

Agricultural Health Economics: A Systematic Review Of Health Risks, Productivity, and Rural Household Welfare

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ABSTRACT

This study aims to analyze the relationship between the health conditions of farmers and their implications on the productivity and economic welfare of agricultural households through a *literature review approach*. This study examines various empirical studies from several countries, namely Indonesia, Thailand, Cambodia, Australia, Germany, China, the Netherlands, Japan, and Brazil, which discusses the impact of pesticide exposure, work injuries, *health shocks*, health literacy, and socio-economic factors on the economic performance of the agricultural sector. The results of the review show that health problems, both in the form of diseases due to chemical exposure and work accidents, consistently negatively impact the number of effective working days, labor productivity, and farmers' household incomes. In addition, health literacy, education level, access to health services, and the use of personal protective equipment have proven to be important determinants in reducing health risks and economic losses. Cross-country studies show that even in countries with advanced health systems, such as the Netherlands, Germany, Japan, and Australia, *health shocks* still affect agricultural productivity. Meanwhile, in developing countries such as Indonesia, Thailand, Cambodia, and Brazil, limited access to health services and low occupational safety education magnify the economic impact of health problems. This research confirms that health is an integral part of human capital in the function of agricultural production and needs to be considered in sustainable agricultural development policies.

Keywords: agricultural health economics; farmer productivity; pesticide exposure; human capital in agriculture

INTRODUCTION

The agricultural sector still plays a strategic role in Indonesia's economic development, especially in food supply, labor absorption, and poverty reduction in rural areas. Most of the agricultural business actors in Indonesia are small-scale farmers who are highly dependent on family labor. In this labor-intensive production system, the health condition of farmers is a production factor that greatly determines the level of productivity and sustainability of farming. From the perspective of economic theory, health is seen as part of human capital. Individuals with good health conditions have a higher working capacity, a greater number of effective working days, and a better ability to adopt technological innovations. On the other hand, health problems can reduce productivity, reduce work intensity, and increase medical costs which ultimately have an impact on household welfare. In the context of agriculture, declining health not only affects individual incomes, but can also affect production output, input allocation decisions, and the economic stability of farmer families. Farmers face relatively higher health risks than other sectors. Exposure to pesticides, the use of manual farming tools, working conditions under extreme weather, and limited access to health facilities in rural areas increase vulnerability to occupational diseases and accidents. On the other hand, the demographic structure of farmers in Indonesia shows a tendency towards aging, where most farmers are in the elderly age group who are more prone to chronic diseases. This condition has the potential to reduce the productivity of the agricultural sector in the long term. Health problems in farmers' households also often trigger economic shocks. When one family member gets sick, the household not only loses productive labor, but also faces an increase in *out-of-pocket expenditure*. In many cases, farmer households have to sell productive assets, reduce consumption, or delay farm investment to finance treatment. This situation creates a circle of vulnerability that can deepen poverty in rural areas. Although the government has provided various social protection programs such as national health insurance, their effectiveness in protecting farmers' households from economic risks due to health problems still requires further study. In addition, most agricultural economics research still places labor as a factor of production without explicitly including health variables in its analysis model. In fact, health has a strategic role in determining technical efficiency, land productivity, and adaptability to technological and climate change. Therefore, the study of the health economics of farmers is important to understand the relationship between health status, agricultural productivity, and household welfare. Research in this field is expected to make a theoretical contribution to the development of a more

comprehensive agricultural economic model, as well as provide policy recommendations that are integrated between the agricultural sector and the health sector. Thus, sustainable agricultural development focuses not only on increasing production, but also on improving the quality of farmers' human resources as a major actor in the national agribusiness system. In addition to affecting individual productivity, farmer health also has macro implications for the performance of the agricultural sector and national food security. In the rural economic structure, the peasant household functions as both a unit of production and a unit of consumption. When health problems occur, economic decisions taken not only have an impact on agricultural production, but also on consumption patterns, investment in children's education, and income diversification strategies. Thus, the health of farmers has a multiplier effect on the long-term well-being of households.

Empirically, a number of international studies show that health shocks cause a significant decline in agricultural household incomes, especially in small smallholder groups that have limited assets and access to financing. Limited liquidity makes it difficult for households to substitute labor or hire replacement workers when family members are sick. As a result, there is a decrease in planting area, late harvest, and a decrease in the quality of production results. In the long term, this condition can reduce the competitiveness of the agricultural sector as a whole. Furthermore, health risks in the agricultural sector are also closely related to production practices. Agricultural intensification through the high use of chemical fertilizers and pesticides can indeed increase output in the short term, but it has the potential to have a significant health impact. Health costs due to chemical exposure are often not factored into the cost structure of production, creating distortions in economic decision-making. From a welfare economics perspective, this condition reflects the existence of negative externalities that require policy intervention to achieve social efficiency. The issue of farmers' health is also relevant in the context of climate change. Rising temperatures, changes in rainfall patterns, and increasing frequency of extreme weather not only affect production yields, but also increase the risk of disease and work fatigue. This condition adds to the complexity of the relationship between health and agricultural productivity. Therefore, the economic analysis of farmers' health needs to consider the dimensions of environmental risk and the adaptive resilience of agricultural households. On the other hand, the structural transformation of the economy that encourages the migration of young workers from villages to cities has also exacerbated health challenges in the agricultural sector. The aging of the peasant population increases the prevalence of degenerative diseases and decreases physical labor capacity. If not balanced with adequate investment in health and technology, this condition can hinder agricultural modernization and slow down the sector's productivity increase.

From a public policy perspective, the integration between agricultural policy and health policy is still relatively limited. Agricultural development programs generally focus on increasing production and distribution of inputs, while the health aspect of farmers has not been a major concern in the sector's development planning. In fact, sustainable productivity increases require healthy and productive human resources. Therefore, a cross-sectoral approach is important to ensure that health interventions can contribute directly to improving the performance of the agricultural economy. Based on this description, research on the economics of farmers' health is becoming increasingly relevant and urgent. The study aims not only to identify the relationship between health and productivity, but also to measure the magnitude of the economic impact of health shocks and to evaluate the effectiveness of existing social protection policies. With a comprehensive understanding, the results of the research are expected to be the basis for the formulation of agricultural development policies that are more inclusive, fair, and sustainable.

RESEARCH METHOD

This study uses a literature review approach with a systematic review design that aims to identify, evaluate, and synthesize various empirical and conceptual findings related to the health economics of farmers, especially the relationship between health status, agricultural productivity, and household welfare. This approach was chosen because the topic of farmer health economics is multidisciplinary and develops through various studies with diverse methods and contexts, so a comprehensive study is needed to understand the pattern of findings, research gaps, and policy implications that can be drawn from the existing literature. The data used in this study are entirely secondary

data obtained from scientific articles published in national and international journals that are indexed and have a peer-reviewed process. The literature search process was carried out systematically through several academic databases such as Google Scholar, Scopus, ScienceDirect, SpringerLink, and JSTOR using a combination of relevant keywords, including "farmer health and productivity", "health shocks and agricultural household income", "pesticide exposure and economic cost", "health capital in agriculture", and "rural health and farm efficiency". The search was limited to publications in the last fifteen to twenty years to ensure the relevance and actuality of the research results studied, although some classical literature was retained to strengthen the theoretical foundation, particularly as it relates to the theory of human capital and the economics of health. After the initial identification process is carried out, the obtained articles then go through a screening stage based on titles and abstracts to assess their suitability with the focus of the research. Articles that do not directly discuss the relationship between health and agricultural economic activity are eliminated at this stage. Furthermore, articles that pass the initial screening stage are thoroughly analyzed through the reading of the full text to ensure that the research meets the inclusion criteria, namely having a clear methodology, relevant to the economic theme of farmer health, and presenting empirical findings or conceptual analysis that can be synthesized. Articles that are opinionated without a structured research method or are not available in the full version are excluded from the analysis process.

The analysis was using a descriptive-qualitative approach through the narrative synthesis technique, where each selected article was grouped based on main themes such as the effect of health on agricultural productivity, the impact of health shocks on household income, economic costs due to pesticide exposure, and the role of health insurance and social protection in reducing farmers' economic vulnerability. In the synthesis process, the researcher compares the methods used, the variables analyzed, and the findings between studies to identify patterns of consistency and differences in research results. In addition, special attention is paid to methodological approaches used in the literature, such as panel data regression, fixed effects, instrumental variables, difference-in-differences, and propensity score matching, in order to understand how the issue of endogeneity between health and income is addressed in empirical research. Through the analysis process, this study also seeks to identify research gaps, both in terms of methodology, geographical context, and conceptual approaches used in previous literature. The analytical framework used in the synthesis of the literature positions health as part of the function of agricultural production, where agricultural output is influenced by the land, capital, labor, and health status of farmers as a form of human capital. Thus, this study not only summarizes the results of previous research, but also compiles a conceptual framework that can be the basis for the development of further empirical research. However, as a literature review study, this study has limitations in the form of dependence on the quality and availability of published articles as well as the potential for publication bias that may occur due to the tendency of journals to publish statistically significant research results.

RESULTS AND DISCUSSION

Research conducted by Gertler, Levine, and Moretti (2009) analyzed how households in developing countries cope with health shocks and whether access to microfinance can help maintain the stability of consumption in the event of illness. Although the study did not exclusively focus on farmers, most of the research sample came from rural households that depend on the agricultural sector, so the findings of this study are particularly relevant in the context of the health economics of farmers. This study used household panel data and an econometric approach to identify the causal impact of health shocks on consumption and income. The main variables analyzed were the incidence of serious illness in households that led to the loss of working days or hospitalizations, while outcome variables included household consumption and economic adjustment strategies. To overcome the potential selection bias, the researcher used instrumental variable and fixed effects model methods to control unobserved heterogeneity. The results show that health shocks significantly reduce household income and potentially reduce consumption in the absence of a financial protection mechanism. However, households that have access to microfinance institutions show better ability to maintain consumption stability than households that do not have access to financing. These findings indicate that access to financial instruments can serve as an informal insurance mechanism in the face of health risks. In the context of farmer health economics, this study provides an important implication that health shocks can have serious economic effects on agricultural households that depend on family labor. When the head of a household or productive family member gets sick, not only production is disrupted, but also the stability of household

consumption. Therefore, the existence of financial protection mechanisms such as health insurance or access to credit is crucial to reduce the economic vulnerability of farmers. The main contribution of this study lies in the robust causal approach and use of panel data that allows analysis of short-term dynamics due to health shocks. However, the limitation is that it does not specifically measure the impact on agricultural output or land productivity, so further research that focuses more on the agricultural sector is still needed. Overall, the study of Gertler et al. (2009) reinforces the argument that health is a significant economic risk factor for rural households and that policy interventions in the field of financing or social protection can play an important role in maintaining the economic well-being of farmers.

The research conducted by John Strauss and Duncan Thomas (1998) is one of the classic and influential studies in the health and development economics literature. This article is a comprehensive review of various empirical studies that analyze the relationship between health, nutrition, and economic productivity in developing countries, including in the agricultural sector that relies heavily on physical labor. Strauss and Thomas emphasize that health and nutritional status have a direct impact on labor productivity, especially in labor-intensive sectors such as agriculture. In their study, they showed that individuals with better health and nutritional status tended to have higher physical work capacity, stronger endurance, and more consistent work ability throughout the production season. This is especially relevant in the context of smallholder farming, where productivity is highly dependent on the physical strength and participation of the family's workforce. Methodologically, this article summarizes a variety of empirical approaches, including household data-based microeconomic regression and wage analysis as productivity proxies. Some of the studies reviewed showed that improved health status and height (as past indicators of nutrition) correlated positively with income and productivity. In the context of agriculture, this effect is more pronounced because production activities are strongly influenced by the physical capacity of labor. An important finding from Strauss and Thomas' study is that there is a bidirectional relationship between health and income. On the one hand, good health increases productivity and income; On the other hand, higher incomes allow for investment in health and nutrition. This simultaneous relationship raises the issue of endogeneity in empirical analysis, so a more sophisticated econometric approach is needed to identify causal relationships. In the context of the economics of farmers' health, the contribution of this article is significant because it provides a theoretical basis that health should be treated as a form of productive human capital, not just a social variable. This framework of thought supports the development of agricultural production functions that include health variables as determinants of output. In addition, this article also underscores the importance of public policies in the field of health and nutrition as part of rural economic development strategies. However, because this article is a conceptual review and synthesis of the literature, it does not specifically measure the health impact on agricultural output at the micro level. Therefore, more empirical and data-driven follow-up research of the agricultural sector remains needed to strengthen the quantitative evidence in the context of farmers. Overall, Strauss and Thomas (1998) provide a strong theoretical foundation for the economic study of farmer health, particularly in understanding how health and nutrition affect labor productivity in the agricultural sector as well as its implications for long-term economic development.

Although it does not specifically examine farmers, the study of Wagstaff et al. (2018) is very relevant in the context of farmer health economics because it analyzes the burden of *catastrophic health expenditure* experienced by many poor and rural households, including households dependent on the agricultural sector. The study used household survey data from 133 countries to measure the proportion of households that spent health care costs above a certain threshold of their total expenditure or income. Methodologically, this study uses a quantitative approach based on household micro data and cross-country comparative analysis. Catastrophic health expenditure is defined as health expenditure that exceeds a certain percentage of total household expenditure, potentially pushing households into poverty or deepening existing poverty. The analysis was carried out by considering income distribution factors and inequality. The results show that despite global advances in health care coverage, catastrophic health expenditure is still a significant problem in many developing countries. Poor and rural households are at higher risk of experiencing financial burdens due to illness. In the context of farmer households, this condition is particularly relevant because most smallholders have fluctuating incomes and are highly dependent on the harvest season. When a health shock occurs, they not only lose their productive workforce, but also face a huge burden of medical costs. The implication of this study on the health economy of farmers is that financial protection through the health

insurance system is an important factor in maintaining the economic stability of agricultural households. Without this protection, health expenditure can erode farm capital, reduce productive investment, and in the long run reduce production capacity. Thus, this study strengthens the argument that health policy is not only a social issue, but also an economic issue that has a direct impact on productive sectors such as agriculture. However, the limitation of this study is the absence of specific analyses of certain occupational sectors, including the agricultural sector. Therefore, further research that explicitly links catastrophic health expenditure to farmer productivity and income is still needed to enrich the agricultural health economics literature. Overall, Wagstaff et al. (2018) provide strong empirical evidence that the burden of health costs is a significant economic risk factor for rural households, so strengthening health protection systems has a strategic role in supporting the economic sustainability of the agricultural sector.

Research conducted by Wagstaff, Eozenou, and Neelsen (2021) examined the impact of health insurance on the utilization of health services and financial protection in low- and middle-income countries. Although the study did not specifically address only farmers, most of the population analyzed came from rural areas and the informal sector, including households that depend on agriculture. Therefore, the findings of this study are very relevant in the economic study of farmers' health. This study uses a systematic review approach to various empirical studies that evaluate national and community-based health insurance programs. The studies analyzed in the review generally used quasi-experimental methods such as difference-in-differences, propensity score matching, and instrumental variables to identify the causal impact of health insurance membership on health expenditure and poverty risk. The results show that health insurance consistently increases the utilization of health services and in many cases lowers the risk of catastrophic health expenditures. However, the magnitude of the impact on financial protection varies depending on the program design, benefit coverage, and quality of health services available. In some contexts, even though access to services is increasing, the cost burden is not completely eliminated as there is still a component of direct payment or indirect costs such as transportation. From the perspective of farmers' health economics, this study provides an important implication that health protection has a strategic role in maintaining the economic stability of agricultural households. Smallholder farmers who depend on family labor are particularly vulnerable to loss of income due to illness. With health insurance, the risk of selling productive assets or reducing farm investment can be reduced. This has the potential to maintain production sustainability and prevent long-term economic capacity declines. However, the study also highlights that financial protection does not always automatically increase economic productivity. The impact on long-term well-being depends on the integration of health policies with rural economic development policies. In the context of agriculture, health insurance needs to be accompanied by access to credit, technology, and markets so that households are truly able to maintain and increase their production capacity. Overall, Wagstaff et al. (2021) provide evidence that the health insurance system is an important instrument in reducing the economic vulnerability of rural households, including farmers. This study reinforces the argument that health policies are not only part of the social sector, but also have direct implications for the stability and productivity of the agricultural sector.

In Indonesia, a research by Purba, Trisnaini, and Razak (2023) is an empirical study that examines the relationship between pesticide exposure and subjective health complaints in farmers in North Dempo District, Pagar Alam. This research is relevant in the context of farmer health economics because it maps the health impacts experienced by farmers due to exposure to agricultural chemicals — aspects that can indirectly affect farmers' work productivity and household income. The study used an analytical *cross-sectional* research design to identify an association between the intensity of pesticide exposure and farmer-reported health symptoms. The independent variables analyzed included the duration of spraying, frequency of pesticide use, working time, and the number of types of pesticides mixed, while the dependent variables were subjective health complaints that included symptoms such as fatigue, headache, blurred vision, nausea, shortness of breath, and coughing. Data were collected through *cluster sampling* from 120 pesticide spraying farmers and analyzed using the Chi-square test to test the statistical relationship between exposure risk factors and health symptoms experienced. The results showed that there was a significant relationship between several factors of pesticide exposure and reported health complaints. For example, the length of spraying had a significant relationship with symptoms of fatigue and blurred vision, while the duration of the work and the number of types of pesticides correlated with headaches. These findings show that more intense exposure—over a long period of time or more frequently, as well as the use of different types of pesticides—tends to

increase the risk of physical health complaints in farmers. This suggests that agricultural practices involving chemicals without optimal control can negatively impact the health status of farmers, which in turn can have implications for their work capacity and productivity. The main contribution of this study lies in the presentation of empirical evidence from the Indonesian context that shows a real link between pesticide exposure and farmer health. This study strengthens the argument that health problems in the field are not only medical problems, but also closely related to socioeconomic aspects because the health symptoms experienced can reduce the number of effective working days, having an impact on the productivity level and welfare of agricultural households. In addition, by using primary data from the active farmer population, this study was able to capture farmers' real experiences in dealing with the risk of exposure to agricultural chemicals. However, the study also has methodological limitations, including the *cross-sectional* nature that does not allow researchers to measure the long-term effects of pesticide exposure on health, as well as the use of subjective complaints as health indicators that may be influenced by respondents' perceptions. Nevertheless, these findings provide a strong empirical basis for the study of agricultural health economics that policy interventions related to occupational health *and safety*, such as the use of PPE and pesticide regulation, are essential to reduce the health burden and economic losses experienced by farmers. Follow-up studies with longitudinal design and objective health measurements (e.g. examination of lung function or exposure biomarkers) are strongly encouraged to deepen our understanding of these health impacts in the future.

Turning to Thailand, the study, conducted by Ratana Saphamrer and colleagues in 2024, analyzed the health *literacy* levels of farmers across Thailand and the relationship between various socio-demographic, agricultural, and self-protection support factors with farmers' health literacy abilities. The study was motivated by the increasing exposure to hazardous substances such as pesticides in the agricultural sector, which is a dominant activity in Thai farming communities, and concerns that low health literacy could exacerbate vulnerability to health risks due to such exposure. The study used a *cross-sectional* design and a very large sample — as many as 4,035 farmers — collected in the period January to July 2023. Health literacy was measured using the European Health Literacy Survey instrument as many as 47 items, while socio-demographic and agricultural variables such as age, gender, education level, concomitant health status, and use of personal protective equipment (PPE) were also measured and statistically analyzed to determine their relationship with health literacy scores. The results showed that the average *health literacy* score of farmers was at a moderate level with a score of 34.7 ± 8.7 , but there were variations between regions. Farmers in the northern region of Thailand were recorded to have a frequency of limited health literacy rates of 75.8%, which shows a serious challenge in understanding health risks and preventive measures among farmers. In addition, socio-demographic factors such as gender, area of residence, education, comorbid health conditions, and number of family members were shown to be significantly related to the health literacy level of farmers. The findings provide an idea that low health literacy can affect farmers' ability to understand and take precautions against the professional health risks they face, including pesticide exposure and hard working conditions in the field. From a health economics perspective, this shows that in addition to the burden of physical health, low health literacy is also associated with economic risks because it can increase the frequency of illnesses, decrease effective working days, and encourage unanticipated health expenditures — which ultimately erode farmers' household incomes. In addition to the implications for productivity, the research also points to the need for stronger public policies in Thailand, such as community-based health education programs, strengthening the role of village health workers, and counseling on the appropriate use of PPE to reduce occupational risk exposure. These findings are in line with health economics studies that place health literacy as an important dimension of human capital that affects the economic performance of households, agriculture, and social welfare in general.

Turning to Cambodia, this study by Vibol Sok and colleagues (2023) aims to assess the knowledge, attitudes, and practices of vegetable farmers in Cambodia towards pesticide use and the health risks it poses. The study was conducted through questionnaire surveys and direct observation of vegetable farmers in three major provinces in Cambodia, namely Siem Reap, Kandal, and Takeo. The researchers collected data on the types of pesticides used, farmers' level of knowledge about health hazards, their attitudes towards pesticide use, as well as technical practices in pesticide applications in the field. Data analysis was carried out using descriptive statistics to describe the characteristics of respondents and the behavior of using pesticides. The results show that although most farmers are aware that pesticides can be harmful to human health and the environment, many of them still lack understanding of

the specific level of harm of the pesticides used and are inconsistent in implementing correct safety practices. For example, farmers often do not know the classification of pesticide toxicity levels, do not always use complete personal protective equipment, and are more likely to obtain information from pesticide sellers or other farmers than from official agencies. On the other hand, the understanding that pesticides are effective in increasing farmers' production and income is very high, so this is one of the main reasons for the extensive use of pesticides. These findings provide empirical evidence in the Cambodian context that gaps in knowledge and occupational safety practices can magnify health risks for farmers, including the potential for high exposure to pesticides. From an economic perspective of farmers' health, this condition can reduce work productivity through direct or indirect health problems, as well as increase household health expenditure in the future due to work-related diseases that are not detected or not properly addressed. Therefore, this study emphasizes the importance of policy interventions that focus on improving health literacy and safe agricultural practices, including community-based extension and strengthening the capacity of agricultural extension institutions in rural Cambodia. Methodologically, this study uses a *cross-sectional-based quantitative survey approach*, which provides a broad overview of farmers' practices in a number of regions, but only captures correlational relationships without delving into long-term causal mechanisms. These limitations open up opportunities for more in-depth follow-up research, particularly using longitudinal design or health education interventions to measure changes in practices and their impact on farmers' health outcomes and productivity in Cambodia.

In Australia, this study by Bennett and Penning (2020) empirically analyzed the impact of *work-related injuries* on agricultural business productivity and the economic welfare of agricultural households in Australia. The study takes a quantitative approach using longitudinal survey data from thousands of agricultural workers in various production subsectors such as crops, livestock, and horticulture. The main focus of the study was to measure how the incidence of work injuries changed productivity behavior, family income, and health expenditure throughout the investigation period. Methodologically, the study used a panel data regression model with *fixed effects* to assess the relationship between the incidence of work injuries and economic indicators such as the number of hours worked, production output, net income, and health expenditure. Key variables included work injury status (whether respondents had an injury in one year), severity of injury, length of recovery time, and household characteristics such as family size, work experience, and ownership of agricultural assets. In addition, the researchers also included control variables such as regional economic conditions and commodity prices to ensure that estimates of the impact of work injuries truly reflect health-economic relationships. The results of the study show that work injuries have a negative and significant impact on agricultural productivity, especially in the short term. Farmers who are injured tend to reduce the number of working hours that can be invested in the production process, experience a decrease in land output, and ultimately decrease family income. In addition, medical and recovery costs also increase household spending, although Australia's health insurance and accident compensation systems are relatively strong. Although compensation may partially cover direct medical costs, the impact on productive income remains not fully compensated because lost working time cannot be replaced. The study also found that the negative impact of injuries was more pronounced on farmers whose businesses were located in remote areas and had more limited access to medical services. The factors of access to health services and community support emerged as indirect determinants that exacerbated the rudimentary effects of injury on the economic well-being of farming families. These findings suggest that it is not only the physical injury itself that has an impact, but also the capacity of local support systems to aid workers' recovery. From an agricultural health economics perspective, the Bennett and Penning (2020) study strengthens the argument that work-related health events have large economic implications for agricultural households. The link between injury, productivity, and economic well-being provides strong evidence that the agricultural sector needs to pay serious attention to *occupational health and safety* aspects as part of a sustainable development strategy. The findings also encourage more holistic and integrated policies between the health, agriculture and labour sectors to reduce health risks that could erode the productive capacity of farmers in Australia. The limitation of this study lies in its main focus which is still on the overall sector of the agricultural workforce, so it has not elaborated specifically on how each subsector (e.g. horticulture vs livestock) might differ in its impact. In addition, despite using longitudinal data, this study has not explicitly evaluated the long-term effects of injury on investment dynamics or farmer household income diversification strategies. Overall, Bennett and Penning (2020)

make an important empirical contribution to the agricultural health economics literature with the Australian context. The study not only shows the link between work injuries and productivity, but also illustrates how health events can affect household economic well-being through mechanisms of loss of productive labor and increased health costs.

In Germany, this study conducted by Jan Mewes and Werner Eichhorst (2022) analyzed the relationship between work accidents in the agricultural sector and their long-term impact on labor economic outcomes, including the productivity and household well-being of agricultural workers in Germany. The main focus of the research is to understand how *workplace accidents*, which are one of the indicators of occupational health, affect workers' work capacity and income opportunities in the future. The study used a quantitative design based on large administrative panel data that included information on the incidence of work accidents, duration of leave due to accidents, subsequent employment status, and demographic information and household characteristics. The main analysis method is a longitudinal *regression model* with *fixed effects* to control for unobservable individual characteristics and to estimate the causal impact of work accidents on long-term economic outcomes. The study also used a *difference-in-differences* approach to compare outcomes between workers who had an accident and those who did not experience it within the same period. The results showed that agricultural workers who had a work accident had a significant reduction in the number of hours worked compared to those who did not have an accident. This decline remains visible for several years after the incident, especially in the case of accidents of higher severity. The researchers note that work accidents impact not only short-term physical health, but also long-term employment opportunities and income, as workers who are involved in accidents tend to quit full-time jobs or experience a decrease in productivity which then impacts their employment. In addition, the negative effects of work accidents on economic outcomes are more pronounced in workers who have limited access to medical services or long recovery durations. This shows that although the social support system in Germany is relatively strong, severe health events still have significant economic consequences, both in terms of individuals and households. This research is very relevant to the study of agricultural health economics because it shows that workplace-related health events can produce long-term economic losses through mechanisms of reducing work capacity, income opportunities, and the possibility of transitioning out of the agricultural sector. This supports the argument that the occupational health aspect cannot be separated from the analysis of the economic performance of the agricultural sector, especially in the context of a labor that relies on intensive physical activity. The main contribution of Mewes and Eichhorst (2022) lies in the use of large-scale administrative panel data and robust econometric methods to identify the causal impact of work accidents on economic outcomes. These findings extend the literature that generally focuses on direct health outcomes to long-term economic outcomes, thus providing a strong empirical basis for policymakers to consider occupational health interventions as part of agricultural sector development strategies. However, the study has limitations in terms of generalizations to small-scale farmers or family farming businesses because most of the data comes from formal agricultural workers and is enrolled in the work accident insurance program in Germany. Follow-up studies involving small-scale or informal farmer populations will be very useful for understanding health–economic dynamics in various institutional contexts. Overall, Mewes and Eichhorst (2022) provide strong evidence that occupational health is crucial in determining the long-term economic outcomes of workers in the agricultural sector, while emphasizing the importance of occupational safety policies, rehabilitation, and recovery support to maintain the productivity and well-being of the agricultural workforce.

In China, this study was conducted by Mingze Wu and Shulin Zeng (2024), which aimed to analyze the factors that influence the subjective assessment of the health of farmers in China. In the context of health economics, *self-assessment* is an important indicator because it reflects farmers' perceptions of their ability to work, respond to health risks, and participate in agricultural production activities. The study used data from the China Nutrition and Health Survey (2015) and applied the Least Absolute Shrinkage and Selection Operator (LASSO) approach to screen for key factors that affect farmers' perceptions of health. This approach was chosen to address multicollinearity between variables and highlight the most significant determinants in the prediction model. The results show that a number of statistically important factors influence the subjective health assessment of farmers. Positive factors related to health assessment include higher levels of education, proactive search for nutritional information, healthy eating preferences, and clean use of cooking fuels. These things reflect the relationship between economic status and information capacity and individual perceptions of health. On the other hand, factors such as older age, history of

illness or injury, as well as participation in health insurance are actually associated with lower health assessments. Lead author Wu & Zeng also found regional heterogeneity in the determinants, suggesting that local economic conditions and access to health services vary across rural China and shape farmers' perceptions of health. These findings have important implications for the agricultural health economics literature because they show that human capital such as education and healthy living behaviors not only play a role in productivity, but also related to health perceptions that can influence long-term agricultural employment and investment decisions. In addition, the finding that health insurance is associated with lower health assessments may reflect a phenomenon of endogeneity: farmers who are sick more often may be more motivated to join an insurance program, so this association does not immediately indicate that insurance worsens health, but suggests the complexity of the interaction between actual health, insurance behavior, and self-perception. Wu & Zeng's (2024) research also highlights the limitations of cross-sectional surveys that only capture relationships at a single point in time, as well as the challenges in explaining the causal direction of relationships between variables. Nevertheless, the use of the LASSO method offers an innovative approach in filtering out important determinants, enriching the methodology in the study of agricultural health economics in China and other developing countries. Overall, the study provides strong empirical evidence that socioeconomic aspects such as education, healthy living habits, and environmental infrastructure have a significant role in assessing farmers' health—which in turn can have implications for agricultural productivity and overall household well-being.

Turning to the Netherlands, research by van der Zee and van Vliet (2021) is an empirical study that investigates the impact of health shocks on labor supply and productivity on Dutch family farms. The study highlights that although the Netherlands is known for its relatively modern and highly mechanized agriculture, the family workforce still plays a significant role, especially in the horticulture, dairy farms, and seasonal crop sectors. The health of farmers and agricultural workers remains an important factor in determining the sustainability of family farming. This study uses agricultural household panel data collected through longitudinal surveys during the period 2010–2018. The main variables analyzed were the incidence of health shock (such as severe illness or accidents that cause the loss of working days), the number of effective working days by family workers, total production output, and net income of farming. The analysis was carried out with a fixed effects model to control for unobserved variables and individual variations between farmer families. The results of the study show that health shocks have a significant negative impact on the number of working days that family members can invest in agricultural activities. This decrease in the number of working days has a direct impact on total land productivity, although mechanization reduces some of these impacts, but does not completely compensate for the loss of human labor. Especially in business units that still depend on manual or seasonal work, the adverse health effects are seen more sharply on the output produced. In addition, the study notes that farm households tend to adjust work strategies after experiencing health shocks, such as hiring more outside workers or delaying cultivation activities, but these strategies often increase production costs and lower net profits. In the economic review of agricultural health, this study shows that health shock not only affects the physical health of individuals but also has a direct impact on the economic outcomes of farmers' households. While partial mechanization can reduce some of the manual workload, not all stages of production can be fully motorized, so family labor involvement remains essential. The health impact of reducing the number of working days shows that agricultural production functions must consider health status as an important input factor, especially in family farms that tend not to have large economies of scale. The contribution of van der Zee and van Vliet's research lies in the use of long-term panel data and robust methodologies that are able to minimize endogeneity bias, so that these findings have strong internal validity. The findings also have significant policy implications, namely the importance of public health policies and health insurance that can reduce the risk of loss of work capacity for farmers, including access to rehabilitation and support systems in the event of illness or accident. However, the study also has limitations, including that the panel's data only included formal farming families and did not include non-family seasonal labor in the same detail, so the health impact of seasonal workers on agricultural productivity has not been analyzed in depth. Advanced research can broaden the focus by including variables of digital technology use, agriculture, or extra-family social support that can mitigate adverse health impacts. Overall, van der Zee and van Vliet (2021) provide strong empirical evidence that health shocks have a significant impact on

the productivity of family farms in the Netherlands, while corroborating the health economics literature that places health as an important component of human capital and economic output in the agricultural sector.

In Japan, research by Sasaki, Yokoyama, and Kondo (2022) analyzed the relationship between work injuries in farmers and agricultural labor productivity in Japan using representative national survey data. The main focus of this study was to understand the impact of work-related injuries (such as falls from tools, injuries while harvesting, or machinery accidents) on the possible loss of working days, decreased productivity, and economic consequences on farming families. The method used is a quantitative approach with multivariate regression analysis that considers variables such as the age of the farmer, the type of commodity cultivated, the use of mechanical tools, and the duration and severity of the injury. The data comes from the Japan Agricultural Workers Survey, which includes thousands of active farmer respondents across the country. The regression model used takes into account fixed *effects* to capture unobserved heterogeneity between respondents. The results of the study show that work injuries have a significant negative effect on the number of working days that farmers can do in the following period. Injured farmers reported reducing the number of hours worked in the following week and often experienced a decrease in productivity measured by output per unit of labor. These findings remain significant after controlling for other factors such as age, work experience, and technology use. In addition, the older group of farmers (aged over 55) are more susceptible to the impact of work injuries and show a slower recovery than younger farmers. From an agricultural health economics perspective, this study provides evidence that health shocks in the form of work injuries can cause direct economic losses through a reduction in the number of working days and low labor output. These findings are consistent with international literature showing that occupational health disorders reduce productivity, increase recovery costs, and lower farm household incomes. In addition, the study shows that although Japan is a developed country with a strong health infrastructure, the impact of work injuries still affects the economic stability of farmers because the loss of productive labor remains difficult to replace, especially in older groups of farmers. The main contribution of Sasaki et al. (2022) lies in the use of large national survey data so that the results can be generalized to the Japanese peasant population at large. Using powerful econometric techniques, the study successfully identified a significant causal relationship between work injuries and economic productivity, which is important for the development of occupational safety and social protection policies in the agricultural sector. The limitation of this study is that it focuses on the direct impact of work injuries without exploring indirect effects such as out-of-pocket health expenditure burdens or household coping strategies after injury. In addition, the study focused more on physical injuries and less discussed other health effects such as chronic stress or psychological distress due to harsh working conditions that can affect long-term productivity. Further research can explore the dimensions of mental health as well as the integration of medical cost burden variables to provide a more comprehensive picture of the impact of health on the farmer household economy. Overall, Sasaki, Yokoyama, and Kondo (2022) provide strong empirical evidence that health shocks in the form of work injuries adversely affect the productivity and work capacity of farmers in Japan, as well as reinforcing the importance of safety policies and rehabilitation programs as part of strategies to improve the welfare of agricultural workers.

In Brazil, research by de Souza, Oliveira, and dos Santos (2022) examined the relationship between health risks due to work accidents and working conditions in family farmers in Brazil and the economic implications they cause. The study was conducted in several rural areas of Brazil with a concentration on family farming communities, which are the backbone of the country's small- and medium-scale food commodity production. This study used a *cross-sectional* design with primary data collection through a structured survey conducted on >600 smallholder respondents in several rural Brazilian states. The variables collected included the incidence of work accidents in the field, the type of activity that caused the accident, the use of personal protective equipment (PPE), short-term health symptoms, as well as demographic and economic data of households such as land area, number of workers, and annual income. Data analysis was carried out with descriptive statistics and logistic regression to test the relationship between occupational risk exposure and the incidence of health disorders. The results showed that the incidence of work accidents among family farmers was quite high, with most accidents occurring during the use of agricultural machinery, pruning tasks, and pesticide applications. All of these types of accidents are positively correlated with reports of health symptoms such as back pain, minor injuries, skin irritation, and respiratory disorders. Regression analysis showed that farmers who used incomplete/inappropriate PPE were more likely to experience health problems

than those who always used complete PPE. Economically, farmers with health problems report a decrease in the number of effective working days and an increase in medical expenses, which in turn impacts farm household incomes. The study also found that factors such as low levels of education, lack of occupational safety training, and limited access to health services further exacerbate the economic impact of health events. This study provides strong empirical evidence that work accidents and exposure to health risks are important determinants in the productivity of smallholders in Brazil. From a health economics perspective, health impairments due to agricultural activities not only affect the physical condition of farmers but also impact work capacity and household income, which can ultimately reduce the contribution of the agricultural sector to the rural economy. These findings are in line with the literature that places health as a component of human capital that has a direct impact on economic output. In addition, the study emphasizes the need for integrated intervention programs, such as better occupational safety training, counseling on the use of PPE, as well as rural health policies that improve access to medical services and rehabilitation. The role of local governments and agrarian institutions is very important in developing risk prevention strategies that can significantly reduce the economic impact of health problems. Although using a representative sample in some rural areas of Brazil, the study was *cross-sectional*, so it could not fully demonstrate the long-term causal relationship between health conditions and economic outcomes. Future research is recommended to use longitudinal designs or data panels to assess the time dynamics between health disorders and farmers' productivity and income. The research of de Souza et al. (2022) reinforces the evidence that work-related health risks in the Brazilian family farming sector negatively impact the productivity and economic well-being of farmer households. Policy interventions that combine aspects of occupational safety, access to health services, and health education need to be prioritized to increase agricultural production capacity in a sustainable manner.

Based on the results of the search and selection of relevant literature, it was found that the study of the economics of farmers' health in general can be grouped into several main themes, namely: (1) health as a determinant of agricultural productivity, (2) the impact of health shocks on the welfare of farmer households, (3) the economic costs due to pesticide exposure and agricultural work risks, and (4) the role of health insurance and social protection in reducing economic vulnerability. Overall, the literature shows that health has a significant and systematic role in determining the economic performance of agricultural households. First, in the aspects of health and productivity, most empirical studies show a positive relationship between the health status of farmers and agricultural output. Research based on household micro data found that farmers with better health conditions had a higher number of effective working days, more optimal work intensity, and better ability to manage production inputs. Within the framework of human capital theory, health is seen as a form of investment that increases the productive capacity of individuals. Some panel studies have even shown that health variables remain significant after controlling for land area, capital, and labor, indicating that health is not just a supporting variable, but a stand-alone factor of production. These findings reinforce the argument that agricultural production functions need to include health as an explicit variable in the analysis model. Second, the literature on health shocks shows that the impact on farmer households is twofold. When an illness occurs in the head of household or productive family members, households not only lose employment, but also face a significant increase in health expenses. Some studies have found that health shocks reduce farm yields in the short term and can impact up to several growing seasons. Households with limited assets tend to use coping strategies such as selling livestock, mortgageing land, or reducing food consumption. This condition has the potential to create a circle of poverty that is difficult to break. In the context of developing countries, this effect is stronger on smallholders who do not have access to alternative labour markets or formal credit. Third, the issue of pesticide exposure and occupational health risks is an important theme in the economic literature on farmers' health. Studies in the horticulture and intensive agriculture sectors show that high pesticide use correlates with an increased risk of health disorders, including respiratory, neurological, and reproductive disorders. From an economic point of view, health costs due to such exposure are often not included in the cost structure of production, thus creating negative externalities. Several studies have tried to calculate the social costs of pesticide exposure and found that if the health costs were fully accounted for, the level of use of socially optimal chemical inputs would be lower than the actual use rate in the field. These findings show that there is a need for policy intervention in the form of regulations, counseling, and subsidies for personal protective equipment. Fourth, the literature on social protection and health insurance shows that access to health insurance can reduce the negative impact of health shocks on

household well-being. An evaluation study of health insurance programs in various developing countries found that households with health coverage were less likely to experience catastrophic expenses and were better able to maintain their productive investments. However, the effectiveness of social protection depends on the quality of health services, the level of public health literacy, and the ease of access to medical facilities in rural areas. Some studies have also found that although health insurance lowers the cost burden directly, the impact on productivity is not necessarily significant if the quality of services received is low.

In addition to these four main themes, the literature also highlights demographic problems, especially the aging of farmers. The age structure of older farmers increases the prevalence of chronic diseases and decreases physical capacity to work. Empirical studies show that the decline in health in elderly farmers is related to a reduction in the scale of farming and an acceleration of exit from the agricultural sector. In the long term, this phenomenon has the potential to affect food security and the sustainability of the agricultural sector if it is not balanced with labor regeneration and increased mechanization. In terms of methodology, most studies use a quantitative approach with OLS regression, fixed effects, and instrumental variables to address the potential endogeneity between health and income. Some recent studies use causal approaches such as difference-in-differences and propensity score matching to evaluate the impact of health insurance programs. However, there are still limitations in terms of the availability of long-term panel data that simultaneously cover health and agricultural production variables, especially in the Indonesian context. Overall, the results of the review show the consistency of the findings that farmers' health has a significant influence on the productivity and welfare of agricultural households. However, there are research gaps in terms of integrating health variables into agricultural production models comprehensively as well as a lack of long-term causal studies that are able to capture the dynamics of health impacts on agricultural investment decisions. Therefore, further research that combines health economics and agricultural economics approaches in a more integrated manner is needed to provide a stronger empirical basis for the formulation of sustainable rural development policies.

CONCLUSION

Based on the results of a review of the international literature, it can be concluded that the health of farmers has a close and significant relationship with agricultural productivity and household economic well-being. Health disorders such as work injuries, pesticide exposure, chronic diseases, and low health literacy consistently reduce the number of effective working days, increase medical costs, and reduce agricultural production output. In the context of production economics theory, health can be positioned as a part of human capital that affects labor efficiency and production output. Studies in developed countries show that although insurance systems and health facilities are relatively good, the loss of working days due to health shocks still has an impact on income and productivity. Meanwhile, in developing countries, the economic impact is greater due to limited social protection and low awareness of occupational safety. Therefore, integrated policy interventions between the health and agriculture sectors are urgently needed, including increasing health literacy, counseling on the use of personal protective equipment, strengthening rural health insurance systems, and occupational safety training. Overall, the health economy of farmers is an important area in supporting sustainable agricultural development, because good health not only improves the quality of life of farmers, but also strengthens the stability of food production and the welfare of rural economies.

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