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Documenting the Impact of Widely-Adopted CGIAR Research Innovations

SPIA TECHNICAL NOTE

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Summary

Innovations in agriculture generally have short-term direct effects on productivity, input use, and income of adopters, but they can have broader effects as well. Innovations that are widely adopted and remain in use over many years may have much wider-ranging secondary impacts, including effects on the price of the product in question and on production, and prices of substitute or complementary products. Effects may extend to urban as well as rural consumption and nutrition, and to persons living in poverty nationally. Innovations in policy-oriented research may affect such non-economic factors as the balance of decision-making between men and women. This note summarizes a recent effort by the ISPC's Standing Panel on Impact Assessment (SPIA) to build evidence demonstrating how CGIAR research may have affected such longer-term and broader dimensions of life in developing countries.

SPIA recognized that such work would likely depend, to some extent, on availability of existing data and that it posed formidable methodological challenges, not the least of which is the challenge of constructing *ex-post* counterfactuals. It anticipated that different strategies and approaches would be employed, targeting various indicators of impact, with the objective of bringing different types and strength of evidence to bear. The innovations considered would have to be selected from among those seen to have been "successful"—or else, they would not be widely spread and persistent. At the same time, SPIA wanted to go beyond studies of varietal change in rice, wheat, and maize—three commodities that have heretofore been extensively studied.

Scope of the Call: "Documenting the Impact of Widely-Adopted CGIAR Research Innovations"

An October 2014 call by SPIA[1] for expressions of interest elicited 22 responses, 12 of which reflected the kind of issues outlined. Proponents of the 12 relevant expressions of interest were encouraged to submit full proposals to ISPC-SPIA's Strengthening Impact Assessment in the CGIAR (SIAC) 2013-2017 program. Of the 12 full proposals received, seven studies were subsequently funded in mid-2015 following external review, and the commissioned studies were completed two years later. Abbreviated summaries of the seven are found at the end of this note.

Contributions of the Commissioned Studies

The seven commissioned studies go beyond most other impact studies by focusing on little-analyzed subjects, using new data, applying innovative analytical approaches, and presenting new empirical findings about the impact of CGIAR research related innovations. Four studies focus on commodities for which relatively few impact studies had heretofore been produced: fish, cassava, potato, and lentils. Two studies address the global effects of CGIAR crop improvement (and accompanying input) contributions to human welfare rather than simply agricultural production, and one examines the contribution of gender research to gender equity. The individual commodity studies use DNA-based tools to identify the genetic derivation of the varieties studied and compare these with producers' self-reported variety data rather than just relying on producer recall to identify varieties. Each of the other three studies relies on

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[1] https://ispc.cgiar.org/workstreams/impact-assessment/impacts/impact-widely-adopted-cgiar-research-related-innovations-2015

an innovative approach to construct the data underlying analysis: one combines data from remote sensing and demographic surveys, a second combines data from many sources into complex models of economic interactions, and yet another traces the spread of a policy idea from a research source to its application by international Non-Governmental Organizations (NGOs) in community activities.

Research innovation can make no contribution unless it is used, so determining whether an innovation is adopted and continues to be used is an important necessary condition for understanding impact. DNA techniques (specifically, fingerprinting) have the potential to identify the genetic derivation of any plant or animal with great precision, so there is much interest in using such tools in adoption studies. However, practical issues like sampling, preserving tissue samples from deterioration, and generating genetic signatures of standard varieties (reference libraries) for comparison with samples all require careful attention, particularly in developing country conditions, in order to ensure that DNA fingerprinting is carried out correctly. The four commodity studies each report their experiences in addressing these issues, adding to evidence base generated in SIAC as a whole.

Using the adoption data, the commodity-oriented studies document current national or provincial use of improved fish in Bangladesh and the Philippines, cassava in Nigeria, lentils in Bangladesh, and potato in Yunnan province of China. Three of the four also show associations with production and income gains and aggregate growth in output, and several address broader issues like the relationship with poverty and nutrition.

Determining the effects on laborers, people in non-farm households, and other broad issues requires consideration of both partial and general equilibrium effects that one of the studies attempt to tackle using a computable general equilibrium approach.

Agricultural innovation and diffusion of varieties, and associated increases in agronomic inputs such as fertilizers, irrigation, and pest control, may lead to growth in agricultural productivity and food availability per capita. These effects, operating through multiple potential impact pathways, may in turn improve human health and welfare. Some aspects of agricultural change may also depress nutrition and health. One of the studies used innovative methodology to derive highly disaggregated proxies for modern variety (and accompanying input) use from remote sensing data that were then analyzed for possible association with infant mortality data for 37 countries from the Demographic and Health Surveys (DHS).

Broader Lessons and Unanswered Questions about Widely-Spread Agricultural Innovations

The seven studies add to the body of knowledge about the impact of CGIAR-related innovations, but of course, many unanswered questions remain.

The four commodity studies all used DNA tools to identify varieties from samples taken from farmers' fields or fish nurseries. Doing so greatly increased confidence in the variety identification data but at an increased cost, raising the question of when it is optimal to use DNA fingerprinting approaches. In the cassava study about 28 percent of farmers reported that they grew local varieties whereas the DNA showed that they grew improved varieties (false negatives); about 13 percent reported that they grew improved varieties whereas the DNA showed that they grew local varieties (false positives). By contrast, in Bangladesh, where lentil had been relatively recently introduced, about 90 percent of the DNA identifications corresponded to farmer reports. In China, 97 percent of the 141 samples reported to be C88

potato were confirmed by DNA analysis to be so, suggesting low levels of false positives in the self-reported data, but no DNA testing was done on potatoes grown by the other 475 households, so the picture is incomplete – we don't know about false negatives. The genetically improved farmed tilapia (GIFT) study provides detailed adoption data validated by DNA, but no corresponding production data so is of limited value for measuring impact. At the same time, as the cassava study shows, the determinants of adoption appear very different when using DNA fingerprinted data and self-reported data. The question remains: when is it worthwhile to use DNA procedures in field studies to identify varieties of commodities? If the objective is to characterize adoption or measure impact, valid data on both the genetics and the production inputs are needed.

The study of GIFT tilapia confirmed their widespread use in Bangladesh and the Philippines. Funding limitations precluded research to confirm their contribution to farmer productivity and income, or broader contributions to nutrition and poverty. Hence, those questions remain unanswered, as do questions about spread and impact in other countries that produce tilapia in Africa, South Asia, and Southeast Asia.

The sampling and study areas were generally representative of large scale and adequately chosen. Each of the four commodity studies reflects part of the story that needs to be told. To draw broader lessons, future commodity studies could consider adding:

1. DNA-based variety identification and matching input/management information for all sample plots

2. Information on whole-farm inputs, production, cropping systems, income, consumption, and gender decision-making for the study year and similar data from an earlier year from recall or earlier research

3. Estimates of adoption rates (over time) rigorous enough to provide some "reasonable" estimate of the economic consumer and producer surplus

4. Evidence that goes beyond the micro-data collected by new field work and draws on earlier work to get a long-term perspective—that is to get a "best guess" of the long-term effects

Would similar studies of other less-examined CGIAR commodity innovations—for example, beans, soybeans, chickpea, pigeonpea, cowpea, sweet potato, yams, banana, millet, sorghum, and barley—give similar results? Given that farmers grow multiple commodities in cropping systems that in many cases are integrated with livestock, how would innovations in those other commodities change the estimates of the impact of innovation in the study commodity? How would changes in population, social factors, and non-farm economic conditions change the impact of these innovations? A national Computable General Equilibrium (CGE) approach offers potential for answering such important questions. But CGE models for individual countries face the question of how international trade affects internal prices and quantities. A multi-country, multi-commodity, dynamic model is designed to address such issues. The CGE model in the World Bank-International Food Policy Research Institute (IFPRI) paper covers 31 countries, representing about 65 percent of the world's poor. The number and diversity of markets, countries, commodities, and innovations makes the exercise inherently challenging. Such models incorporate many parameters, any one of which may make a great difference in the implications for any innovations examined. A critical parameter used in the World Bank-IFPRI study is total factor productivity for crop agriculture as a whole—its size and the length and functional shape of the "lag" associated with its introduction, uptake, and eventual decline. The dramatic difference implied by the results generated by the

30-year polynomial lag and the 50-year gamma function lag used in the current study illustrate the challenges.

Another important parameter for CGE approaches is Total Factor Productivity (TFP) for individual crops within countries. The authors report that TFP values used in the modeling exercise were internally derived within the model by combining "historical data and our structural CGE to provide a set of TFP estimates consistent with our theoretical structure, parameters values, and actual evolution." The procedure provides 297 estimates of crop productivity growth rates per year, from 1995 to 2005, for 9 crops or crop groups and 33 countries or country groupings. The study also reviews and presents tables of TFP elasticities with respect to research and development (R&D) expenditures estimated from earlier studies. Given the importance of these TFP parameters, one might ask how sensitive the model results would be to variation in them and in other key parameters of the model.

In case of the study on IFPRI's policy-oriented research, the ability to directly link the results of IFPRI's gender research to policy and action in the field was known in advance to be extremely difficult given the need to disentangle it from so many other factors of influence, to empirically identify influence in the absence of clear markers (such as citations), and the relative dependence on people's association of their policies and practices with a "core message" of a particular research program. This is particularly the case in International Non- Governmental Organizations (INGOs), where the message is probably being received second- or third-hand, stripped of clear identifying markers. Given the relative scarcity of such studies on the uptake and impact of research in this field, it is perhaps not surprising that empirical methods for observing and measuring influence are still a work in progress. However, a better job could have been done on designing the sampling frame and methodology for interviews. In particular, where the unit of analysis is an organization (donor, NGO), multiple interviews per organization are likely needed. The same principles that inform quantitative sample selection, thinking through likely variability in responses, should apply to qualitative work (Gollin, Probst, and Brower, 2017).

In spite of the methodological challenges, we well realize that *ex-post* impact studies of the type funded in this call—that is, those that examine the consequences of adopting CGIAR research-related outputs long after dissemination—are necessary to observe impacts that go beyond plot- or farm-level productivity, and are the kinds of impacts many stakeholders are interested in. Both improving methods and increasing the number of studies—so that results of studies of a similar innovations conducted in different contexts using different methods can be compared and synthesized—will help strengthen the evidence base.

Summaries of Commissioned Studies

1. ***Using global agricultural, health, and demographic datasets to identify the impacts of CGIAR's modern seed varieties since the 1960s*** (UC San Diego and George Washington University)

   This study uses geocoded data on births of 600,000 children in 37 countries, together with newly constructed, spatially precise proxies of modern-variety (MV) adoption, to determine the contribution of intensive and productive cropping practices stimulated by the use of MVs to reductions in child mortality.

   The lack of high-quality subnational data on MV diffusion at the required spatial and temporal resolution has hampered previous attempts to measure the effects of MVs. This analysis uses

three different harvested crop area datasets to determine the relative crop mix in each location in each country. A MV diffusion index is constructed as the weighted average of crops' MV diffusion rate at the year reported at the country level by Evenson and Gollin. Infant mortality data are obtained from the Demographic and Health Surveys, which ask each mother her fertility history. The data used cover 18,382 villages in 437 administrative regions spread across 37 countries, focusing on children born from 1959 to 2001.

Infant mortality is related in a regression model to the constructed indicator of MV diffusion in the grid cell of each village, country, and year together with a vector of child-level controls that includes the child's sex and a quadratic function of the mother's age. The regression controls for village fixed effects and country-by-year fixed effects including a range of binary indicators for each DHS sampling cluster that absorb all time-invariant village characteristics that could confound inference.

The resulting estimates suggest that the observed level of MV diffusion reduced the mortality rate of infants by 3 percentage points, which translates into 15–18 million infant deaths averted per year by the year 2000. The results also suggest that the diffusion of MVs and broad-based increases in agricultural yields contributed to improvements in infant health.

2. *A systematic and global assessment of the impact of CGIAR technologies on poverty* (IFPRI and World Bank)

The analysis used a multi-country, multi-sectoral, dynamic computable general equilibrium model (MIRAGRODEP) to estimate how macroeconomic variables affect production and consumption at the household level. To estimate rates of productivity growth at the commodity level, the researchers used their CGE model "running backwards through time with information on the evolution of prices and output quantities." It arrived at estimated annual rates of crop productivity growth for 1995–2015 for 297 crops or crop groupings for 33 countries and regions of interest. To model the impact of productivity improvements on poverty, the study used both the estimated direct impact of the productivity change on the income of producing households and the estimated impacts of changes in key economic variables, such as commodity prices and wage rates, on the welfare of the household. The resulting distribution of income was used to estimate the change in poverty at the national level. These estimations suggest that productivity gains generated by agricultural research over the past two decades reduced the global number of poor people (living under the US$1.90-per-day poverty line) by 165 million in 2015, including 110 million in rural areas and 84 million in Africa south of the Sahara.

To estimate the CGIAR's contribution to the reduction in poverty, the authors used a Delphi approach to obtain subjective estimates by a panel of observers of the rates of productivity gains in crops and the share of CGIAR research responsible for those gains. Based on the Agricultural Science and Technology Indicators (ASTI) data on CGIAR investments, the study used a 30-year polynomial lag and a 50-year gamma function to generate two estimates of the stock of R&D for CGIAR R&D investments. The calculations suggest that CGIAR research investments contributed to a reduction of about 44 million in the global poverty headcount; however, the sensitivity of the results to changes in the underlying assumptions suggest that the results should be interpreted with caution.

3. ***Assessing the impacts of improved cassava varieties in Nigeria*** *(International Institute of Tropical Agriculture [IITA])*

This study estimated the impacts of improved cassava varieties associated with IITA based on a sample of 2,500 households from 125 enumeration areas in each of the four major cassava-growing areas of the country. Plot-level inputs, management, and adoption data were collected for each household in the 2015/16 growing season. Farm- and plot-size data were obtained using GPS procedures. Cassava variety information was reported by farmers and confirmed using DNA analysis on samples of cassava leaves obtained from each of 7,428 plots. Data on crop income, food and nonfood expenditures, food security indicators, and yields were obtained from household surveys, along with quantity of cassava sold in the market, quantity left in storage, quantity consumed, and prices received for cassava sold. Food expenditure data on more than 150 food items and nonfood expenditure data for main items such as education, health, and clothing were collected. Data on seasonal food shortages and coping strategies were obtained to help quantify food security.

The study found that 60–65 percent of farmers grew improved IITA varieties, which was associated with a 45–55 percent increased yield compared with local varieties. While the relationships are not necessarily causal, the use of improved varieties was further associated with increases in per capita food expenditure of 24 percent, in the probability of food security by 17 percent, and in reduction of rural poverty by 4 percentage points at a poverty line of US$1.25 per person per day (applying an economic surplus model).

4. ***Adoption and diffusion of C88 potato variety in China: Spatial variability of productivity gains, cost savings, and value chain development*** *(International Potato Center [CIP], Virginia Tech, and Yunnan Normal University)*

This study estimated the impacts of Cooperation-88 (C88) potato variety, developed cooperatively by CIP and Chinese researchers and released in 1996, in Yunnan province. Factors associated with the probability and intensity of adoption of C88 were estimated using regression. An economic surplus analysis was conducted to quantify the economic benefits of the variety. Stakeholders in the potato value chain provided their insights about factors associated with C88 use in processing.

The study of 616 households in 47 villages showed that 23 percent of farmers were growing C88 in 2015, and DNA fingerprinting of plant material from the declared adopters was used to confirm the veracity of the self-reported adoption status. Seed potato producers provided about 1,000 tons of C88 out of 50,000 tons of total seed, and most farmers used their own saved seed. Gradually, however, the C88 variety has lost its original disease resistance, so it is less popular than in the past. An expert panel estimated the time path of adoption between 1996 and 2014. That estimate, together with data from the study and other sources, was used to calculate that C88 may have generated US$2–3 billion in economic benefits over the 19-year period.

5. *Adoption of improved lentil varieties in Bangladesh: Comparison between expert estimates, nationally representative farm household survey, and DNA fingerprinting* (International Center for Agricultural Research in the Dry Areas [ICARDA] and Virginia Tech)

This study measured the adoption and impact of improved lentil varieties released from 2006 onwards in Bangladesh. Improved lentil varieties developed cooperatively by Bangladesh researchers and ICARDA have become widely grown as a "relay" crop in ripening rice fields, mostly rain-fed, since 1991. The Pulse Research Center of the Bangladesh Agricultural Research Institute (BARI) and the Bangladesh Institute of Nuclear Agriculture (BINA) developed and released 15 modern varieties of lentil between 1991 and 2015, including 8 developed in collaboration with ICARDA.

A multi-stage stratified sampling technique (with proportional distribution of samples) was used to sample 1,000 farming households from 52 villages across all 10 districts in western Bangladesh. Extension agents provided estimates of adoption at the district level. The expert panel estimated that 69 percent of the lentils across the 10 districts of western Bangladesh were improved varieties released since 2006. The household survey data found that 98 percent of the lentil area was planted to varieties released since 1991, with 84 percent of the area planted to the three most important varieties: BARI-6, BARI-3, and BARI-4. Adoption of the post-2006 releases plotted over time took a typical sigmoid shape, progressing from zero to more than 50 percent in eight years. Comparison of the varieties identified by the farmers during the household survey with the varieties identified through DNA fingerprinting showed that 89 percent of the samples were matched by the two methods. Importantly, the DNA fingerprinting data confirmed the large-scale diffusion of the improved varieties.

Results of analysis using endogenous switching regression showed that varieties released after 2005 are associated with yield increases of 382 kg/ha (29 percent) for those who adopted. The estimates also suggest that were the non-adopters to adopt these varieties, they would have seen yields rise by 240 kg/ha (17 percent). An instrumental variables estimation applied to the same data with a similar set of variables suggests that the adoption of improved lentil varieties raises yields by 356 kg/ha. Adoption also was associated to higher net income and higher share of total income from lentil production, with an increase in total production by 25,826 tons, worth US$26 million, annually in recent years. It is however not clear that these associations should be interpreted as causal, given concerns regarding the validity of the identifying assumptions.

6. *Estimating improved tilapia adoption using DNA fingerprinting: Philippines and Bangladesh* (WorldFish)

This study provides new estimates of the extent of adoption of genetically improved farmed tilapia (GIFT) using innovative molecular identification tools. Ninety-nine hatcheries from Bangladesh and 104 from the Philippines, representing about half of the hatcheries in each country, were surveyed. Tissue samples from broodstock fish from the surveyed hatcheries were collected for DNA analysis using 1,300 SNP markers. The assignments made using the Single Nucleotide Polymorphisms (SNPs) show some marked discrepancies with what hatchery operators believed they had in both Bangladesh and the Philippines. When grouped into GIFT, non-GIFT,

and GIFT-derived categories, most individual fish were assigned to their expected category, but 20–25 percent of fish were allocated to an alternative group. This was the case in both Bangladesh and Philippines hatcheries.

Extrapolating from hatchery data to national production is challenging. Nonetheless, the report summarized its findings as follows: "In 2015, the Philippines sector displayed a greater range of improved strains compared with Bangladesh and fewer hatcheries producing from a mix of strains (3% of production in the Philippines compared with 28% of production in Bangladesh). GIFT or GIFT-derived strains were the most commonly produced strains in both countries accounting for almost 53% of production in the sampled hatcheries in Bangladesh and 40% of that in the Philippines. However, a significant amount of production in both countries came from hatcheries where the strain being used was unknown, 19% of production in the sampled hatcheries in Bangladesh and 42% of that in the Philippines." About half the farmed fish production in each of the countries in 2015 comes from GIFT or GIFT-derived fish, although the study stressed that there are errors in identifying strains in hatcheries and in farms both in the Philippines and Bangladesh, and hence there is substantial uncertainty in these broader national estimates.

7. ***Measuring the impact of IFPRI's research on strengthening food policy through Intra-household Analysis on the behavior of International NGOs** (TANGO)*

The study was designed to ascertain whether the core message of the IFPRI research program on "Strengthening Food Policy through Intra=household Analysis" had an impact on how INGOs conducted field programs—specifically whether International NGO program activity relating to more equitable control between men and women within households over allocation of resources, time, income, and program benefits had increased because of IFPRI research. The researchers reviewed documents summarizing the gender policies of the OECD Development Assistance Committee (OECD-DAC) group of donors, interviewed gender experts in DAC donor headquarters, and interviewed donor and international NGO country office staff in Burkina Faso, Mozambique, Nepal, and Rwanda. The authors of the study are cautious—unwilling to draw a conclusion about whether there is "sufficient evidence to justify making a determination of widespread impact," but they suggest that "more systematic exploration of the origins of the intermediate sources of influence in these instances might reveal upstream IFPRI impact that our research method did not capture." The authors found it unlikely that academic researchers would have undertaken the program in such a collaborative way, building networks of collaborators and providing opportunities for knowledge-sharing across disciplines and national boundaries. While the feminist research network would have "continued its work and the focus on gender equality as a human right" the element attributed to IFPRI is "the contextualization of the intra-household gender gap in specific rural settings in developing countries," which was essential for triggering action by NGOs and for adapting approaches to local conditions.

References

Gollin, Probst, and Brower (2017). Assessing poverty impacts of agricultural research: Methods and challenges for the CGIAR.