

EFFECT OF AGRICULTURAL TECHNOLOGICAL INNOVATIONS ON INCOME INEQUALITY: LESSONS FOR DEVELOPING COUNTRIES

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Abstract: This review paper examines the effect of agricultural technological innovations on income inequality in developing countries. It synthesizes and analyzes existing literature, case studies, and empirical evidence to identify the relationship between agricultural technological innovations and income inequality. By exploring various agricultural innovations, such as mechanization, genetically modified crops, precision agriculture, and access to agricultural information, the paper aims to draw valuable lessons for policymakers and stakeholders in developing countries. The findings of this review highlight the potential of agricultural technological innovations to reduce income inequality and provide recommendations for effective implementation strategies.

Keywords: agriculture, technology, innovations, income inequality, economic growth.

1. INTRODUCTION

Growth in the agricultural sector exhibits significantly higher effectiveness in increasing the incomes of the poorest individuals, ranging from two to four times more effective compared to other sectors. Agriculture is very important for economic growth, accounting for 4% of global gross domestic product (GDP), and can account for more than 25% of GDP in some least developing countries (World Bank report, 2023). Despite these notable achievements, technological innovations have not been fully explored in developing countries due to limited financial resources, fragmented land ownership and small-scale farming, limited technical knowledge and skills, traditional farming practices, and cultural barriers. This indicates the sector's untapped agricultural potential, which could further boost national growth and development.

According to the World Bank Development Report (2012), two-thirds of agricultural development originates from products in developing countries. In the early 1960s and 1970s, China vigorously pursued technological acquisition, making her a superpower today. This highlights the significance of technological advancement in countries like China, where aggressive acquisition of technology in the past has contributed to their current prominence on the global stage (Yuet *et al.*, 2019).

Furthermore, technological advancements have raised concerns among workers due to changing labor demands caused by agricultural mechanization, industrial robotics, and automation. While these advancements favor highly skilled workers, they also lead to reduced production costs, increased productivity, and potential wage inequality. The unskilled workers however become replaced with automated or mechanized systems or by skilled workers in the sector. The rise in wage inequality has then been attributed to globalization and skill-based technological advancements, offering alternative

explanations. Economists frequently contend that changes in productive technologies contribute to the rise in inequality. The underlying idea behind this assertion is that technical advancements favor skilled workers by replacing tasks previously performed by unskilled laborers. Wernerova (2019) provided a straightforward discussion of the economic theory that supports this hypothesis.

However, one of the major concerns in modern economies is the challenge of establishing a fair distribution method for the benefit of economic progress to promote well-being and social cohesion (Odhiambo, 2022). The presence of income inequality not only leads to economic and social instability but also hampers overall economic progress. One core objective of a well thought economic policy should be to ensure an equitable distribution of income to enhance social welfare. The 20th century witnessed a rapid acceleration of innovations in information and communication technology, with technological advancements being hailed as the primary drivers of growth, welfare, and productivity. However, the swift progress in technology has also brought to light significant shifts in the dynamics of income inequality. In recent years, many countries have experienced a notable increase in income inequality. Consequently, the idea that the proliferation of technology has contributed to the rise in income inequality has garnered significant attention, as highlighted by Algan *et al.* (2019). Economists have explored theories linking technological change, growth, and inequality and Research suggests that excessive inequality can hamper economic growth and is correlated with various social issues, such as health problems and school dropouts (Nasfi & Dina, 2023).

For over a century, economic development has sought to explain the phenomenon behind the prosperity of some countries and the poverty of others across the technological world. Innovation is recognized as a crucial driver of labor-based economic growth in various economic theories and approaches. It is indisputable that innovation plays a pivotal role in long-term economic growth, as highlighted by Aghion and Howitt (1992), Schumpeter (1942), and Solow (1957).

However, the IMF (2007) identified technological progress as the main driver of increasing inequality across countries. It explains a significant portion of the rise in the Gini coefficient since the 1980s, particularly due to the amplification of skill demand and substitution of low-skill inputs. The research identified that technological progress has a stronger impact in Asia compared to Latin America, reflecting the prevalence of technology-intensive manufacturing in Asia. Additionally, globalization has a relatively smaller effect on inequality compared to technological change, with trade globalization helping to reduce inequality, especially in agricultural exports and developing countries.

While a positive correlation exists between skill-biased technological change and wage inequality, it is important to note that correlation does not imply causation. However, the correlation observed in other countries suggests that technology is likely a contributing factor to the growing inequality observed in high-income countries (Max & Esteban, 2013).

The strategies to reduce inequality in the long term involve structural changes in economies and development processes. Consequently, this study aims to examine the effect of new agricultural technological innovations on income inequality and identify strategies for economic growth in developing countries.

2. INCOME INEQUALITY

2.1 Concept of Income Inequality

De Maio's study (2007) provided a comprehensive overview of contemporary methods used to measure inequality. The most popular method is the Gini coefficient, derived from the Lorenz curve. The Lorenz curve illustrates the distribution of income among the population, with the perfect equality line being a 45-degree line where each percentile of the population earns the same percentage of total income. In societies with income inequality, the Lorenz curve deviates from the equality line, and the Gini coefficient measures the area between the Lorenz curve and the equality line divided by the total area under the equality line. The Gini coefficient ranges from 0 to 1, where 0 represents perfect equality and 1 represents perfect inequality. However, the Gini coefficient has limitations as it cannot differentiate between different types of inequalities, even if different Lorenz curves intersect and result in similar Gini coefficients. This restricts the comparability of Gini coefficients.

Various measures of income inequality exist beyond the Gini coefficient. The Atkinson Index addresses the Gini's limitation by allowing for different sensitivities to inequalities across the income distribution, incorporating the concept of social justice. The coefficient of variation (CV) compares the standard deviation of income distribution to its average but lacks an upper bound like the Gini coefficient. Decile ratios compare the income of the top and poorest 10% of households. The

Generalized Entropy (GE) index considers inequalities at different parts of the income spectrum, with positive values indicating income inequality. GE is decomposable and can be broken down into subgroups. Other methods include the Kakwani progressivity index, proportion of total income earned, Robin Hood index, and Sen poverty measure.

2.2 Empirical Cases on the Impact of income inequality on Growth

According to the 2015 United Nations Development Program (UNDP) Report, income inequality has been on the rise in both advanced and developing countries. This increase in inequality poses significant threats to social cohesion, hinders economic development, and can even lead to a recession, ultimately impeding human development (Brzezinski, 2018).

Extensive theoretical and empirical research conducted in recent decades has aimed to understand the impact of inequality on economic growth. While some studies suggest that the impact of inequality on growth can be positive or negative, depending on the initial GDP per capita (Brueckner & Lederman, 2018) and varying between the short and long run (Halter *et al.*, 2014). Theoretical arguments exist on both sides of the debate. Some argue that inequality may lead to lower economic growth due to political instability and social unrest. On the other hand, it is also posited that inequality can promote economic growth by providing stronger incentives for productive investments.

Data from the Organization for Economic Co-operation Development (OECD) indicated a negative correlation between inequality and economic growth across various sub national regions in Europe and OECD countries in the Americas (Max & Esteban, 2013). This suggests that higher levels of inequality tend to hinder economic growth.

Furthermore, some economists argue that moderate inequality can serve as an incentive for growth by stimulating innovation and project completion. They contend that when there is a certain degree of inequality, individuals are motivated to work efficiently, which directly impacts economic growth. This perspective highlights a trade-off between equity and growth, as described by Okun (1975). Okun proposed that the market is more efficient when there is some level of inequality, implying that reducing inequalities could lead to a decrease in efficiency. Consequently, society faces a choice between striving for equality or prioritizing efficiency.

2.3 Agricultural technological innovations

In the field of economics, the concept of innovation has a longstanding presence. It entails the creation of new technologies and their application within the economy. Economists generally adopt a broad definition of technology, which encompasses not only new machines or inventions but also novel approaches to various processes, including knowledge. Classical economists, for instance, considered market behavior and mechanical advancements as forms of innovation that contributed to economic growth (Galindo & Méndez-Picazo, 2013).

Innovation plays a crucial role in development, and effective innovation systems involve the active engagement of all relevant stakeholders who can contribute to uncovering underlying processes and principles. These principles are subsequently translated into technologies and practices that are further adjusted to enhance efficiency and performance. Governments have recognized that a firm's ability to innovate is significantly influenced by factors such as public research, infrastructure, regulations, taxation, and other public policies. These factors have both direct and indirect impacts on the operational environment of businesses.

3. CASE STUDIES

3.1 Case Studies and empirical evidence on Technological Change and Income Inequality

A study conducted by Kharlamova *et al.* (2018) examined the influence of technological change on income inequality in European countries. The research focused on two distinct periods: the first period from 2006 to 2017 and the second period representing the post-global financial crisis era from 2010 to 2017. The study findings revealed that countries with higher levels of economic development exhibit less pronounced effects on income inequality resulting from technological change. In contrast, countries with greater income inequality demonstrate higher sensitivity to technological change, leading to both positive and negative impacts on inequality. Similarly, Tang *et al.* (2022) presented supporting evidence of a direct and positive relationship between technological innovations and inequality based on a comprehensive panel data sample encompassing 73 countries worldwide. This relationship between inequality and technological innovation is influenced by factors such as government spending, manufacturing, agricultural employment, and export diversification. These findings suggest that one potential downside of technological innovation is its propensity to increase income inequality.

Moreover, Nasfi & Dina, (2023) conducted two econometric studies that focused on a group of African countries during two distinct periods: 1992-2019 and 1995-2019. The results of these studies indicated the significant role of technological change in both economic growth and the dynamics of inequality. Technological change acts as a pathway through which human capital influences economic growth and inequality. This can be attributed to the fact that, in the presence of technological change, only skilled workers can benefit from its advantages, while unskilled workers may face temporary unemployment as they seek jobs that require lower levels of skill. The econometric studies also emphasize that economic growth in the sampled countries has been accompanied by a rise in inequality, which in turn poses a hindrance and constraint on further growth.

3.2 Impact of agricultural mechanization on Employment and Wages

The introduction of machinery and technology in agriculture has the potential to transform production processes, increase productivity, and bring about changes in the labor market.

Agricultural mechanization has been found to have both positive and negative effects on employment. On one hand, the adoption of machinery can lead to a reduction in the demand for labor, particularly in tasks that can be automated or replaced by machines. As a result, there may be a decline in the number of agricultural jobs available, particularly for low-skilled laborers. Studies have shown that in certain contexts, the introduction of mechanization has led to the displacement of workers from agricultural activities (Haggblade, *et al.*, 2010). On the other hand, agricultural mechanization can also create new employment opportunities. The use of machinery may require specialized skills for operation, maintenance, and repair, leading to the emergence of new job roles in the agricultural sector (Jayne *et al.*, 2016). Additionally, increased productivity resulting from mechanization can stimulate growth in downstream industries, such as food processing, transportation, and marketing, which in turn can generate employment opportunities.

The impact of agricultural mechanization on wages is another important aspect to consider. Mechanization can potentially affect wages in different ways. When labor-intensive tasks are replaced by machines, it may lead to a decline in the demand for low-skilled labor and consequently put downward pressure on wages. However, in cases where mechanization leads to increased productivity and overall economic growth, it can contribute to higher wages as a result of increased demand for skilled labor and improved market conditions. The impact of agricultural mechanization on employment and wages can vary depending on contextual factors such as the level of development, the size of agricultural holdings, and the availability of complementary inputs and infrastructure.

3.3 Adoption of farm machinery and income disparities

The adoption of farm machinery can have both positive and negative impacts on income disparities. On one hand, the use of machinery can lead to increased productivity and efficiency, enabling farmers to expand their operations and generate higher incomes. Farm machinery, such as tractors, harvesters, and irrigation systems, can significantly reduce labor requirements and enhance agricultural output (Fuglie *et al.*, 2012). As a result, farmers who adopt mechanization may experience increased incomes and potentially reduce income disparities within the agricultural sector.

However, the adoption of farm machinery can also contribute to income disparities, particularly in the early stages of adoption. The high costs associated with purchasing and maintaining machinery can create barriers for small-scale and resource-poor farmers, limiting their ability to access these technologies (Kushwaha *et al.*, 2019). This can result in a divergence between farmers who can afford mechanization and those who cannot, exacerbating income disparities within the farming community.

Furthermore, the availability of support services and infrastructure can influence the extent to which the adoption of farm machinery affects income disparities. Access to credit, training, and technical assistance can play a crucial role in enabling small-scale farmers to adopt and effectively utilize mechanized technologies (Kumar *et al.*, 2019). In regions where such support systems are lacking, income disparities may widen as wealthier farmers have better access to resources and opportunities for mechanization. The impact of farm machinery on income disparities is also influenced by broader socio-economic factors, such as land distribution, market access, and government policies. The concentration of land ownership and unequal access to markets can limit the benefits of mechanization to a select group of farmers, leading to income inequalities (Rada *et al.*, 2018).

3.4 Precision Agriculture and Income Disparities

Precision agriculture, also known as smart farming or digital farming, refers to the use of advanced technologies such as sensors, drones, GPS, and data analytics to optimize agricultural practices. This approach enables farmers to make more precise decisions regarding irrigation, fertilization, pest control, and harvesting, among other factors. While precision agriculture offers numerous benefits in terms of increased efficiency and productivity, it can also have implications for income disparities within the agricultural sector.

Numerous studies have examined the relationship between precision agriculture and income disparities, focusing on different regions and agricultural systems. These studies investigated how the adoption of precision agriculture technologies affects farm incomes and whether it exacerbates or mitigates income disparities among farmers.

A study by Balafoutis, *et al.* (2017) explored the impact of precision agriculture adoption on farm income in Latin American countries. The findings suggested that precision agriculture technologies positively affect farm performance and income, especially for larger farms. However, the study also highlights the potential for increasing income disparities between small-scale and large-scale farmers due to differential access to resources and technology adoption.

Another research paper by Zhou, *al.* (2015) focused on the United States agricultural sector. The study compared the farm incomes of precision agriculture adopters with non-adopters and finds that farmers utilizing precision agriculture technologies tend to have higher incomes. However, the analysis revealed that the income benefits vary across different farm sizes and geographical regions, indicating potential disparities in income gains.

Economic and environmental impacts of precision agriculture technologies revealed that while precision agriculture technologies can enhance farm profitability, the initial investment costs and knowledge barriers may limit their adoption, potentially creating income disparities among farmers.

3.5 Adoption Barriers and Implications for income inequality

The adoption of new technologies in any field, including agriculture, can face barriers that influence the extent to which they are adopted by different individuals or groups. These adoption barriers can have implications for income inequality, as they may affect the distribution of benefits derived from technological advancements.

Several studies have examined the adoption barriers of agricultural technologies and their implications for income inequality. These studies investigate the factors that hinder technology adoption and how these barriers can perpetuate income disparities among farmers.

A study by Bitzer, V. (2016). explored the adoption barriers faced by smallholder farmers. The research highlighted factors such as limited access to credit, inadequate infrastructure, and information asymmetry as significant barriers to technology adoption. The study argued that these barriers can perpetuate income inequality, as farmers with limited resources may struggle to adopt and benefit from new technologies. A research paper by Spielman, *et al* (2006) examined the constraints faced by small-scale farmers in adopting agricultural technologies in low-income countries. The study identified barriers such as high costs of technology, lack of training and technical support, and inadequate market access as key factors inhibiting technology adoption. These barriers can contribute to income disparities by limiting the ability of small-scale farmers to increase their productivity and income levels.

Another study by Ndolo *et al.* (2014) provided an overview of adoption barriers faced by farmers in developing countries. The research highlighted major constraints, such as lack of awareness and information, risk aversion, and limited access to inputs and markets. These barriers can hinder technology adoption and perpetuate income inequality among farmers.

4. FINDINGS

4.1 Key findings on the effect of agricultural technological innovations on income inequality: Lessons for developing countries

The findings of the study conducted by Nasfi and Dina (2023) indicated the statistical significance of technological change in explaining the variability of economic growth in the sample countries. Technological change enables the production of more goods or higher-quality goods using the same amount of inputs, resulting in increased economic growth. This result supports the empirical work of Aghion (2002), Bosworth, and Collins (2003), highlighting innovation as the main driver of

growth. Innovation is widely recognized as a key factor in economic growth and development. Similar results are also presented in the analysis conducted by Thirtle *et al.* (2003), who used the Malmquist sequence index to calculate productivity indices in the agricultural and commercial sectors.

In another study, Asamoah *et al.* (2021) discovered a positive correlation between income and government spending coefficients in MLI (Middle-Low Income) countries and income inequality. These findings align with the views of Dulani *et al.* (2013), suggesting that high reported growth and use of public resources do not benefit the poorest citizens and may exacerbate income inequality. To address the inequality gap, policies promoting fair wages for the poor should be implemented. Asamoah *et al.* also found that institutional quality is positively associated with income inequality in MLI (Middle and Low income) countries compared to HI (High Income) countries. These results have conventional significance levels. This finding in MLI countries supports the evidence found in Latin America, Africa, and Asia by Dobson & Ramlogan (2010), Amendola *et al.* (2013), Perera & Lee (2013), Brunoriet *et al.* (2013), Hartmann *et al.* (2017), and Aiyar & Ebeke (2020). The positive relationship between institutional quality and inequality suggests that some institutional reform policies in these economies may be misguided, as argued by Andres and Ramlogan-Dobson (2011). Institutional quality, such as property rights, may protect the interests of influential elites who control key markets, access investment opportunities, and exert disproportionate political influence through political clientelism.

In a study on income inequality in Mexico, Camposet *et al.* (2014) examined the period from 1989 to 2010. They identified various market factors, including labor supply and demand based on skill level, as well as institutional factors such as minimum wage rates, unionization, and cash transfers. The study revealed that income inequality initially increased from 1989 to 1994 due to institutional factors and labor demand. However, from 1994 to 2010, inequality decreased primarily due to changes in labor supply and, to a lesser extent, in labor demand. Government transfers also played a significant role in reducing inequality after 2000. Additionally, the study found that the decline in non-labor income inequality contributed to the overall reduction in inequality. Furthermore, Liet *et al.* (1998) identified several determinants of income inequality, including measures of civil liberties, the initial level of secondary schooling, financial depth, and the initial distribution of land.

Xie & Zhou (2014) conducted a study in China that examined income inequality trends over the past three decades. The findings revealed a continuous rise in income inequality in China, with the highest levels observed in 2010. The study attributed this inequality to regional disparities and the gap between rural and urban areas, emphasizing significant variations and disparities among different regions and between rural and urban residents. In contrast, the study noted that factors such as personal and family income levels and race played a more significant role in determining inequality in the United States.

Additionally, the study explored the indirect channels through which innovation, entrepreneurial activity, and institutional quality interacted to influence income inequality, considering the heterogeneity among income groups. The results indicated a negative and statistically significant relationship between the interaction of innovation and institutional quality. This implies that, in the presence of good institutional quality, innovation can contribute to reducing income inequality in high-income countries. However, this relationship was only statistically significant at the 10% level for middle and low-income countries.

In another study, El Benniet *et al.* (2011) discussed the development of income inequality in Swiss agriculture, specifically focusing on valley, hill, and mountain regions from 1990 to 2009. The results showed an increase in household income inequality within the study sample. The effects of agricultural policy reforms on income inequality varied across regions. The study found that an increase in direct payment income was associated with a decrease in household income inequality. Furthermore, off-farm income contributed to a reduction in income inequality, while market income had the opposite effect of increasing income inequality.

5. CROSS-CUTTING THEMES AND PATTERNS FROM THE REVIEWED LITERATURE AND CASE STUDIES

The literature review of this report further highlights that the factors influencing income inequality can vary significantly across countries. For instance, the factors affecting income inequality in China and the United States differ substantially. These variations are attributed to several country-specific factors, including geographical location, infrastructure development, political and judicial systems, and law and order conditions. Consequently, each country needs to tailor their policies and interventions based on their unique circumstances and challenges.

By recognizing the specific contexts and characteristics of their respective countries, policymakers can develop targeted strategies to address income inequality effectively. This approach acknowledges the importance of understanding and considering local factors that shape income distribution dynamics. As highlighted by Furqan *et al.*, (2016), adopting a country-specific approach enables policymakers to develop policies that align with their country's socioeconomic landscape's specific needs, opportunities, and constraints.

6. CONTRIBUTIONS AND IMPLICATIONS FOR POLICYMAKERS

These studies provide valuable insights into the dynamics of income inequality and its determinants in various contexts, which have significant implications for policymakers and researchers. One important finding is that financial development has contributed to rising inequality, as higher-income groups have been better able to take advantage of increased borrowing opportunities. Conversely, greater access to education has supported a more equitable distribution of income. By equipping a larger portion of the population with the necessary skills for a knowledge-based economy, education facilitates the transition from agriculture to industry and services, ultimately boosting productivity in the agricultural sector.

To address income inequality in developing countries, policymakers should focus on sharing national wealth and providing equal opportunities for innovation. Enhancing science, technology, and innovation (STI) education is crucial for achieving inclusiveness, which can lead to economic progress and poverty reduction. Policies that promote technology sharing, such as licensing, joint ventures, and strategic alliances, should be adopted to reduce monopoly power resulting from intellectual property rights. This enables local industries to catch up with more advanced counterparts through research and development cooperation, thus breaking the cycle of wealth accumulation among a few large firms. Successful examples of technology-sharing policies have been observed in countries like South Korea, India, Indonesia, and India, which have scaled up innovation at the rural level for productivity gains. Moreover, banking institutions can play a role in reducing income inequality by providing market-based innovation financing for start-ups and small and medium-sized enterprises (SMEs), supporting the entrepreneurial poor and those with promising business models and government should consider the impact of industrial presence in areas originally sustained by the agrarian sector about income distribution.

In addition to education and innovation, improving institutional quality is crucial for addressing income inequality. Institutions that reduce clientelism and favoritism should be established to ensure equal access to resources for small and medium enterprises. This will encourage individuals to create enterprises and provide attractive job opportunities. It is important to note that technological progress and foreign direct investment (FDI) are associated with higher economic growth, even though they may contribute to income inequality due to the increased returns from acquiring higher skills. Therefore, rather than suppressing FDI or technological change, policymakers should prioritize increasing access to education. This will allow less-skilled and lower-income groups to benefit from the opportunities presented by technological progress and globalization. Additionally, improving access to finance, particularly through institutions that promote lending to the poor, can help enhance the overall distribution of income.

7. CONCLUSION

Policymakers should focus on addressing income inequality by promoting inclusive education, facilitating technology sharing, supporting innovation financing for start-ups and SMEs, improving institutional quality, and ensuring equal access to resources. These measures can contribute to reducing income inequality while harnessing the potential of technological progress and globalization for sustainable and inclusive economic growth.

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