- Declarations

7-1- Author Contributions

Conceptualization, A.D., N.S., and T.M.; methodology, A.D., N.A., and K.K.; software, S.Kha.; validation, A.D. and N.S.; formal analysis, S.Kha., K.R., and K.K.; investigation, N.A., A.M., K.R., and T.M.; resources, S.Kha.; data curation, A.D.; writing—original draft preparation, N.S., M.M., and K.R.; writing—review and editing, A.D., N.A., A.M., and S.Kho.; visualization, S.Kho; supervision, A.D.; project administration, A.D.; funding acquisition, A.D. All authors have read and agreed to the published version of the manuscript.

7-2- Data Availability Statement

The data presented in this study are available in the article.

7-3- Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

7-4- Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki; ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements.

7-5- Informed Consent Statement

Written informed consent to participate in this study was provided by the participants.

7-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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Appendix I: Questionnaire

Table A-1. The questionnaire items used in this study

1. Rate your opinion on the economic interest (IM) factor on the scale.

		I am very dissatisfied	I am dissatisfied	Don't know / neutral	I agree	I agree very much
1	From the amount of income received from the activity of the greenhouse	☐	☐	☐	☐	☐
2	To justify the amount of money invested in the operation of the greenhouse economy	☐	☐	☐	☐	☐
3	Due to the increase in the price of chemical, biological and mineral fertilizers	☐	☐	☐	☐	☐
4	From increasing the rental price of the greenhouse	☐	☐	☐	☐	☐
5	About the service of those who transport your product to the market	☐	☐	☐	☐	☐
6	A large number of buyers for the produced product, lack of identity in the consumption process	☐	☐	☐	☐	☐
7	Quality and natural safety of the produced product	☐	☐	☐	☐	☐
8	From the volume of credit allocation of financial institutions	☐	☐	☐	☐	☐
9	From the tax burdens imposed on the activity	☐	☐	☐	☐	☐
10	From customs duties	☐	☐	☐	☐	☐

2. Mark your opinion on the scale of infrastructure (favorable conditions) factor.

		I am very dissatisfied	I am dissatisfied	Don't know / neutral	I agree	I agree very much
1	Communication and information from services	☐	☐	☐	☐	☐
2	Financial from services	☐	☐	☐	☐	☐
3	From transport services	☐	☐	☐	☐	☐
4	Trade from services	☐	☐	☐	☐	☐
5	Rent from services	☐	☐	☐	☐	☐
6	Personal from services	☐	☐	☐	☐	☐
7	Engineering research, technical tests and analysis in the field from services	☐	☐	☐	☐	☐
8	Other from services	☐	☐	☐	☐	☐
9	Vegetable storage warehouses from the service	☐	☐	☐	☐	☐
10	Selection of genetic scientific research centers and breeding-breeding from the centers	☐	☐	☐	☐	☐
11	From biological (gas) services	☐	☐	☐	☐	☐

3. Easy learning of greenhouse operation skills (Ease of using the greenhouse)

		I am very dissatisfied	I am dissatisfied	Don't know / neutral	I agree	I agree very much
1	From special training courses	☐	☐	☐	☐	☐
2	From working in partnership	☐	☐	☐	☐	☐
3	Developing experience in developed countries on this activity	☐	☐	☐	☐	☐
4	From state support for this activity	☐	☐	☐	☐	☐
5	Availability of appropriate resources	☐	☐	☐	☐	☐
6	Business activity	☐	☐	☐	☐	☐
7	The presence of traditional experience	☐	☐	☐	☐	☐
8	Availability of natural fertilization	☐	☐	☐	☐	☐
9	The size, forms and ease of payment systems and labor force adequacy	☐	☐	☐	☐	☐
10	The presence of one's own yard, the possibility of land allocation by the state	☐	☐	☐	☐	☐
11	Ease of obtaining credit	☐	☐	☐	☐	☐
12	Cultivation of products for daily consumption	☐	☐	☐	☐	☐
13	It is possible to work as a team	☐	☐	☐	☐	☐

4. Rate your opinion on the competitor impact factor on the scale.

		I am very dissatisfied	I am dissatisfied	Don't know / neutral	I agree	I agree very much
1	A large number of producers of the same product	☐	☐	☐	☐	☐
2	The development of open field vegetable farming	☐	☐	☐	☐	☐
3	Instability of share distribution	☐	☐	☐	☐	☐
4	Effect through price	☐	☐	☐	☐	☐
5	Impact through quality	☐	☐	☐	☐	☐
6	Influence through services	☐	☐	☐	☐	☐
7	The volume of production is not limited	☐	☐	☐	☐	☐
8	Creation of opportunities for foreign businessmen to operate	☐	☐	☐	☐	☐
9	The presence of conditions for the entry of foreign investors into the activity	☐	☐	☐	☐	☐

5. The development of the greenhouse depends on the following factors:

		Very wrong	Wrong	Neutral	That's right	Very true
1	Orientation of agrarian policy to the activity of greenhouses	☐	☐	☐	☐	☐
2	Tax rates are set according to the development of the greenhouse economy	☐	☐	☐	☐	☐
3	Loan rates are set according to the development of the greenhouse economy	☐	☐	☐	☐	☐
4	The volume of preferential loans justifies the establishment of a greenhouse	☐	☐	☐	☐	☐
5	Quotas have been set for the export volume of greenhouse products	☐	☐	☐	☐	☐
6	New discoveries and the opportunity to apply them to your field	☐	☐	☐	☐	☐
7	The level of change and adaptation to new technologies	☐	☐	☐	☐	☐
8	Technologies related to industry development	☐	☐	☐	☐	☐
9	Trends in the emergence of new products and services in the field	☐	☐	☐	☐	☐
10	Scientific and technical progress	☐	☐	☐	☐	☐
11	Impact of demographic changes	☐	☐	☐	☐	☐
12	The impact of changes in the standard of living of the population	☐	☐	☐	☐	☐
13	Consumption level of consumers	☐	☐	☐	☐	☐
14	Changes in the level of education	☐	☐	☐	☐	☐
15	People's purchasing power	☐	☐	☐	☐	☐
16	Greenhouse heating sources (solar energy, alternative energy and bioenergy, etc.)	☐	☐	☐	☐	☐