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REVIEW

Agricultural, Economic, and Human Development: Joint Research Contributions of Japan and International Food Policy Research Institute

Hiroyuki TAKESHIMA[1]*, Futoshi YAMAUCHI[1] and Masahito ENOMOTO[1, 2]

[1] International Food Policy Research Institute, Washington, D.C., USA
[2] Sophia University, Tokyo, Japan

Abstract

Over the past four decades, IFPRI Japanese Researchers (IFPRI-JR) significantly contributed to the knowledge advancement for various agrifood system issues in ways that are central to IFRRI's mandates and complementary to the whole CGIAR system. This paper summarizes IFPRI-JR's key knowledge work, its evolution over time, and its collective contributions. In earlier years especially up to the 2000s, various policy and market analysis tools were applied to agricultural policy reforms and price policies in Japan and elsewhere. More recently, to respond to the food crisis in 2007-08, IFPRI-JR's research contributed to building empirical evidence on agrifood system policy issues in developing countries, including identification of key market failures and the appropriate role of the public sector in public goods provision in the presence of externalities and economies of scale. Over time the analytical scope expanded to institutional issues on resource management and markets, human capital formation, gender issues, agrifood system transformation, food and nutrition security. Finally, promising Japanese technologies and know-how were (i) identified for sustainable agrifood system development, and (ii) transferred to developing countries in the field of global nutrition security and their effectiveness shown. Collectively, IFPRI-JR have a long track record of addressing emerging as well as long-term structural issues, in both Japan and the world at large.

Discipline: Social Science
Additional key words: agrifood systems, policies, institutions, human capital, Japanese technologies and knowhow

Introduction

The International Food Policy Research Institute (IFPRI), based in Washington DC, USA, as one of CGIAR (formerly the Consultative Group on International Agricultural Research) centers, pursues its mission to "provide research-based policy solutions that sustainably reduce poverty and end hunger and malnutrition." Through its five major strategies/themes as well as the cross-cutting gender theme, and several regional and country offices in developing countries in Asia, Africa, and Latin America, IFPRI directly addresses Sustainable Development Goals (SDGs) 1, 2, 5, 8, and 15, and contributes to other SDGs, including SDGs 3, 10, 12, 13, and 17 (Figure 1).

Since the establishment of IFPRI in 1975, Japan has been one of its largest supporters. Over the past four decades, many Japanese researchers have participated in research at IFPRI under various designations, as either IFPRI staff or visiting scholars. IFPRI Japanese Researchers (IFPRI-JR hereafter) responded to issues of emerging importance as they arose, and their extensive work has covered a wide range of topics relevant to agricultural development, economic development, and human development. While exact research topics and focus countries were often determined by donors and IFPRI's or its division's strategies, IFPRI-JR successfully generated knowledge that is often applicable to broader contexts.

In this context, a review and synthesis of key research contributions by IFPRI-JR can help identify promising future collaborations among the Japanese government, IFPRI, and One-CGIAR to enhance the achievement of the

*Corresponding author: H.takeshima@cgiar.org
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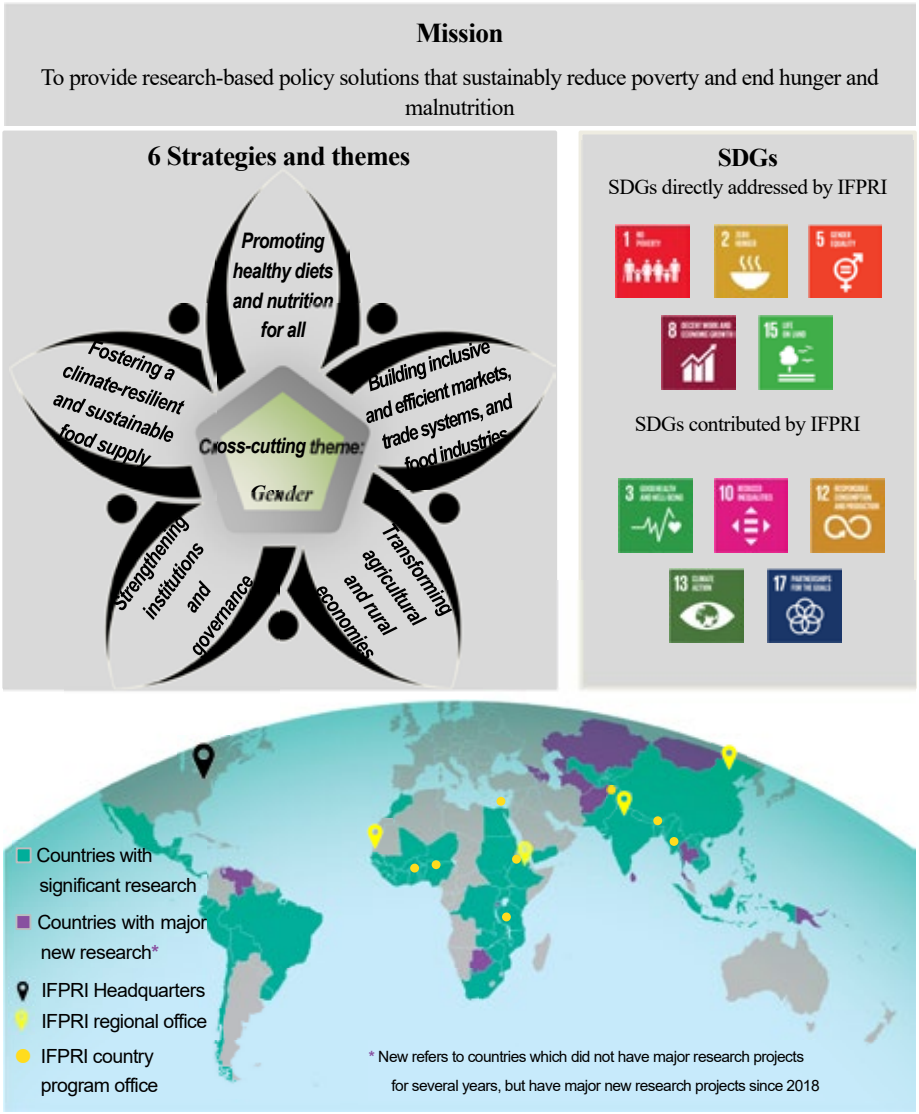

Fig. 1. IFPRI's mission, strategies, linkages to SDGs, and locations of activities
Source: Authors.

SDGs and other global development targets. We review the large body of IFPRI-JR works by focusing primarily on studies archived in IFPRI's publications database, organized along the three main types of development to which this research has contributed. As is described in the subsequent sections, IFPRI-JR have collectively contributed to widening evidence base on technological development induced by changing factor prices, institutional changes induced by market imperfections including those of land and labor, how these have emerged in responses to the economic conditions surrounding the agrifood sectors over the last few decades (e.g., trade liberalization and subsequent price impacts, rising wages in developing countries, and climate change), and how the public sector can facilitate the process through price policies, transfers of technologies and knowhow, and human skill development.

Early contributions to theories and policy analyses tools in agrifood system development

1. Formalization of induced innovations in technological and institutional development

Theories of induced technological and institutional innovations were formalized by the 1980s by scholars including Yujiro Hayami who served as IFPRI's Board of Trustees between 1988 - 1994 (Hayami & Ruttan 1985). The theories also guided many of IFPRI-JR's research. Induced innovations represent endogenous, dynamic responses that emerge in response to growth in demand, in ways that save factors that become relatively scarcer while making greater use of factors that become

relatively more abundant (Hayami & Ruttan 1985). The mechanisms apply to both technological innovations, as well as institutional innovations, the latter of which can include property rights and contractual agreements, as well as suppliers of nonmarketed, public goods.

Induced innovation theories guided IFPRI-JR's research in various emerging contexts; agrifood trade liberalization sharpened the roles of factor endowments like land, water, or nature of demands in different countries; economic development raised labor costs relative capital costs in agriculture, inducing mechanization growth and farm size growth, among others. The growing scarcity of natural resources, including land and forest trees, also induced efforts in developing property rights. Climate changes and their effects on factor prices can also induce the directions of innovations.

As is described in later sections, literature in recent decades further identified knowledge gaps regarding how induced innovation is accelerated. These included agricultural R&D, human capital development and education, equality including gender, health improvement and nutrition security, as well as the transfer of advanced technologies and know-how, including those from Japan, toward facilitating the effective supply of such innovations to address increasingly complex challenges of today's agrifood global systems. As Hayami & Ruttan (1985) puts it, IFPRI-JR's research that improved understanding of agrifood systems[1] also advanced social science knowledge to design more efficient institutions.

2. Early application of IFPRI research tools to Japanese agricultural policies

A substantial part of IFPRI-JR's research work started in the 1980s. This was the period when Japan's agriculture sector, particularly that of rice, was losing price competitiveness, and support to the sector was imposing increasing pressure on the government budget. IFPRI-JR applied cross-country comparisons and analytical tools to assess policy options for the Japanese rice sector, including price policies and trade policies (Tsujii 1982a, 1982b). By reviewing rice-sector policies in Japan, Taiwan, and Thailand, Tsujii (1982a) showed how a country shifts from taxing the rice sector to protecting the sector as its economy grows. Tsujii (1982b) showed quantitatively through a multi-country rice trade model that quality heterogeneity has implications on actual rice trade flows. In doing so, Tsujii (1982b) expanded the previous models used in the literature by explicitly modeling equilibrium price determination mechanisms. In the 1990s, facing stronger pressure to further reform tariff policies on rice, a better understanding of quality variations among exporters became important in assessing optimal tariff rates. Ito et al. (1995) analyzed this issue and, by taking quality differentials between Chinese and American rice into account, showed that optimal tariff rates should differ depending on exporting country. While not for the Japanese or for rice markets, IFPRI's expertise on price policy research during that time was applied by other IFPRI-JR to other commodities and countries. For example, Suzuki & Bernard (1987) contributed to the debates on maize market policies in Tanzania, one of the African countries that were undergoing significant grain market reforms under the Structural Adjustment Program.

IFPRI-JR applied IFPRI's expertise in policy analyses to Japan's overall agriculture sector policies. Honma & Hayami (1988) used policy analysis tools to identify appropriate directions for agriculture sector reforms in Japan. Specifically, they used quantitative empirical methods to show that agriculture sector reform in Japan required not only protection policies, but also support for changing agricultural terms of trade through an increase in average farm size (particularly through the reduction of part-time farming) enabled by a more liberal land-use policy. Relatedly, Honma (1991) investigated policy measures for enhancing global trade efficiency for horticulture commodities with the aim of supporting both developing country exporters and import markets in Japan.

These sets of research by Hiroshi Tsujii, Shoichi Ito, Masayoshi Honma and Yuriko Suzuki recognized that trade liberalization brings out to policy debates more clearly the issue of comparative advantages of countries (which play crucial roles in the induced innovations process discussed in the previous sub-section), and quantified their implications on induced responses in supply and demand, trade by multiple-countries, as well as institutional and technologies changes, such as price policies, R&D and infrastructure development. Studies focusing on rice (Tsujii 1982b, Ito et al. 1995) also highlighted the roles of preference heterogeneity and quality differentiation as important factors affecting actual rice trade outcomes.

Analyses of emerging agrifood-sector issues in post-Cold War era

Since the 2000s, IFPRI-JR's research has shifted its focus toward emerging issues associated with the rise of neo-liberalism in the post-Cold War era, the global food crisis, and developing country governments' efforts to

[1] Agrifood systems can be defined as the entire supply chain ranging from the supply of inputs and services for the various agricultural sector activities, on-farm production, as well as activities that take place post-farm that include trading and retailing of agricultural commodities and food to consumers.

facilitate institutional innovations under such changing environments.

1. Research contributing to institutional innovations in agrifood system in the 21st century

(1) Institutions for managing agrifood resources and markets

Research on various forms of institutions in the agrifood sector[2] collectively highlighted the importance of ensuring incentive compatibility for these institutions' effectiveness. Incentive compatibility here relates to a mechanism for appropriate payoff and costs embedded in the designs of institutions, which sufficiently incentivize agents to adhere to the rules set by the institutions. This was emphasized by Otsuka et al. (2001), among others, for the land tenure system. They explained how a stronger tenure security system has been evolving in rural Asia and Africa because of growing land scarcity, and how this has emerged endogenously within the customary tenure system in ways consistent with the induced institutional innovation theorem.

Other studies highlighted strengthening individual ownership rights as an important element of such evolution. Positive effects of stronger individual ownership rights for on-farm asset accumulation, including trees, were demonstrated for Indonesia (Otsuka et al. 2001; Suyanto et al. 2001) and Malawi (Place & Otsuka 2001). Studies that use trees as an example of agricultural assets and production factors underscore that strengthening individual ownership can induce the provision of environmental goods that have positive externalities. Because of significant private efforts required for natural resource management (such as maintaining trees), individual ownership rights have become important drivers of optimal agroforestry in Uganda (Place & Otsuka 2000), forest recovery in Indonesia (Otsuka et al. 2001), and timber forest management in Japan (Kijima et al. 2000). These sets of evidence reemphasized the importance of incentive compatibility in institutional development and informed the emerging debate on land tenure reform in developing countries (Otsuka & Place 2001). Similar messages were forwarded by other IFPRI-JR, including Miyata & Fujii (2007), who showed that in Turkey water management institutions evolved in response to the provision of irrigation infrastructure, involving an endogenous shift from tribal relations to a more equitable system. On agrifood market institutions, Miyata et al. (2009) and Tada & Miyata (2006) identified similar conditions for incentive compatibility required for vertical coordination, using the example of contract farming in China for apples and green onions grown for supermarkets and export markets. Ito (2002) provided similar insights, focusing on one type of rural institution, Township and Village Enterprises (TVES) in China. This work showed that TVES was ineffective, especially in poorer areas, due to insufficient attention to the economic viability of its development plans, contributing to more, rather than less, economic inequality across China.

(2) Other emerging issues of agrifood systems

The global food crisis in 2007–2008, as well as a reemphasis on the importance of agriculture in development (for example, World Development Report 2008), expanded the scope and depth of direct research on agriculture sector issues by IFPRI-JR. Research on the agrifood system, food and nutrition security by IFPRI-JR since the late 2000s has focused on the key agricultural economic aspects for which policy interventions are particularly relevant, including public goods provision (and more broadly, the appropriate roles of the public and private sectors) in the presence of externalities, and other market failures, including transactions costs, risk, and credit market failures.

(a) *Public sector roles:* Agricultural input subsidies, particularly those for fertilizer, became one of the major policy instruments in many Sub-Saharan African (SSA) countries between the 2000s and the early 2010s. A key policy question in the quickly emerging literature on modern agricultural input subsidies in SSA was whether public sector subsidy provisions for the acquisition of chemical fertilizer had crowded out the private sector, including the commercial sector fertilizer market. Past literature on the effects of subsidized fertilizer on the demand for and the use of nonsubsidized fertilizer often focused on the endogeneity of the former to the latter, which arises because farmers have the freedom to choose both the quantity of subsidized fertilizer used and the quantity of nonsubsidized fertilizer, leading to potential reverse causality. In a study of chemical fertilizer subsidy programs implemented in Nigeria up to 2011, Takeshima & Nkonya's (2014) model incorporated the potential endogeneity due to such potential reverse causality, not only of subsidized chemical fertilizers, but also of the prices paid for the fertilizer. This was particularly important in countries like Nigeria up to 2011, as subsidized fertilizer was distributed through channels parallel to that of nonsubsidized fertilizer within the same market, such that any leakage of the former could significantly affect the price of the latter. Relatedly, Takeshima & Liverpool-Tasie (2015) provided further evidence of the limited

[2] Institutions in the agrifood sector here may include examples like property rights granted to individual farmers for resources like land and trees, or systems established for managing common goods like irrigation water, contractual relationships established between producers and buyers, or organizations that facilitate the creation of non-farm jobs in rural areas.

effectiveness of chemical fertilizer subsidies, which had minimal effects on major staple crop prices in Nigeria. This is potentially due to the possibility that, provision of subsidized fertilizer does not lead to a substantial increase in overall fertilizer use because subsidized fertilizer largely crowds out the use of non-subsidized fertilizer, and also potentially because fertilizer responses of outputs are still low in countries like Nigeria (Gyimah-Brempong et al. 2016). Focusing on Nigeria, with its large population and thus a high number of food markets, enabled them to provide this important evidence.

Closely connected to these were studies on agricultural R&D (research and development), including plant breeding. Takeshima (2019) was particularly instrumental in highlighting that in countries like Nigeria, plant breeding by National Agricultural Research System (NARS) was strikingly insufficient compared to that done in Asian countries, and likely to explain critical differences in regional agricultural productivity, not only of yield but also of total factor productivity (TFP). Specifically, Takeshima (2019) used a novel concept of "agroclimatic similarity" to quantify the spillover potential in each subnational region of improved varieties developed by NARS. Using this agroclimatic similarity indicator as a key factor associated with the locations of NARS, Takeshima (2019) showed that public investments in plant breeding and the location of NARS experimental stations were decisive determinants of TFP in agriculture, and reemphasized the importance of NARS's institutional structure, including its locations, for agrifood system development in countries like Nigeria. An important area of future research may be to decompose the effects on TFP to the effects on each factor, such as land, labor, capital, which have implications on the institutional development for these factor markets.

The importance of the public sector's complementary role in plant breeding on the adoption of other modern inputs was demonstrated. Takeshima & Liu (2020) examined the role of public sector plant breeding on smallholder mechanization adoption. In particular, they showed that for both Nepal and Ghana, yield-enhancing biological technologies, including improved varieties, directly induced the adoption of tractors, at both the extensive margin (whether to adopt tractors or not) and the intensive margin (how intensively to use tractors).

(b) *Market imperfections for outputs and insurance*: Market imperfection arises when it fails to enable economically optimal transactions due to information failures and high transactions costs. While market imperfections in the agriculture sector are common in SSA, the policy focuses have been rather uneven, as have the roles of research. Market imperfections for inputs like fertilizer were relatively well recognized by many SSA governments, and research questions focused on the efficiency of their approaches in addressing such imperfections. Market imperfections for outputs and insurance had not yet received similar government responses. Thus a number of IFPRI-JR's studies provided evidence to fill the gaps. Takeshima & Winter-Nelson (2012) contributed to the literature on output market imperfections. Specifically, they showed how high transactions costs make Beninese cassava producers decide first how much to produce, then decide whether to sell the surplus in the market, and then where to sell if so, instead of deciding these simultaneously, reducing producers' ability to compare different sales locations or to adjust production decisions based on market conditions. Similarly, Takeshima & Yamauchi (2012) provided indirect evidence of insurance market failures in Nigeria: when provided with a matching grant (in which farmers mobilize their own resources to supplement externally provided resources through aid, to meet the overall investment requirements), farmers significantly increased asset investments in ways to reduce risks (e.g., irrigation pumps in areas with greater rainfall risks or processing machines in areas with greater market price risks of unprocessed outputs), which would not have been the case if insurance markets were well-functioning.

(c) *Externalities associated with irrigation dams:* Agriculture gives rise to significant externalities, both environmental and socioeconomic, including through water usage. Takeshima (2018a) highlighted one aspect of externalities and their effects, assessing the impacts of irrigation dams in Nigeria. Specifically, the study identified more positive drought-mitigation effects in drainage basins located downstream of dams than in drainage basins that contained dams.

(d) *Inter-linkages of sub-sectors within and around agrifood systems:* In recent years, IFPRI-JR contributed to synthesizing several agriculture sector and commodity issues in the form of edited books or book chapters. Gyimah-Brempong et al. (2016) provided holistic (demand, supply response, market integration, and economywide) analyses of the rice economy and policy issues in Nigeria, the largest rice producer, consumer, and importer in Africa. Furthermore, in a recent book edited by Otsuka & Fan (2021) aimed at updating Hayami & Ruttan (1985), IFPRI-JR highlighted issues for global agricultural development that have emerged in the last few decades. Specifically, Yamauchi et al. (2021) and Takeshima et al. (2021) synthesized recent trends and issues for Northeast/Southeast Asia and South Asia, respectively, focusing especially on changes in factor endowment-induced innovation, modernization of agrifood systems, as well as growing linkages with the rural nonfarm sector.

IFPRI-JR also informed the debate on how

agriculture contributes to broader economic growth in developing countries. Based primarily on the experiences of the Green Revolution in the Philippines, Estudillo & Otsuka (1999) showed that agriculture played a key role in rural capital accumulation, where agricultural incomes provided the necessary capital to finance nonfarm sector growth. Similarly, Estudillo et al. (2000) showed that the Green Revolution was more inclusive and equitable compared to the emerging income inequality originating in nonfarm incomes. Otsuka (2000) identified the appropriate types of technologies that agricultural research should generate for reducing poverty, to inform the growing need for prioritization under declining overall support for agricultural research at that time. That study emphasized that technologies for the poor need to meet three goals: they must lead to the increased supply of food; they must develop labor-using technologies with sufficiently high factor-share capture by labor; and they must be suitable for marginal (unfavored) areas increasingly associated with poverty, including technologies like agroforestry.

2. Human capital development, Agricultural transformation, Food and Nutrition Security

Since the 2000s, IFPRI-JR also contributed to research on the relationship between human development and agrifood systems transformation, to explore multiple functions of agrifood systems in enhancing human well-being in an inclusive manner. Specifically, IFPRI-IR's research focused on human capital development and gender equity, agrifood systems transformation through substitution of labor to capital, and agrifood system's roles for achieving food and nutrition security.

(1) Human capital formation

The links between human capital development and the agrifood system were increasingly recognized. A higher human capital level can facilitate the mastering of modern agrifood technologies or practices and thus complement them. Higher human capital can also facilitate income diversification, which provides the means to finance further agrifood system modernization.

IFPRI-JR contributed to filling the knowledge gap on rural human capital formation in the developing world. Research on the instruments of human capital formation broadened the evidence on social learning and school quality. In investigating the role of social learning during the Green Revolution in India, Yamauchi (2007) showed that social learning is fastest and most efficient where observed heterogeneity in schooling is greatest, as agents learn about returns to schooling from the income realization of their neighbors. Research on the roles of food and nutrition security on schooling and rural labor supply decisions showed that in countries like Malawi and South Africa, higher adult mortality rates due to HIV/AIDS, among others, had significantly negative effects on adolescents' and women's labor supply and on decisions about marriage (Yamauchi et al. 2008; Ueyama & Yamauchi 2009). Research on returns to human capital analyzed heterogeneity in such returns and empirically identified key factors that raise these returns (Yamauchi 2005a). Specifically, Yamauchi (2005a) showed that in the Philippines, returns to schooling in terms of wages earned appear to be higher for the private school. The higher returns from private schools are also because of their seeming success in attracting higher-ability students than public schools do. Other factors that affect the returns to schooling also included road infrastructure in Indonesia (Yamauchi et al. 2011), and complementarity between human capital and labor market experiences gained by migrants in Thailand (Yamauchi 2004). Specifically, Yamauchi et al. (2011) showed that, in Indonesia, returns to post-primary education in terms of income earning and employment in the non-agricultural sector are higher in areas that are closer to and/or connected by better-quality road to economic centers. Yamauchi (2004) showed that, for migrants to Thailand, their wages tend to increase faster as they accumulated more work-experiences in destination markets if they had been more educated in terms of schooling upon-arrival in Thailand.

On school quality, studies highlighted significant cross-school variation (for example, in learners-to-educator ratios) due to historical/geographic factors, with considerable implications for the overall effectiveness of human capital formation (Yamauchi 2005b, 2010, 2011). These studies show that in South Africa, inequality in school quality between whites and non-white population has persisted, with better quality schools disproportionally concentrated in communities where whites are dominant, school fees and government subsidy increase the quality of education, and better early childhood nutrition status significantly improves schooling investments and outcomes. These studies were largely motivated by the possible long-lasting legacy of segregation policies developed during apartheid in South Africa.

(2) Gender equity

Gender issues in the agrifood sector have been and continue to be complex and multifaceted. IFPRI-JR generated key evidence related to gender equity, including how gender differences coevolve endogenously with agrifood sector development. Estudillo et al. (2001) demonstrated that in the Philippines, while more land tended to be allocated to sons and more education resources to daughters, such allocation was actually optimal and equitable, maximizing collective lifetime incomes. Yamauchi & Tiongco (2013) and Yamauchi & Liu (2018)

showed that in the Philippines women's wages are more responsive to education than men's wages, explaining why households invest more in daughters' education than in sons'. Such differential returns to education between females and males, in the case of the Philippines, are due to the fact that women with lower education tend to face greater disadvantages than males, because labor markets for lower education population tend to be more biased toward males than the labor markets for higher education population. Quisumbing & Otsuka (2001) showed that in Indonesia, the relative gender gap was declining on the agricultural production side (for example, land access), but growing in human capital investment and a widening gender gap in incomes. Quisumbing et al. (2001) showed that individualization of land tenure (from communal ones) contributed to strengthening women's rights to land in Ghana. More recently, Liang et al. (2021) showed that the cotton revolution in China's Ming and Qing Dynasties increased demand for female labor and thus contributed to improving women's livelihoods.

(3) Agricultural transformation through capital-labor substitution

Recent decades, particularly the 2010s, witnessed a significant economic transformation in developing countries in Asia and SSA, and the relative efficiency of smallholders compared to medium-to-large farmers became a hotly debated issue. Several IFPRI studies in which Japanese researchers were closely involved contributed to this growing literature. Otsuka et al. (2013, 2016a, 2016b) provided evidence supporting the rising (declining) relative efficiency of medium-to-large (smallholders) farmers in Asia, and the importance of land arrangements, among others, in realizing scale economies largely driven by rising real wages in agriculture and mechanization processes that substitute for labor. Wang et al. (2016a), Wang et al. (2016b) and Wang et al. (2020) found evidence of the above phenomena in China. Yamauchi (2016) showed similar evidence supporting this hypothesis in Indonesia.

Relatedly, a series of research on the impact of agricultural mechanization provided direct evidence that mechanical technologies are the direct cause of the increase in returns to scale in farm production functions, realized broadly through tractor adoption among Nepalese farmers (Takeshima 2017), tractor ownership by Ghanaian farmers (Takeshima et al. 2018), and both animal traction and tractor adoptions in Nigeria (Takeshima 2018b). A study in Nepal (Takeshima et al. 2017) showed that economic response functions of chemical fertilizer use at farm household level exhibit relatively greater (albeit still less than constant-) returns to scale in more mechanized areas, which can have different policy implications for those inputs other than mechanization. These studies identified such effects by simultaneously addressing the endogeneity of mechanization adoption and the endogeneity associated with production functions. The potential endogeneity of mechanization adoption arises because idiosyncratic shocks that can affect outputs and impacts of mechanization, can also affect farmers' decisions to adopt mechanization . Similarly, estimations of production functions also suffer from the endogeneity of production inputs use variables. The aforementioned studies addressed both of these types of endogeneity through variants of propensity-based estimation methods, which use the information on farm households' propensity to adopt mechanization to appropriately adjust the estimations of the impact of mechanization. These studies were particularly important in separating the effects of mechanical technologies from many other potential drivers of returns to scale in agriculture.[3]

In SSA, the inherent link between mechanization and greater returns to scale and the unique conditions of the mechanization sector in the continent today (for example, preferences for larger, higher horsepower tractors) made supply-side policies on mechanization increasingly important. Diao et al. (2020) identified key principles for such policies in SSA through detailed reviews of experiences in five SSA and eight Asian countries where tractor tillage grew considerably among smallholders in recent years. They showed that market imperfections may be severe in the provision of custom-hired mechanization service to farmers in SSA,[4] particularly due to insufficient R&D, insufficient operational and maintenance skills, or insufficient coordination, in addition to the aforementioned credit and insurance market imperfections. Importantly, within the context of custom-hired tractors-based services provided to farmers, Takeshima et al. (2015) showed that in Nigeria, informal sector providers (those who purchase tractors solely from the competitive market) are still more economically efficient than formal sector service providers (those who are identified by the government to become service providers and receive subsidized tractors for that purpose). The study implied that arbitrary targeting may

[3] Some studies on the impacts of mechanization extended beyond returns to scale. Takeshima et al. (2020b) showed that in Nigeria, switching from hand-hoe to animal traction or tractors enhanced economies of diversifications (economies of scope) between rice and nonrice crops, while enhancing economies of specialization among nonrice crops, suggesting the potential role of mechanical technologies on on-farm crop diversification, and related benefits like risk mitigation and rural dietary diversity.

[4] Custom-hired mechanization service is a mode of service in which machine owners bring machines to other farmers' farms and provide mechanization services.

not be optimal, and that different approaches were needed to support the growth of mechanization service providers in SSA.

(4) Agrifood system and food, nutrition security

IFPRI-JR's research included nutrition-sensitive agriculture and its linkages with agrifood market integration, in which nutrition-sensitive agriculture is defined as agricultural production that considers not only profitability but also the overall nutrition produced, including richness in micronutrients or dietary diversity. Yamauchi & Larson (2019a) showed that the food price spike in 2008 had negative long-term effects on child growth in Indonesia, but this effect was mitigated for farm households that had been producing food for own consumption. Yamauchi & Larson (2019b) showed evidence of the impacts of food price surges on the intrahousehold allocation of food among siblings. Specifically, they showed that, facing food price surges, parents allocated more food to more vulnerable household members (who had lower height-for-age z-score), relatively reducing the intrahousehold inequality. In a study that disentangled the relationship between food prices and birth outcome, Yamauchi (2012) showed that birthweight has a seasonality largely explained by rice price seasonality. Interestingly, the effect of Ramadan was not detected after controlling for the effects of rice price movements. In these studies, food price shocks and seasonality can have long-term impacts on human capital formation, starting from the prenatal stage. Early childhood nutrition status also affects school attendance and learning outcomes at later stages (Yamauchi 2008). Takeshima et al. (2020a) contributed to the growing literature on agriculture–nutrition linkages, providing rare evidence from Tajikistan, a low-income but understudied country. Specifically, the study provided evidence consistent with others that household food production strongly affects dietary diversity and various other nutritional outcomes of household members, including women and children, particularly in a semisubsistence setting. Relatedly, Takeshima & Nagarajan (2012) provided evidence of the role of market participation on crop diversity. They showed that participation in the sales market induced producers in southern India to produce a greater variety of crops, suggesting that marketability is still important for enhancing dietary diversity through production diversification among semisubsistence farmers in developing countries.

Collaboration with Japan for human development: Transferring Japanese technologies and know-how

In recent years, IFPRI-JR increased their focus on identifying and transferring Japan's advanced technologies and know-how toward achieving nutrition security as well as broader SDG goals, including sustainable energy and reduced food loss and waste, while enhancing the resilience of developing country populations against future emergencies. The research approaches used were guided by the following: (i) Japan is on the frontier in the field of nutrition security and health improvement; for example, Japan is one of the few countries not suffering from the so-called "double burden" of coexistent malnutrition and overweight in the same population; (ii) advanced technologies and know-how practiced among stakeholders in Japan that support the above achievements have great potential to transform the realities of many developing countries; and (iii) imperfections in capital markets and information justify the potential role of an agent who can experiment with such technologies in developing countries to achieve the SDGs' mandate of "inclusiveness."

In 2019, IFPRI-JR organized a side event at the Seventh Tokyo International Conference on African Development (TICAD 7),[5] where examples of these technologies and know-how and their potential in African countries were discussed. Examples included: nutritional supplements for young children in disadvantaged communities; the Japanese fish processing technique for surimi, which particularly benefits women as its prime users and improves livelihoods in fishing communities; and the use of solar-powered cold-chains for horticulture crops (reducing food loss) in conflict-affected communities. These three ideas materialized into new projects in Ghana, Côte d'Ivoire, and Nigeria in 2020, respectively. All three projects principally aim at improving nutrition intake but also help improve livelihoods, gender equity, and other SDGs in the face of emergency situations. In 2021, IFPRI-JR started two projects in Uganda and Ethiopia/Kenya. In Uganda, market-oriented horticulture farming will be introduced in regions hosting refugee camps to improve nutrition intake and farmers' incomes. In Ethiopia, commercial microwave linkages between cellphone signal towers will be used to forecast heavy rains and encourage proactive measures, including ensuring timely evacuations and mitigating actions farmers can take in food production.

[5] https://www.ifpri.org/blog/ticad7-side-event-how-japans-know-how-can-help-address-africas-food-and-nutrition-challenges

The main theme of these five projects is to build sustainable resilience for vulnerable populations against emergency situations that may recur. The goal is to help people avoid falling into similar situations in the future based on the evidence these projects provide. This theme is in line with (i) the "people-centered approach" advocated by Japan in international arenas, and (ii) evidence-based policy making, which Japan is emphasizing across its entire policy process. In addition, this theme could eventually contribute to more effective, efficient implementations of Japan's overseas development aid.

Conclusions

Over the past four decades, IFPRI-JR contributed significantly to the knowledge advancement for various agrifood systems and, more broadly, on human development issues. In earlier years, various policy and market analysis tools were applied to agricultural policy reforms and price policies in Japan and elsewhere. Around the 2000s, the analytical scope expanded to institutions, gender issues, and human capital, and linkages of agrifood systems to broader human development. In the 2010s, to respond to the food crisis and evolving issues on nutrition security, IFPRI-JR research contributions deepened into agriculture sector policy issues, identifying market failures and the appropriate role for the public sector. Collectively, IFPRI-JR addressed emerging as well as long-term structural issues, at both the global and country level. Many of the analytical approaches used in their studies can still be applied to today's policy, institutional, and economic issues in the context of dynamic agricultural and economic development and broader human development. Finally, IFPRI-JR transferred advanced Japanese technologies and know-how to developing countries in the global nutrition security arena, and provided evidence of the effectiveness and efficiency of the associated policies in enhancing the resilience of vulnerable communities against emergency situations.

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