International Journal of Innovative Technologies in Economy

e-ISSN: 2414-1305

Operating Publisher
SciFormat Publishing Inc.
ISNI: 0000 0005 1449 8214

2734 17 Avenue SW, Calgary,
Alberta, T3E0A7, Canada
+15878858911
editorial-office@sciformat.ca

ARTICLE TITLE	ECONOMIC IMPACTS OF ROBOTICS TECHNOLOGY IN REMOTE GREENHOUSE FARMING: EVIDENCE FROM NORTHWEST INDIANA
DOI	https://doi.org/10.31435/ijite.1(53).2026.4205
RECEIVED	12 November 2025
ACCEPTED	17 January 2026
PUBLISHED	09 February 2026
LICENSE	The article is licensed under a **Creative Commons Attribution 4.0 International License.**

ECONOMIC IMPACTS OF ROBOTICS TECHNOLOGY IN REMOTE GREENHOUSE FARMING: EVIDENCE FROM NORTHWEST INDIANA

Amlan Mitra
Ph.D., Professor of Business Economics, Purdue University Northwest, USA

ABSTRACT

This study examines the economic impacts of robotics adoption in greenhouse farming, focusing on Northwest Indiana (NWI) as part of the U.S. Economic Development Administration's Project TRAVERSE. The research aims to quantify how robotics and automation enhance productivity, reduce labor dependence, and generate regional economic benefits. Employing an input–output (I–O) modeling framework using IMPLAN 2022 data, the study estimates the direct, indirect, and induced impacts of investments in greenhouse and robotics sectors. Findings indicate that robotics adoption yields higher multipliers for output, employment, labor income, and value added compared to traditional greenhouse farming. These results highlight stronger regional linkages, increased efficiency, and sustainable employment opportunities. The analysis demonstrates that technological innovation in agriculture not only boosts productivity but also contributes to broader regional resilience and economic diversification. The paper concludes that systematic economic impact assessment is vital for guiding public investments, workforce development, and policy decisions. Future research should track long-term adoption trends, evaluate policy incentives, and integrate sustainability metrics to inform climate-resilient and inclusive agricultural innovation.

KEYWORDS

Economic Impacts, Robotics Technology, Greenhouse Farming, Labor Efficiency

CITATION

Amlan Mitra. (2026) Economic Impacts of Robotics Technology in Remote Greenhouse Farming: Evidence From Northwest Indiana. *International Journal of Innovative Technologies in Economy*. 1(53). doi: 10.31435/ijite.1(53).2026.4205

Introduction

Greenhouse farming is undergoing rapid transformation with the integration of robotics and automation. These technologies offer precise seeding, harvesting, and climate control capabilities that improve yields while reducing reliance on scarce labor. Robotics in greenhouse farming builds upon decades of advances in automation and precision agriculture, ranging from robotic harvesters and autonomous sprayers to climate-controlled hydroponic systems. International research highlights how these systems improve efficiency, reduce resource use, and stabilize production under labor constraints. Studies also emphasize that robotics is not limited to high-tech farms alone but increasingly accessible through cooperative ownership models and robotics-as-a-service platforms, lowering barriers for smaller producers.

In Northwest Indiana (NWI), a region facing both agricultural labor shortages and economic restructuring, robotics in greenhouse farming represents an opportunity to stimulate growth while enhancing sustainability. This study is part of the U.S. Economic Development Administration (EDA) funded project which seeks to advance agricultural technology through robotics integration, renewable energy use, and workforce development. The purpose of this paper is to assess the regional economic impacts of robotics adoption using input–output modeling and provide evidence-based insights that inform policy, investment, and training strategies. Specifically, the study seeks to measure the economic impacts of innovative technologies in developing entrepreneurship support models through remote-based robotics and automated production processes, positioning greenhouse farming as a testbed for scalable innovation. Measuring the economic impacts of technological innovation is central to the study's goal, since the public and stakeholders need to understand the net benefits of investments in new technologies for jobs, income, and community development.

The economic impact component contributes directly to demonstrating technological feasibility, quantifying regional benefits, and supporting the creation of sustainable, high-skill employment opportunities.

This paper reviews recent literature and provides regional evidence to demonstrate why robotic greenhouse farming is economically beneficial to NWI. It does so by combining a strong theoretical foundation with empirical input–output modeling to quantify the broader benefits of robotics adoption. The study emphasizes that evaluating economic impacts is not simply an academic exercise but a practical necessity for policymakers, industry leaders, and communities who must decide how to allocate resources to new technologies. By linking to measurable outcomes, this paper highlights both the significance of robotics for Northwest Indiana and its wider relevance to regions across Indiana and the United States where farming remains central to economic development.

This research is significant because it demonstrates how technological innovation in greenhouse farming—while often evaluated through engineering performance and efficiency—must also be assessed in terms of its economic contributions to regions and communities. By measuring the direct, indirect, and induced impacts of robotics adoption, this study highlights how innovation affects employment, labor income, output, and value added in Northwest Indiana. Such evidence is especially critical when public funds support research and infrastructure, as it provides transparency and accountability to taxpayers by showing how investments in new technologies generate tangible regional benefits.

Equally important, this paper addresses a gap in the literature. While the fields of agricultural engineering and automation have produced extensive studies on the technical feasibility of robotics in controlled environment agriculture, there is comparatively little empirical research that quantifies the regional economic impacts of these innovations. This study contributes to filling that gap by combining engineering insights with regional economic modeling, providing a framework that can be replicated in other regions and sectors.

More broadly, the research underscores that studies of emerging agricultural technologies should extend beyond questions of technical feasibility. They should also answer whether innovation creates measurable economic value and net benefits for communities. By bridging engineering innovation with regional economics, this paper ensures that public and private stakeholders understand the broader implications of technological adoption for economic development, sustainability, and community resilience.

Literature Review

Robotics and automation in greenhouse farming have proven to be transformative globally. Pure Green Farms in South Bend, Indiana, operates a 174,000 ft² fully automated hydroponic greenhouse that grows lettuce from seed to harvest without human contact (Semmler, 2021). The facility uses robotic seeding, automated harvesting and packaging, and integrated climate control systems. It consumes 90 percent less water than field operations and distributes produce to Midwest markets within days, reducing spoilage. Labor shortages and seasonal volatility are major concerns in Midwestern agriculture, and robotic systems reduce reliance on migrant and seasonal workers by automating repetitive greenhouse tasks such as transplanting and harvesting (Griffiths, 2021).

Automated hydroponic and robotic systems deliver consistent planting density, nutrient dosing, and microclimate management. Studies show water savings of 90–95 percent and fertilizer reductions of over 90 percent compared to conventional farming (Impact Lab, 2014; Micro Farms, 2019). Li et al. (2021) found a 10.15 percent increase in yield and a 92.7 percent increase in net profit compared to expert-managed controls.

The Indiana green industry generated $6.9 billion in output, 3,800 direct jobs, and $96 million in labor income in 2018 (Purdue Landscape Report, 2021). Robotics adoption is expected to amplify these contributions by strengthening value-added activities and expanding market competitiveness. Adoption of robotics is gradual, influenced by institutional, labor market, and capital investment conditions. Cooperative models and robotics-as-a-service can help smaller producers overcome entry barriers. While some jobs are displaced, new opportunities emerge in programming, maintenance, and system integration.

Regional economics journals emphasize broader development implications. Deller and Whitacre (2019) highlight how automation and robotics reshape regional labor markets, often shifting employment toward higher-skill occupations. Goetz and Han (2020) show that agricultural innovation fosters rural entrepreneurship, spillover growth, and regional diversification. Isserman and Westervelt (2006) provide methodological insights into regional input–output analysis that strengthen the rigor of economic impact modeling. Prior research by Mitra (2011, 2014) has also contributed to the literature on economic impact analysis, including studies on sustainable development challenges and regional economic multipliers, which provide useful context for assessing the broader implications of robotics adoption.

Conceptual Framework

To synthesize insights from the literature, Figure 1 illustrates the conceptual framework applied in this study. Robotics adoption in greenhouse farming directly improves efficiency and productivity through labor savings, resource optimization, and yield improvements. These direct gains then create spillover effects that stimulate supply-chain industries (indirect impacts) and boost household spending in consumer-oriented sectors (induced impacts). Collectively, these effects generate regional economic development outcomes, including higher output, labor income, value-added contributions, and tax revenues.

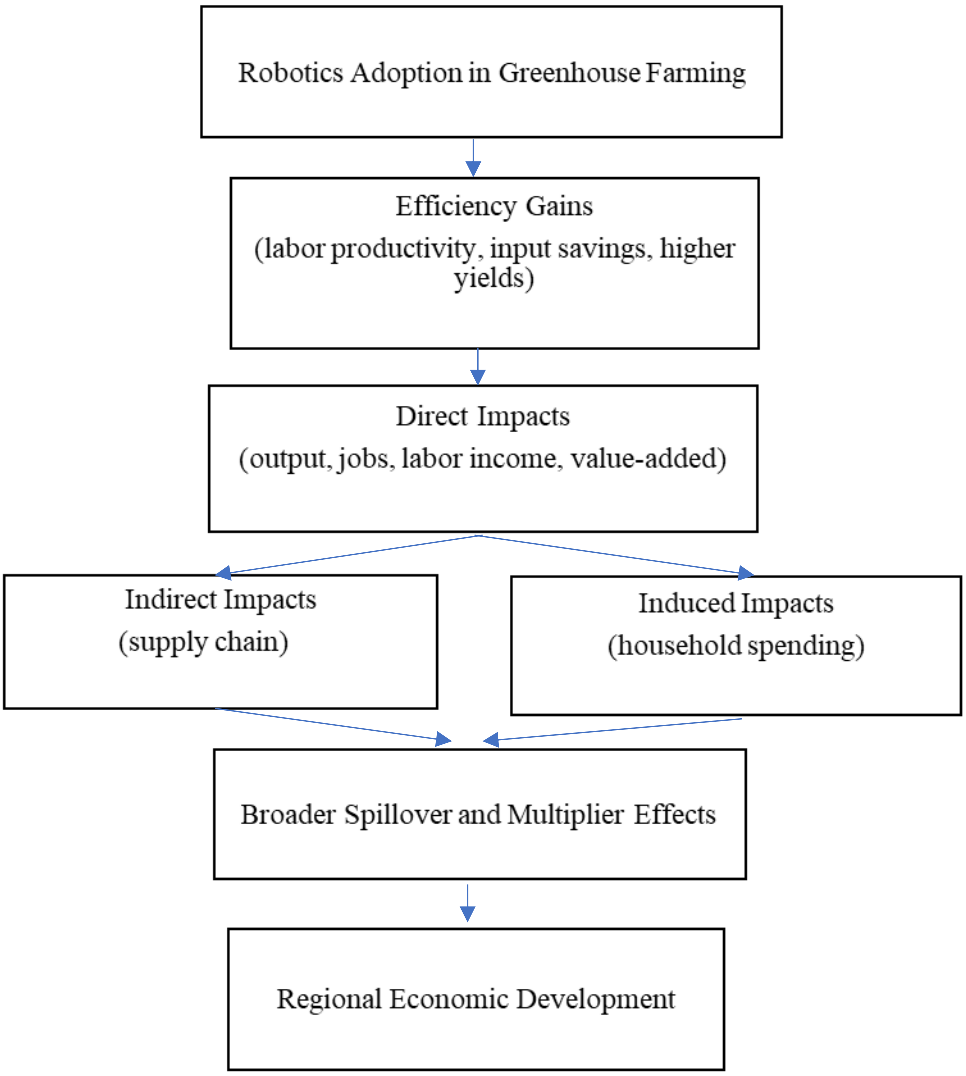

Fig. 1. *Conceptual Framework: Pathways from Robotics Adoption to Regional Economic Development*

Methodology

This study employs an **input–output (I–O) modeling framework** to estimate the economic impacts of robotics adoption in greenhouse farming in Northwest Indiana. The I–O model is specified as:

The standard I-O model in matrix notation is given by:

$$Y = (I - A)X \quad (1)$$

The solution structure of (1) is

$$X = (I - A)^{-1}Y \quad (2)$$

X is a vector of inputs, Y is the vector demand of final demand variables, and $(I - A)^{-1}$ is the matrix of interdependence coefficients.

For example, in the case of a regional employment model, the elements in the $(I - A)^{-1}$ matrix measure the direct and indirect employment levels from each sector of the economy to satisfy given levels of final demand. Using equation (2), the levels of employment from all sectors required to support specified levels of final demand in all sectors of the economy can be obtained. In addition, equations (1) and (2) have dynamic representations of

$$\Delta Y = (I - A)\Delta X \quad (3)$$

$$\text{and, } \Delta X = (I - A)^{-1}\Delta Y \quad (4)$$

Direct effects represent immediate changes in greenhouse and robotics sectors. Indirect effects capture supply-chain linkages, and induced effects account for household spending generated by new income.

Data Sources

Economic data were drawn from IMPLAN 2022 for Lake County and Northwest Indiana. IMPLAN provides county-level accounts consistent with BEA and BLS data. The greenhouse sector was mapped to NAICS 1114; robotics to NAICS 333 and 541. Employment, output, value-added, labor income, and tax impacts were estimated in 2022 dollars. All remote robotics operations—including robot camera monitoring, communications, system integration, and cyber-physical systems testing—were conducted at a university laboratory.

Input–Output Modeling Results

The input-output model assumes $100,000 million in initial investment each in the greenhouse farming and robotics technology sectors. This assumed level of investment serves as the basis for estimating the scale of direct, indirect, and induced impacts across Northwest Indiana.

Robotics adoption generates higher output per worker and higher earnings than traditional farming. Based on IMPLAN modeling with an assumed $100,000 million initial investment in each sector, the direct effects in Lake County include approximately $0.31 million in additional output, 2.65 direct jobs, $0.11 million in labor income, $0.04 million in new tax revenues, and $0.16 million in value-added contributions. These direct impacts reflect the immediate effects in greenhouse and robotics operations.

Indirect and Induced Effects

Indirect effects from the $100,000 million investment show additional gains of roughly $0.22 million in output, 1.75 jobs, $0.09 million in labor income, and $0.05 million in value added across supporting industries such as real estate, wholesale trade, employment services, and petroleum refining. Induced effects, generated by household spending of new wages, contribute about $0.18 million in output, 1.20 jobs, $0.07 million in labor income, and $0.03 million in value added. These impacts extend into consumer-oriented sectors such as retail, healthcare, and education, reinforcing local community vitality.

Multiplier Effects

Combining direct, indirect, and induced effects, the total impact reaches approximately $0.71 million in output, 5.6 jobs, $0.27 million in labor income, and $0.24 million in value added. The output multiplier for robotics-enhanced greenhouse farming is estimated at 1.60, compared to 1.47 for greenhouse farming without robotics. The employment multiplier is 1.72 versus 1.24, indicating a stronger capacity for job creation. The labor income multiplier (1.55) and value-added multiplier (1.68) also exceed traditional benchmarks, highlighting the broader regional benefits of robotics adoption. Robotics produces stronger multipliers across output, employment, income, and value-added. This indicates greater regional resilience.

Summary of Results

Robotics adoption enhances labor productivity, stabilizes costs, reduces input use, and improves market integration. Spillover effects stimulate secondary industries, while indirect and induced effects support households and local services. Multipliers confirm stronger linkages. Measuring economic impacts of innovation is essential, since stakeholders want to know net benefits in jobs, income, and spillovers. This approach should be extended to other technologies.

Table 1 summarizes the key multipliers estimated from the input–output analysis. The output, employment, labor income, and value-added multipliers for robotics-enhanced greenhouse farming are consistently higher than those for traditional greenhouse farming, underscoring the broader regional benefits.

Table 1.

Multiplier Type	Robotics-Enhanced Greenhouse	Traditional Greenhouse
Output Multiplier	1.60	1.47
Employment Multiplier	1.72	1.24
Labor Income Multiplier	1.55	1.33
Value-Added Multiplier	1.68	1.42

Conclusions

The purpose of this paper was to measure the economic impacts of robotics adoption in greenhouse farming and demonstrate how innovative technologies contribute to entrepreneurship support models. By employing input–output (I–O) modeling and integrating operational testing, the study provided applied evidence of the economic implications of robotics.

The results demonstrate significant net benefits: reduced reliance on seasonal labor, stabilized costs, enhanced resource efficiency, increased yields, and economic diversification through spillover effects. Multipliers confirm stronger linkages than traditional farming. Indirect and induced impacts show benefits extending to supply chain and consumer-driven sectors.

These implications extend beyond Northwest Indiana: regions across Indiana and the U.S. can learn from these findings as robotics offers pathways to productivity, resilience, and sustainability. By aligning practical case studies such as Pure Green Farms and Project TRAVERSE with regional economic modeling, this paper achieved its objective of quantifying the broader economic benefits of greenhouse robotics. The findings also reinforce insights from regional economics scholarship, positioning greenhouse robotics as both a technological innovation and a catalyst for regional development.

Just as emphasized throughout the paper, measuring the economic impacts of new technologies is vital. This study demonstrates how rigorous economic impact analysis under Project TRAVERSE not only informs policymakers and stakeholders about the efficiency of robotics in greenhouse farming but also provides transparent evidence of the net benefits to the public in terms of jobs, income, and community development.

Policy Implications

Policymakers, educators, and industry leaders should maximize benefits of robotics adoption. Workforce development is essential through training and partnerships. Financial incentives such as tax credits and cost-sharing programs can help small farms access robotics. Regional governance should promote collaborative clusters linking operators, tech firms, and universities. Broader sustainability planning should integrate robotics into climate adaptation strategies.

Importantly, future research directions identified in this study have direct relevance for policymaking. Longitudinal tracking of robotics adoption can inform adaptive workforce and training policies. Comparative analysis across regions can highlight where investments deliver the greatest returns. Sustainability metrics tied to robotics adoption can guide climate and energy policy.

Future Research Directions

While this study demonstrates the economic potential of robotics in greenhouse farming, several avenues remain for further research:

- **Longitudinal Studies**: Tracking robotics adoption over time to capture long-term impacts on productivity, labor markets, and regional growth.
- **Comparative Analysis**: Expanding analysis to other agricultural regions in Indiana and across the U.S. to evaluate how regional characteristics influence outcomes.
- **Technology Spillovers**: Investigating cross-sectoral effects, such as how robotics in agriculture stimulates innovation in manufacturing, logistics, and information technology.
- **Policy Evaluation**: Assessing the effectiveness of government incentives, grants, and workforce training programs in accelerating robotics adoption.
- **Sustainability Metrics**: Integrating environmental benefits, such as water and energy savings, into future impact assessments to align with climate resilience planning.

These directions will strengthen understanding of how robotics in agriculture contributes to both local and national economic development and will provide a clearer roadmap for scaling innovations across different contexts.

Acknowledgement

This work was funded by the U.S. Economic Development Administration (Award ID ED21HDQ3070043) “Project Traverse: Agtech robotics, automation and the virtually employed resiliently scaling enterprises,” for which the author is grateful. Special thanks to Joel F. Schwartz for research assistance. However, the author is solely responsible for the contents of the research work.

REFERENCES

1. Belasco, E. J., & Galinato, S. P. (2019). The economics of automation in specialty crop production. *Choices, 34*(3), 1–7.
2. Bogue, R. (2016). Growth in e-agriculture: Robotics and automation in crop production. *Industrial Robot, 43*(5), 463–468.
3. Deller, S. C., & Whitacre, B. (2019). Automation, robotics, and regional economic development. *Journal of Regional Analysis and Policy, 49*(1), 56–72.
4. FANUC. (2022). Robotic automation and AI harvests tomatoes. FANUC America.
5. Fiechter, T., & Schumacher, D. (2019). Autonomous robots in agricultural fields advance through $200,000 investment to Purdue startup. AgriNovus Indiana.
6. Goetz, S. J., & Han, Y. (2020). Rural entrepreneurship, agricultural innovation, and regional growth. *Growth and Change, 51*(1), 3–25.
7. Griffiths, C. (2021, April 22). Pure Green Farms’ fully automated greenhouse a new way to farm. *The Packer/AgWeb*.
8. Impact Lab. (2014, February 5). Indiana Amish farm leads the way to local food security.
9. Isserman, A. M., & Westervelt, J. (2006). 1–2–3 I–O: Simplifying regional input–output analysis. *International Regional Science Review, 29*(3), 327–348.
10. Li, X., et al. (2021). iGrow: A smart agriculture solution to autonomous greenhouse control. *arXiv preprint*. https://arxiv.org/abs/2107.05464
11. Micro Farms. (2019, March 25). Micro farm, macro impact. *Produce Grower*. Purdue Landscape Report. (2020). The economic contribution of the Indiana green industry.
12. Mitra, Amlan (2014). “Challenges to Sustainable Economic Development,” *Indian Journal of Economics and Business,* Volume 13, No. 2, pp. 265-288.
13. Mitra, Amlan (2011). “Regional Economic Impacts of the Transportation Industry,” *International Economics & Finance Journal,* Volume 6, No. 2, pp. 209-219, July – December 2011.
14. Purdue Landscape Report (2021). “Economic Contribution of The Indiana Green Industry, 2020 Report,” Issue:21-12, July, 2021.
15. Semmler, E. (2021, April 10). Hi-tech indoor farm in South Bend taking on lettuce market. *AgriNews*.