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Systematic Review of the Effects of Information and Communications Technology on Expanding Agricultural Markets in Developing Countries

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Systematic Review of ICT on Expanding Agricultural Markets in Developing Countries

Prepared by Social Impact, Inc.
for the US Department of Agriculture

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EXECUTIVE SUMMARY

The United States Department of Agriculture's (USDA's) Food for Progress (FFPr) Program contracted Social Impact Inc. (SI) to conduct a systematic review on information and communication technology (ICT) interventions to help inform future FFPr interventions aimed at expanding agricultural markets in developing countries. The review synthesizes the impacts of agriculture market-focused information and communication technology (ICT) interventions on various outcomes for farmers in developing countries, including income, crop-price dispersion, input use, crop yield, crop loss, and change in cropping patterns.

Farmers in developing countries often struggle to maximize their profits. They are frequently unable to adopt agricultural best practices, obtain reliable and timely weather forecasts, and/or access local markets offering the best prices for selling their crops (nor are they usually able to price their crops according to demand). In addition to affecting individual farmers' incomes, the limited availability of market-related information on matters such as prices and consumer preferences also causes large price discrepancies across geographic locations. In recent years, many donors and national Governments have recognized these issues and have, thus, focused efforts on reducing barriers to information access by employing interventions to increase the use of ICT.

The use of ICT interventions in agriculture is quickly evolving, and many academic institutions and donor agencies are conducting studies on their effectiveness in improving farmers' outcomes. Most of these studies are descriptive and focus on the qualitative contributions of ICT towards a variety of farmer- and community-level outcomes. There are, however, a number of impact evaluations that focus on interventions related to mobile phones or the provision of information services[2] and quantify these outcomes. Therefore, this systematic review examines the ability of ICT interventions in developing countries to improve farmer livelihoods, based on relevant rigorous impact evaluations to date. This is the first such quantitative systematic review focused on these topics. Following the Campbell Collaboration approach, this review consists of a narrative and a meta-analysis, and was conducted over a period of eight months – from protocol development to drafting and finalizing the report. The narrative examines all of the afore-mentioned farmer outcomes, while the meta-analysis focuses only on income and crop-price dispersion. A total of 31 studies were included in the systematic review for narrative analysis, and 12 of those were also included in the meta-analyses.

The systematic review suggests that ICT interventions affect farmers' use of different inputs, their crop yields, crop losses, and types of crops grown. Two of the three papers that SI researchers reviewed that examined use of inputs showed that ICT increased use of inputs such as pesticide and

[2] Information services include interventions that disseminate information on crop prices, agricultural techniques, weather, etc. via ICT channels. This might include, for example text message notifications about inclement weather or a hotline for farmers to call in with questions on farming techniques.

improved seeds by better informing farmers about these inputs. Eight of the eleven studies that examined yields suggested that the interventions increased yields. Both papers that examined crop losses found that losses decreased with ICT interventions. The mechanisms for this decrease varied. Very few papers examined changes in the types of crops that farmers grew. Of those that did, there was some evidence that in the presence of an ICT intervention, farmers grow more of certain crops based on additional information the farmer received about what was profitable or practical.

The findings from the meta-analysis indicate that ICT interventions are effective in increasing farmer income and in decreasing crop-price dispersion. ICT helped to increase farmer income in some cases because farmers had better access to information on prices, which improved their ability to negotiate with buyers. In other cases, ICT interventions provided information about agricultural techniques or weather, which enabled farmers to increase their yields, improve their efficiencies, and/or ultimately have more and higher-quality products to sell at market. The impacts on income were small-to-moderate with the largest impacts in South Asia and Sub-Saharan Africa. ICT interventions in low and lower-middle income countries showed more impact than those in upper-middle income countries. While additional study is needed to shed light on the reasons for these differential impacts by region and income level, the literature suggests that lower-income countries may have a larger information gap, which ICT interventions work to effectively address (UNFAO, 2013).

Researchers suggested that ICT interventions lowered price dispersion by providing farmers with better information about crop prices in different locations. The impacts on price dispersion were generally moderate, with the greatest impacts being for perishable goods. This is likely because sellers of perishable goods have greater urgency and therefore have less time to compare prices in different locations.

1 BACKGROUND

1.1 OVERVIEW

The United States Department of Agriculture's (USDA's) Food for Progress (FFPr) Program contracted Social Impact Inc. (SI) to conduct three systematic reviews, including one on information and communication technology (ICT) interventions to help inform future FFPr interventions aimed at expanding agricultural trade and markets in developing countries. The review synthesizes the impacts of agriculture market-focused information and communication technology (ICT) interventions on a number of outcomes for farmers in developing countries. These outcomes include farmer income, crop price dispersion, crop yield, crop loss, and changes in crop type. The review also includes two meta-analyses that examine the impacts of ICT interventions on income and price dispersion, which provide more quantitative detail on the nature of these impacts and how they vary based on country context.

1.2 DEFINING ICT

For the purposes of this review, ICT is defined as any devices, tools, or applications that permit the collection or transmission of information. ICT is used as an umbrella term that could include, but is not necessarily limited to: radios, satellite imagery equipment, mobile phones, computers, televisions, and electronic money transfer equipment (The World Bank, 2011). Information is defined as verified information from an official source such as research centers, government extension services, marketing boards, or other specialists. Information can also include information gleaned from other farmers or individuals regarding market prices. Interventions are considered to be agricultural in nature if they affect agricultural processes directly in terms of crop choices; adoption of new practices; crop loss; access to agricultural finance or other inputs; or access to markets, sales, or incomes from agriculture.

1.3 THE ISSUE: HOW TO INCREASE ACCESS TO MARKETS AND TRADE FOR FARMERS IN DEVELOPING COUNTRIES?

According to the World Bank, farmers in many developing countries face challenges, such as price shocks, climate change, and continued deficiencies in infrastructure in rural areas. The majority of smallholder farmers are unable to adopt new agricultural technologies, obtain reliable and timely information on weather and prices, or access the markets that offer the best prices for buying inputs and selling outputs due to geographic remoteness combined with poor, inadequate, and less-affordable transportation infrastructure and ICT (The World Bank, 2011).

More pervasive and high-speed connectivity, availability of adaptable and affordable communication devices, reductions in the cost of communication technologies, availability of open data and information, and better business models and partnerships to provide services have made ICT more accessible to farmers (The World Bank, 2011). As such, according to the International

Institute for Communication and Development (IICD), donors, implementing partners, and farmers are beginning to use ICT as a mechanism to reduce information gaps and manage transportation barriers in order to improve efficiency in farming, trade, and marketing. Studies on ICT interventions have shown that ICT can improve farmers' lives by helping them increase their incomes and obtain better prices (Stienen et al., 2007). Depending on the nature of the intervention, these programs have also been seen to lower crop-price dispersion, increase use of certain inputs, increase yields, decrease crop losses, and change the types of crops farmers grow. Organizations including the International Initiative for Impact Evaluation (3IE), the World Bank, the International Food Policy Research Institute (IFPRI), the International Fund for Agricultural Development (IFAD), and others conduct studies on this topic.

1.4 FOOD FOR PROGRESS AS A MECHANISM TO ADDRESS EFFECTIVENESS OF ICT FOR AGRICULTURE

To date, there are very few systematic reviews of ICT for agriculture, and all of them are primarily narrative in nature (Goyal, 2013; Etransform Africa, 2012). None of these papers quantify the impacts of ICT interventions on outcomes for rural farmers or apply meta-analysis. Based on the currently available rigorous literature, the purpose of this systematic review is to quantify the impacts of ICT interventions on farmers' incomes, price dispersion, input use, yields, crop losses, and changes in crop types. This is accomplished through both the descriptive narrative and meta-analysis. The review also examines how different contexts and conditions such as country characteristics influence the efficacy of such interventions. FFPr, originally funded under the Food for Progress Act of 1985 (17 USC 1736), is a program run by the Foreign Agricultural Service (FAS) of the USDA. Food for Progress (FFPr) helps developing countries and emerging democracies modernize and strengthen their agricultural sectors. FFPr has two principal objectives: 1) to improve agricultural productivity and 2) to expand the trade of agricultural products. In order to achieve its objectives, USDA donates agricultural commodities to recipient countries through implementing partners. Implementing partners are selected by FFPr through a competitive process each year, and sell the goods at the local market to obtain funding for agricultural development programs.

FFPr has funded a wide variety of projects in developing countries over the years, including projects that have trained farmers in improving animal health and the quality of crops, taught farmers effective farming methods, developed infrastructural systems, established and built capacity for producer cooperatives, provided microcredit and agricultural loans, and developed value chains for a variety of agricultural products. Program participants have included private voluntary organizations, universities, foreign governments, and intergovernmental organizations. After 2010, FFPr began to focus its funding on select countries and activities in order to ensure that resources could be effectively allocated to achieve its objectives. However, prior to 2014, FFPr had not conducted country needs assessments nor in-depth research to help inform its agricultural and trade development approach in the countries in which it works. Therefore, in order to better inform its activity selection, FFPr commissioned a series of research activities through a task order with SI that began in September 2014. As part of this task order, SI completed an activity mapping of FFPr

activities in early 2015 to help FFPr staff better understand the most common types of program activities implemented between 2009 and 2014. The activity mapping also examined variations in activity funding over time and across regions. The task order also included an annotated bibliography of rigorous impact evaluations completed between 2000 – 2014 on agricultural interventions with post-production and trade outcomes, and SI completed this bibliography in early 2015, as well. These two reports informed the FFPr team's selection of ICT in agriculture for systematic reviews. FFPr selected the topic based on the frequency with which FFPr has funded ICT type activities, the number of rigorous impact evaluations available for review, and perceived gaps in the literature on ICT with regards to systematic reviews and meta-analysis. The systematic review on ICT, in addition to filling in the gap in literature, will also help FFPr gain a better understanding on whether the ICT interventions make a difference in the lives of farmers.

2 OBJECTIVES

2.1 BACKGROUND ON THE USE OF ICTS FOR AGRICULTURAL INTERVENTIONS

Between 2009 and 2014, FFPr funded 13 agreements that included at least one project that focused on facilitating or developing market information systems (MIS) and/or used ICT in some capacity. During this time period, FFPr also funded 12 agreements that included at least one project that disseminated knowledge to the public through ICT such as cell phones, radios, or digital technology.[3] FFPr has not conducted any impact evaluations of these interventions. The FFPr is unable to establish the causal linkage necessary to definitively determine the impacts attributed to ICT interventions.

In addition, over the past five years, the use of ICT in agriculture has been the focus of multiple conferences, lectures, and discussions as well as the focus of an increasing number of studies. Despite this, few efforts have been made to consolidate evidence on the effectiveness of such interventions.

Studies exist on the use of ICT for distributing market-price information, weather forecasts, and best practices in farming and trading. For example, a study on the fishing industry in Kerala, India showed that fishermen were able to reduce their unsold catch by six percent as a result of using a mobile phone to exchange market price and other related information, leading to an increase in their profits by 8 percent (Abraham, 2006; Jensen, 2007). A similar study of grain retailers in Niger showed that the use of mobile phones enabled retailers to reduce price variations across markets by 6.4 percent and inter-annual market disparity by as much as 10 percent (Aker, 2008). Fafchamps and Minten, in 2011, used a randomized controlled trial to study the effects of a short-message service (SMS) intervention that provided farmers with information on market prices and weather, and Lokanathan et al. (2010) showed the impact on prices for those who were able to obtain market-price information through mobile phones by subscribing to a service. A survey of beneficiaries from 50 development interventions who use ICT to access information on agriculture indicated rapid increases in income for ICT projects that provided price and market information. The same survey found that interventions focused on the provision of information about best practices in agricultural production had less direct and immediate impacts, likely because farmers do not always integrate new practices into the production process immediately (Stienen et al., 2007). Despite the many helpful studies, no systematic reviews or meta-analyses have been completed to show which type of agricultural ICT interventions, if any, have consistently improved outcomes. Further, no studies have shown which type of device has the most significant impacts on outcomes or which target beneficiaries benefit the most from such interventions.

[3] Some ICT projects also pertained to MIS, so these categories are somewhat overlapping.

2.2 PURPOSE

The purpose of the systematic review and meta-analyses is to help FFPr make evidence-based decisions about program funding for future interventions focused on ICT. The findings and recommendations will help FFPr staff target interventions based on existing research about the contexts in which such interventions tend to produce promising results. Next, the review will help the FFPr team to gain a better understanding of other actors working on promoting ICT so that FFPr can network with these other actors and, potentially, identify synergies between FFPr interventions and those of other donors or implementing partners. Such networking might result in complementary or partner interventions between FFPr and these other donors or actors and may also position FFPr to become a thought leader in the development and use of ICT to boost agriculture-led development.

2.3 MAIN OBJECTIVES AND QUESTIONS

The objectives of this review are: (a) To gather, summarize, and integrate rigorous empirical research to help FFPr and other stakeholders understand the evidence regarding use of ICT for agricultural interventions. This will allow FFPr to make practical decisions about social and behavioral interventions and public policy on the use of ICT to improve agricultural trade and markets in developing countries. (b) To identify evidence gaps in the literature so that future research can be targeted to address those gaps in research about ICT agricultural intervention program effectiveness. To that end, the systematic review intends to identify trends and collective impacts of ICT interventions on farmer-level outcomes in the developing world in order to inform future interventions. The questions addressed through this review include:

2.3.1 Main Questions

1) Do ICT-based interventions impact farmers' incomes in developing economies?
2) Do ICT-based interventions impact crop-price dispersion in developing economies?

2.3.2 Supplemental Questions

3) What are the common trends and mechanisms for achieving impacts?
4) How do moderators such as country conditions or crop type affect impacts?
5) Do ICT interventions affect other outcomes including production, crop loss, input use, or change in crop types?

3 METHODOLOGY

In conducting this systematic review, the research team searched for, reviewed, coded, and analyzed the results of rigorous impact evaluations. In doing so, SI followed the Campbell and Cochrane Collaboration (2C) approaches to systematic reviews, as described in more detail below. SI developed the methodology to select studies to include in the review in close consultation with FFPr, and FFPr approved the final protocol in July 2015.[4]

Per the Campbell Collaboration 2C method, the team used a theory-based approach, relying on the theories of change described herein as the framework for the review. The theories of change informed the inclusion criteria, data extraction, and coding. Wherever available, SI extracted information about the causal chains to ensure the theories of change held true. The team focused on higher-level outcomes and impacts but also addressed some of the intermediate outcomes, such as increased knowledge and adoption of practices, so that the team could identify and make recommendations to address any breakdowns in the theory of change. The research team conducted a descriptive qualitative review of all supplementary outcomes listed in question five above, and it conducted both a descriptive qualitative review and a meta-analysis for each of the outcomes identified in the main questions—questions one and two, above. The methodology for locating studies; criteria for inclusion in the systematic review and meta-analysis; and information on coding, assessing quality, and identifying biases are all discussed below.

3.1 SELECTION CRITERIA FOR SYSTEMATIC REVIEW

To be eligible for inclusion in the review, the study had to meet the following criteria:

3.1.1 Subject Area

All studies included in the review must focus on agriculture and agricultural outcomes linked to farm production and agricultural trade or marketing.

3.1.2 Type of Intervention

This systematic review only includes ICT interventions that use ICT devices, tools, or applications for collection and/or transmission of information in order to increase access to communication and

[4] Discussion of the protocol began in early January 2015 with SI's submission of an annotated bibliography. This was followed with a proposal for systematic review topics in early March 2015. At this time, USDA selected the ICT topic as one of the three topics. Based on the preliminary findings from the literature, as well as conversations between SI and USDA on FFPr's priorities, SI developed a set of three topic proposals, including details on the protocol and methodology to be used for each. The ICT proposal was initially submitted in April and was approved by FFPr in July 2015. SI conducted the systematic review and meta-analyses between June and August, and wrote the report during the month of September 2015.

information. ICT is used as an umbrella term that could include, but is not necessarily limited to: radios, satellite imagery equipment, mobile phones, computers, televisions, and electronic money transfer equipment (The World Bank, 2011). Information is defined as verified information from an official source, such as research centers, government extension services, marketing boards, and other specialists. Information can also include information gleaned from other farmers or individuals regarding market prices. Interventions are considered to be agricultural in nature if they affect agricultural processes directly in terms of crop choices; adoption of new practices; crop losses; access to agricultural finance and other inputs; and access to markets, sales, and incomes from agriculture.

Studies included in this review discuss the following outcomes: income, price dispersion, yields, input use, crop loss, or changes in crop type. The research team included all of these outcomes in the narrative sections of the systematic review and additionally conducted a meta-analysis of two outcomes—income and price dispersion. Meta-analysis requires that there be a substantial number of impact evaluations on the outcome and that these evaluations include a number of very specific statistics on the outcomes. The reasons for the choice of these two outcomes for meta-analysis were:

1) Initial bibliographical searches showed that these two outcomes were among the most commonly assessed outcomes in rigorous impact evaluation studies of agricultural interventions in developing countries;
2) These outcomes can more easily be compared across crops and geographies, and they tend to have less variation than outcomes such as yields, input use, crop loss, or changes in crop type;
3) SI's task order with USDA focuses on trade-related outcomes rather than production-related outcomes. The reason for this focus, according to FFPr staff, is that there have been fewer studies conducted on the effects of agricultural interventions on trade outcomes and also because FFPr believes it has a comparative advantage in trade as opposed to productivity, which is the focus of many other donors.

Outside of these reasons, income and price dispersion also make good meta-analysis topics because of the theory of change associated with both. Often farmers do not have the information they need about prices to make an informed decision about the price they should charge for their crop when they are selling either to a middle-man or in a market, and, thus, they often undersell their goods or are unable to sell them because they have set their price too high. This leads to market-price dispersion, which ICT interventions could potentially mitigate by providing farmers with the

information needed to better set prices. Income/profit is an important outcome because it provides a long-term measure of the effectiveness of ICT interventions.[5]

3.1.3 Outcomes Defined

As described above, to be included in the review, studies had to include at least one of the outcomes as defined below. These definitions are based on typical terminology in agriculture research.

1) **Market Price Dispersion** is defined for this review as the variation in prices across locations. This is based on the pricing of an agricultural product by a common unit. It can be measured globally across a larger area or more locally, where circuity of markets is taken into consideration in the calculation of variation. A market is defined as any space where multiple vendors are selling agricultural products. Similarly, a market price is the price an agricultural product receives at a market.
2) **Profit** is defined as the amount of money that the household earns from selling a crop, including the net of input costs such as fertilizers, seeds, transport costs, and loans for financing agricultural work. **Income** includes profit after taxes and the return on investments. Income can also be measured using proxy indicators such as consumption, expenditures, and assets, all of which are considered to be better indicators of household income and wealth than income in developing countries. This is because often times, farmers will trade other items for their products rather than trading only crops for money.
3) **Crop yield** is defined as the volume of a crop that is cultivated at the end of a growing season and it is often measured by weight or size.
4) **Adoption of Inputs and Technology** includes any outcome that measures uptake of new agricultural technologies. Technology includes pesticide usage, fertilizer usage, improved farming practices, modern and improved seed varieties, and mechanization.
5) **Crop Loss** is the amount of a specific crop lost during or after harvest at farm levels due to diseases, pests, and poor transport and/or storage, etc. This does not include losses due to systemic risks such as natural disasters or conflicts.
6) **Changes in Crop Type/Acreage** are all associated with cropping patterns, and interventions focused in these areas generally work to shift farmers' focus from subsistence crops to higher-value crops. They also work to get farmers to shift from using traditional seed varieties to using modern and improved seed varieties and from using mono-cropping to using mixed or multiple-cropping. Finally, these changes can result in farmers either expanding or reducing the amount of crops planted.

[5]While input prices are also important, they are a difficult outcome to assess because of the diversity in input types and variations in prices in wholesale, retail, domestic, international, and regional markets, as well as the variations in the ways inputs are procured (e.g., through cooperatives, in-kind loans, etc.). These variations made finding an adequate number of studies that assess similar types of input prices to conduct a meta-analysis on this topic nearly impossible.

3.1.4 Study Type

The review only includes rigorous impact evaluations that used counterfactuals to infer impacts. The impact evaluation designs include: experimental designs where randomized assignment to the intervention is made and quasi-experimental designs with well-defined before-and-after timeline and comparison groups. Quasi-experimental designs include regression discontinuity designs, studies that use techniques for controlling for selection bias such as statistical matching (for example, propensity score matching or covariate matching), and regression adjustment (for example, difference-in-differences and single-difference regression analysis, instrumental variables estimation, and Heckman selection models).

3.1.5 Timing and Duration

Only studies published or made available to SI after the year 2000 are included. Additionally, only studies that had a final evaluation with at least one full growing season after the baseline are included since shorter timelines are not thought to yield any significant results.

3.1.6 Population

The population includes developing countries only. This includes countries classified as low-, lower-middle, or upper-middle income-countries as classified by the World Bank in 2015. Participants include farmers, agricultural households, women and men, agribusinesses, and cooperatives.

3.2 ADDITIONAL SELECTION CRITERIA FOR META-ANALYSES

In addition to the criteria listed above, studies included in the meta-analysis:

- Address outcomes related to farmer-level income and/or price dispersion
- Were rated by SI to be highly rigorous in design with a counterfactual, adequate sample size and length of study, and rigorous analysis of data
- Present adequate data needed for aggregating results in a meta-analysis. Specifically, a study needed to include data on the measured impact on the outcome variable that was attributable to the intervention, the standard deviations of the outcome variable for both the treatment and control groups, and the numbers of observations of the treatment and control groups.

3.3 THEORY OF CHANGE FOR OUTCOMES

Conceptually, the SI research team began its research with the assumption that many farmers in developing countries are limited in their knowledge about such key phenomena as modern farming techniques, access to inputs, finance, markets, seasonal weather forecasts, and price information. This constrains their ability to use the best farming methods, adapt to weather predictions, and sell crops for their full value. Appropriate ICT interventions that focus on distributing agricultural

information or making ICT more accessible to allow for the exchange of information where knowledge gaps exist can help reduce those and other constraints.

The theory of change follows that improved dissemination of information to farmers will lead them to make better farming decisions, including adopting advanced technologies which also helps to reduce crop losses. Improved information on market prices and business practices, including calculating profit and loss, also helps farmers to negotiate prices for seeds, inputs, and loans, leading to: increases in production (yields) and productivity, the ability to locate better markets and agents, and the ability to negotiate prices for crops leading to better prices for their produce. These outcomes ultimately result in increased farm and household income. Therefore, helping farmers to access information through ICT will likely lead to better agricultural decisions, which in turn will lead to better yields, higher profits and incomes, and improved livelihoods.

ICT can also reduce both transactional and unit costs of information. Farmers in rural areas are often difficult to reach in person with information or trainings. ICT has the potential to eliminate that challenge by providing up-to-date information regularly to intended beneficiaries, thus saving costs related to frequent, difficult, and costly travel. In this way, the use of an ICT device to obtain services that reduce the spatial disparity between agents has the potential to really make a difference in the lives of farmers, as it gives them the ability to: 1) gain access to information and knowledge that would have otherwise been inaccessible or unavailable, 2) connect to and maintain social and business relationships, and 3) coordinate with other economic actors at lower transaction costs. Appendix 6 includes additional details on the theory of change.

3.4 STUDY SEARCH STRATEGY

The websites, journals, and databases selected for the search are listed in Appendix 1. The research team used specific keywords to search for relevant articles on each of these websites. Keywords followed PICOS (Population, Intervention, Comparison, Outcomes, Study design) format. Each search was conducted by entering a combination containing one word from each PICOS category. A complete list of these search terms is displayed in Appendix 2. Relevant studies were then coded into Database 1.

Since complete PICOS format would have resulted in upwards of 7,000 word combinations to search, and because these searches tend to overlap, returning irrelevant or repetitive hits, SI adjusted searches according to the format of each web site's search engine. Some websites had search filters that allowed for a more targeted search. The World Bank website, for example, had a filter for "Agriculture," while JPAL had a filter for "Agricultural Technology Adoption Initiative." Other common filters included "date range," "field," and "study type." Using these filters resulted in much more precision, but less overall retrieval of studies in the search process. As such, many fewer studies were retrieved and coded into the databases, but those that were coded were much more likely to be useful for the systematic review. To ensure that no useful studies (studies that met the systematic review or meta-analysis inclusion criteria) would be missed using this technique, the research team also tried searching without using the filters for a few of the search terms to ensure no relevant studies were missed. The team found that the use of the filters only improved the

efficiency of the process but did not eliminate any relevant studies. The filters used and the number of searches conducted for each website are recorded in Appendix 3.

The searches, particularly those in web sites that did not have filters, returned a very large number of hits. In order to maximize efficiency and minimize extraneous information, analysts continued coding each consecutive page of hits until they reached a page with no additional hits eligible for the review. Certain word combinations were omitted in cases where similar search patterns were only returning irrelevant and/or repetitive hits. In cases where a particular search returned no relevant hits, based on the above-listed selection criteria, no articles were coded into the database. Many hits were easily excluded because they were not relevant to the proposed review. This was the case for many of the university websites, including Kansas State University and Florida State University.

Additional searches were conducted through an iterative process of searching through reference lists and bibliographies of relevant studies.

3.4.1 Search for Unpublished Studies

In order to reduce publication bias, SI included both published and unpublished documents. In order to locate unpublished studies, SI contacted lead researchers and organizations in the ICT field and also all authors of publications included in the systematic review, asking for recommendations of additional studies, including studies in languages other than English. While there were many non-responses despite repeated requests and follow-ups, some authors responded with recommendations – both published and unpublished – that were then considered for inclusion in the systematic review. Unfortunately, we did not find any unpublished studies that met the criteria for inclusion in this systematic review.

3.4.2 Studies in other Languages

In order to avoid language bias, in addition to English, SI searched for studies in Spanish, French, and Portuguese. The SI research team found that English was the most common language for impact evaluations, particularly for those pertaining to ICT. Many impact evaluations initially written in English were later translated into other languages, but SI found only three studies originally written in another language. These included one Spanish study (Machado, 2011) and two French studies (Adjovi, 2013 and Arodokoun, 2011). All of these studies were included in the systematic review.

3.5 DATABASE CONSTRUCTION

In line with the Campbell Collaboration approach to systematic reviews, the team developed three databases to compile literature searches and analysis, as described in more detail below.

3.5.1 Database 1 (Search Database)

This database contained all publications that SI retrieved based on the search strategy above as well as more detail on whether the study was included in the systematic review.

In Database 1, SI analysts recorded basic information on search results, including search terms, search source, study title, year of publication, author information, type of study, study design, topic, type of intervention, population, country, language, and outcomes. Lastly, analysts made recommendations for whether the study should be included or excluded from systematic review based on the above-listed selection criteria. A full 30 percent of all studies were double-coded by two separate analysts to ensure both agreed on whether the study should be included in the systematic review or not (based on the inclusion criteria described above).

3.5.2 Database 2 (Systematic Review Database)

Analysts read the publications determined to meet the criteria for inclusion in the systematic review (based on Database 1) in full and further coded them for additional details pertaining to quantifying the effect sizes, statistical significance, quantitative rigor and reliability. Specifically, they recorded country information; crop types; unit of assignment to beneficiary and comparison groups; method of assignment to treatment or control groups; method of sampling; whether there was a balance test; effect size, t-statistic, pooled standard deviation for each outcome; numbers of observations in beneficiary and comparison groups; and key moderators, as well as a decision to include/exclude the studies in one or both of the meta-analyses. All studies in Database 2 were also double coded to ensure consistency and agreement on key indicators used in the qualitative analysis for the systematic review and the quantitative analysis for the meta-analyses.

A number of proxies were used in coding study outcomes. Proxies for income included revenue, household expenditure, and crop prices, all of which are known indicators of income status. Price dispersion was measured in terms of standard deviation, coefficient of variation, or price difference within a market pair.

Each of the studies was coded for key moderators, including the percentage of country budgets dedicated to agriculture, the country wealth designation, region, level of international funding, and overall state of fragility. SI used these moderators later in the process to examine whether impacts varied based on country-specific characteristics. The data sources for these moderators are listed below:

1) **Percentage of Country Budgets Dedicated to Agriculture:** FAO's data on agricultural expenditure as a proportion of government expenditure for the year 2011 (United Nations Food and Agriculture Organization). Where data were unavailable for the year 2011, data were drawn from the most recent year available for the particular country.
2) **Country Region and Wealth Designation:** World Bank's List of Economies as of July 2015 (The World Bank).
3) **Level of International Funding:** Official Development Assistance as a proportion of Gross

National Income as listed for the year 2013 in the World Bank's World Development Indicators.

4) **State Fragility Index:** The Center for Systemic Peace's 2013 index, which is a composite of states' effectiveness and legitimacy in terms of security and political-, economic-, and social-wellbeing.

3.5.3 Database 3 (Meta-Analysis Database)

The documents selected through Database 2 for at least one of the meta-analyses were further screened for quality using a quality checklist. Analysts then coded each of the studies for each of the quality criteria in Database 3, which was used for the meta-analyses only. The quality criteria focused on the different types of biases that might appear in the studies. Analysts scored each potential bias as high, medium, or low and made additional notes on the specific biases in the studies. The types of bias are listed below along with the questions the team considered in rating each of the biases:

1) **Bias due to baseline confounding:**
    - Did the study design or analysis account for important confounding and modifying variables?
    - Were confounding variables assessed consistently across groups using valid and reliable measures?
2) **Bias due to selection of participants into the study**
    - Did the study design and the start of the intervention coincide?
    - Were the comparison groups appropriate?
    - Did the study use randomization correctly and adequately?
3) **Bias due to departure from intended interventions**
    - Did the study adjust or control for other interventions that may have resulted in biased results?
    - Were baseline study conditions balanced across beneficiary and control or comparison groups?
4) **Bias due to missing data**
    - Were outcome data missing or incomplete due to attrition or exclusion from analysis? How was this issue dealt with, if so?
5) **Bias due to measurement of outcomes**
    - Can readers be confident in the assessment of the outcome?
    - Were the methods of outcome assessment comparable across intervention groups?
6) **Bias due to selection of results**
    - Were there missing and incomplete information? Were they handled well?
    - Were there any other potential threats to internal validity (e.g., inappropriate statistical methods)?

3.6 CODING RELIABILITY

As described above, to ensure that the decisions made for inclusion/exclusion in the systematic review were unbiased and consistent for Database 1, the research team used double coding. Two primary coders first coded all the documents and a third coder randomly selected and reviewed a sample of 30 percent of the above. Any discrepancies in coding were closely examined and reconciled. In all cases, the decision to include or exclude the study in the systematic review was consistent.

All studies (100 percent) selected for inclusion in both the systematic review (through Database 2) and meta-analysis (through Database 3) were double-coded using the same method to ensure accurate effect sizes. Coders discussed and reconciled discrepancies to ensure reliability. All decisions on whether to include studies in meta-analyses were consistent, and coders were in agreement. All studies that were initially selected for the meta-analyses (based on the inclusion/exclusion criteria) were assessed for quality, as discussed in more detail below.

The above search and coding strategies resulted in the following number of studies in each database as displayed in Figure 1.

Figure 1. Databases Used to Develop the Systematic Review

3.7 CRITERIA FOR DETERMINATION OF INDEPENDENT FINDINGS IN THE META-ANALYSES

Only one result per outcome in a study was used in each meta-analysis. SI's review of studies included in the meta-analyses showed that most studies only provided one measure of each outcome. For instance, most studies that report income did not also report expenditures and consumption (proxies for income). However, some studies included the same outcome measured using various definitions or techniques. In other cases, studies included multiple measures of profit for different crops or at different points in times. Tadesse (2014) for example included price statistics for four different types of grain. SI used the following protocol, approved by USDA, to determine which outcome to use in such instances, as discussed below.

When there were multiple points in time for measurements of the same outcome in the same study, the team selected the latest measurement using the most rigorous methodology. When there were multiple measures of the same outcome, the more rigorous measure was used. If none was clearly more rigorous, the factor identified by the study authors as more rigorous was selected.

A few examples from this review are included here to show the use of selection criteria to assure independence of findings. While Tadesse (2014) listed the changes in prices for four different crops, only one of them was included in the income meta-analysis in order to avoid bias. The crop selected was wheat because it was the most common crop grown within the sample, and, therefore, its price change was the most influential for farmers. In another case, Beuermann (2012) provided the logarithm of household income each year for several years following a phone-access intervention in Peru in order to shed light on long-term impacts. SI selected only the outcome for the year immediately following phone access, because that was the most attributable to the intervention, and it was the most consistent with outcomes from other papers.

A few studies reported on multiple outcomes. In such cases, if the outcomes were different, the results from the same study could be used in different meta-analyses. For example, Goyal's (2010) study examined both income and price dispersion. In this case, results of both outcomes were used in the two different meta-analyses. The study's appearance in two different meta-analyses does not violate independence as long as it does not appear more than once in a single meta-analysis.

Additionally, in cases where the same author has written multiple papers, the following criteria was used to avoid redundancy or misrepresentation: If an author wrote multiple papers on the same region and outcome, only the latest one with the most rigorous methodology was included for meta-analysis. Aker, for example, wrote four papers on Niger, but only two were selected for the meta-analyses – one for income and one for price dispersion.

3.8 STATISTICAL PROCEDURES USED IN META-ANALYSIS

SI applied a two-step meta-analysis methodology to calculate figures for the 12 studies included in the meta-analysis section of this report. First, SI calculated a summary statistic (including averages, standard deviations, and standard errors) for each study in order to describe the intervention effect. Since all studies included in the meta-analyses were reporting results as continuous rather than discrete/binary outcomes, the research team calculated the standardized effect sizes by assessing the differences in means between the beneficiary and control or comparison groups. In doing so, the team followed Lipsey and Wilson's (2001) well-established practice in conducting meta-analyses and calculated the standardized mean differences (Cohen's d) for the two continuous outcomes – income and price dispersion.

The Cohen's 'd' statistic is the most appropriate statistic for measuring effect sizes through group differences (between beneficiary and comparison groups) in mean levels of continuously measured outcomes, and is expressed in units of standard deviations. Researchers entered the information needed to calculate Cohen's d (See Appendix 5 for more information on how the research team

calculated Cohen's d) into the Comprehensive Meta-Analysis (CMA) software, and then, the research team calculated the pooled-effect size as a weighted average of the intervention effect calculated above, with the weights assigned based on the standard error for continuous outcome studies. Because of the presumed heterogeneity in different interventions, populations, and countries, researchers used a random-effects model to produce the pooled effect from all the individual studies. The team then used the CMA software to depict the above information, individual effects, and pooled effects through forest plots.

Finally, the team examined some moderators related to the countries' economic standing, agricultural conditions, and the countries' state of fragility to examine heterogeneity in results. Given the small number of studies that met the criteria for the meta-analyses, the analyses should be interpreted with caution and primarily considered only as descriptive depiction of results broken out by moderators.

SI entered the data for calculating Cohen's d into the CMA software, which produced Cohen's d values with confidence intervals for each study. Cohen's d values can be compared across studies.

As described above, in cases where there were missing data, SI contacted authors by e-mail. Up to three follow ups were made within a period of three months to obtain the missing data. The data most commonly missing related to the pooled standard deviations of the outcome variables for beneficiary and comparison groups. In cases where the pooled standard deviation was not available in the study or from the authors, the overall standard deviation was used as a very close proxy. If the overall standard deviation was also unavailable and could not be obtained from the author, the study was dropped from the meta-analysis. A number of studies were thus excluded from meta-analysis, though they were still included in the systematic review. For example, studies by Campenhout (2013) and Mitra (2013) were excluded from meta-analysis because the papers did not include the standard deviations of income, and the authors responded that they could not provide that information.

3.9 EXAMPLES OF STUDIES INCLUDED IN THE SYSTEMATIC REVIEW

In order to be included in the systematic review, studies had to meet all six of the listed criteria discussed earlier in this review—subject area, type of intervention, outcome, study type, time/duration of the study, and study population. As such, all studies included in this systematic review include a discussion of the impacts of ICT interventions on rural populations in developing countries for at least one of the listed outcomes (income, price dispersion, yield, crop loss, input use, or changes in crop type). Further, the studies needed to be rigorous, include a counterfactual, and were published or made available after the year 2000.

SI came across many qualitative studies, including a small number of qualitative systematic reviews of ICT for agriculture. But, USDA asked SI to exclude studies that were qualitative in nature in both the narrative and the meta-analysis, which eliminated the vast majority of papers found during the search. However, SI reviewed these papers in search of references to quantitative studies and to

examine commentaries on such studies. These papers help to inform recommendations and gaps in the existing literature.

Lastly, although the focus of the systematic review is on interventions, SI did include a small number of studies that did not administer a formal intervention, but rather investigated the impacts of existing ICT-usage patterns, using quasi-experimental methods. For example, Machado (2011) used surveys on whether farmers used ICT devices and what their incomes were to examine whether there was correlation between ICT use and income. The author used a propensity score matching methodology in which she paired farmers who used ICT with farmers who did not use ICT but who shared similar demographic characteristics otherwise. She then assessed the correlation between ICT usage and income. Because the treatment group in such cases (those using ICT) was self-selected, it was essential that the author use a rigorous methodology to infer causality. In cases where the methodologies were sufficiently rigorous, such studies were included in the systematic review, though not in the meta-analysis.

3.10 EXAMPLES OF STUDIES EXCLUDED FROM THE SYSTEMATIC REVIEW

Studies that failed to meet SI's established protocol discussed above were excluded from the systematic review. Examples of papers that were excluded include non-agriculture-related interventions, qualitative studies, quantitative studies lacking counterfactuals, and studies that did not seek to identify attribution of outcomes.

For example, a number of studies on ICT interventions measured outcomes for populations in the developing world, but were not substantially related to agriculture. In 2005, Vodafone released an impact evaluation of the macroeconomic impacts of cell phones in developing countries. This study, though rigorous, identified urbanization as one of the mechanisms for change in income and did not substantially examine outcomes within the agricultural sector. This study was, thus, excluded from the systematic review.

SI also came across a number of studies that were conducted in non-developing countries. Based on location, these studies did not meet the criteria and were also excluded.

3.11 METHODOLOGICAL LIMITATIONS

Standardized Mean Differences Bias

Information about the average standardized mean difference and the variance of standardized mean differences are valuable to understanding the effectiveness of the interventions. However, standardized means differences assume that the differences in standard deviations among studies reflect differences in measurement scales and not real differences in variability among the possible effects on ICT interventions on study populations. This assumption may be problematic in some circumstances where researchers expect real differences in variability between the effects in different studies due to contextual factors.

Selection Bias

Due to the nature of ICTs, a few types of bias were particularly common in the studies reviewed. The most common was bias due to participant selection. Many of the treatment groups were self-selected. For instance, people who own a mobile phone were sometimes taken as the beneficiary group, and those participants self-selected into owning a phone in most cases. People who self-select into treatment are likely systematically different from those who don't or the comparison group. For instance, it could be that those with cell phones have more money than those that don't or that those with cell phones are more prone to seeking out communication and information through other sources already, making them more motivated or better connected than those who don't own a mobile phone. While the study authors attempted to control for such variables between beneficiary and comparison groups as much as possible, some characteristics cannot be controlled for as they are unobservable. This includes things like motivation.

Multiple-Treatment Bias

A few of the studies included in the systematic review and meta-analyses may have been biased due to confounding variables otherwise known as multiple-treatment bias. In these studies, there was an additional component to treatment other than ICT that confounded findings. For example, in Goyal's paper, in addition to the computer kiosks, the treatment group also received services from "hubs," which were warehouses where specialists assessed soybean quality and facilitated sales to large companies. The hubs were administered shortly after the kiosks, which allowed researchers to separate the impacts of the two interventions somewhat, but the measure of the effectiveness of the computer kiosks may still be slightly biased by possible secondary effects of the hubs. A second example is in Kizito's paper, which identified treatment as receiving market information through various channels, most, but not all, of which were ICT channels. Because there are some non-ICT information channels that may have been included in the study impacts may be slightly biased since they wrongly assume the effects of these other interventions are part of the ICT effect.

Missing Data Bias

In terms of missing data, there were two main issues that may have led to a small amount of bias. The first is that many authors listed the overall number of observations but did not report on the breakdown between the treatment or control groups. In these cases, SI assumed that the total number of observations were split equally between beneficiary and comparison groups, since this is the most often commonly used sampling strategy. Any bias arising from this issue would be small and not likely to substantially alter outcomes. The second issue is that a number of studies did not provide sufficient information to calculate the pooled standard deviation. In these cases, SI used the overall standard deviation, which is a very close proxy of pooled standard deviation.

Publication Bias

As described in the publication bias section of the report, there appears to be some "missing" studies. These might potentially bias the results of the findings. However, the SI team believes that these "missing" studies are not real but simply theoretical. In other words, these studies have not

yet been conducted or published and merely represent gaps in existing literature. The research team is confident that its search was as comprehensive as possible.

4 FINDINGS: CHARACTERTISTICS OF STUDIES UNDER REVIEW

A total of 31 studies were included in the systematic review for narrative analysis, and 12 of those were also included in the meta-analyses. Studies included in the systematic review and meta-analyses included studies using: an experimental design (randomized controlled trials), a difference-in-differences design, a propensity-score-matching design, and an instrumental variables design.

Roughly half of the studies in this systematic review examined interventions that occurred in Sub-Saharan Africa, while the remainder examined interventions occurring in Asia, and Latin America and the Caribbean, respectively. The breakdown was similar for both the narrative portion of the systematic review and the meta-analyses, the latter of which included five papers from Africa (3 studies on East Africa and 2 on West Africa), four from by Asia, and three from Latin America. The systematic review also includes studies conducted of interventions in low-income, lower-middle-income, and upper-middle-income economies, as classified by the World Bank. The most commonly studied countries include Peru, Niger, India, Uganda, and Kenya, all of which had at least two published studies on interventions in their countries. The clustering of papers in a few countries suggests that there may be gaps in the literature. A complete list of studies by intervention and outcome is listed in Table 4.

4.1 INTERVENTION TYPES

In terms of types of interventions, the vast majority of the papers examined for the narrative and meta-analyses of this systematic review included interventions related to mobile phones. These interventions ranged from mobile phone coverage, to mobile phone ownership, to information services sent via mobile phone. Other interventions examined ICT applications such as internet kiosks, landline phones, radio, television, etc. These are differentiated from mobile-phone-based interventions in the discussion below.

An important feature of mobile phone ICT interventions is that they require the population to have some minimum level of electronic literacy, particularly since many of the interventions involve text messages. This limits the benefits of the interventions to those who are literate. A few interventions

addressed this issue by providing some basic training on use of mobile devices though the larger issue of working with illiterate beneficiaries remains.

The ICT interventions included in this systematic review generally fall into three categories as described below. Details about the number that fall into each category are also included in Table 1.

4.1.1 ICT Infrastructure Interventions

ICT infrastructure interventions focus on improving the connectivity and geographic coverage of ICT networks through building telecommunications and electricity grids to make networks available to previously unconnected and under-connected areas/populations. Infrastructure interventions primarily target service providers, households, and communities, and generally involve heavy investments and long-term projects focused on infrastructure development.

A total of 5 of the 31 papers included in the narrative of the systematic review and two of the 12 papers included in the meta-analyses examined increases in mobile phone coverage or the installation of local payphones and how these increases in access affected rural farmers' outcomes. Although mobile phone coverage is a long-term investment that affects populations beyond farm households, the papers SI reviewed that fell into this category focus on areas or communities in which farming was the primary livelihood.

4.1.2 Access to ICT Device Interventions

Access device interventions work to improve access to physical devices such as mobile phones, SIM cards, computers, radios, televisions, etc. The devices can be used for a variety of communication purposes, including accessing information related to farming. Access device interventions primarily target individuals, households, communities, and businesses.

A total of 9 of the 31 studies included in the narrative of the systematic review and 3 of the 12 studies included in the meta-analyses examined access device interventions. Most of these studies examined household ownership of a mobile phone, while a few examined access to other ICT devices such as radio or television.

4.1.3 Service Provision through ICT Interventions

Service interventions include the provision of relevant services such as information about prices, agricultural advice, mobile money, and mobile health (m-health) and are made available to the population for free, for a small fee, or with charges reimbursed by the donor, local government, or service provider. Such interventions tend to target farm households, communities, agribusinesses, and value-chain actors.

Both the narrative portion of the systematic review and the meta-analyses included more studies from this category than any other category, with 17 of the 31 studies analysed narratively falling here and 7 of the 12 studies used in the meta-analyses falling in this category. Much of the ICT

literature suggested that access to an ICT device alone usually does not cause an impact; rather, it is the use of that device for specific agricultural purposes that tends to result in changes to outcomes. For this reason, the vast majority of the studies reviewed for this systematic review focused on service interventions.

SI had initially planned to focus only on service interventions. However, in searching, the research team found a number of very strong studies on interventions related to infrastructure and access. For example, Jensen and Beuermann both found that, under certain circumstances, farmers improved ICT infrastructure and were able to achieve outcomes after receiving access to ICT devices, without providing services. These types of studies were, thus, included in the review. The number of studies under each type of intervention is listed below in Table 1, below.

Table 1. Number of Studies by Type of Intervention

Type of Intervention	Number of Studies	Percentage of Studies
Infrastructure	5	16%
Access Device	9	26%
Service	17	58%
Total:	**31**	**100%**

4.2 STUDY DESIGN TYPES

Within the above-listed intervention types, 9 studies used experimental designs (randomized controlled trials) and 23 used quasi-experimental designs, as detailed more extensively below. Additional details on findings and trends in study design are included in Appendix 7.

4.3 GEOGRAPHIC COVERAGE

As displayed in Table 2, about half of the 31 systematic review studies and 5 of the 12 meta-analysis studies examined interventions in Sub-Saharan Africa. A good portion also examined programs in South Asia and Latin America. There were a large number of studies in a handful of specific countries, including Peru, India, Kenya, Niger, and Uganda. This may be in part because these are countries for which data are more readily available. In the case of Uganda and Peru, these countries had phased rollouts of mobile phone coverage, which created a good quasi-experimental setting for impact evaluation. In a few cases, a single author conducted extensive local research and published multiple papers on one country. This was the case for Jenny Aker, who was the author of all four of the included studies on Niger.

Putting aside the researchers who authored multiple papers on the same country, the clustering of studies in a few specific countries may also be indicative of gaps in the literature. Countries with less readily available data may be systematically excluded from study, for instance. Upon further investigation, it appears that study designs also exhibited clustering patterns, with difference-in-difference designs and RCTs clustering in a few specific countries. This is further evidence of gaps in the literature. Additional discussion of these clustering patterns is included in Appendix 6: Study Design Findings.

Table 2. Studies by Country and Region

Region/Country	Number of Systematic Review Studies	Percentage of Studies
East Asia & Pacific	**2**	6%
Cambodia	1	3%
Philippines	1	3%
Latin America & Caribbean	**7**	21%
Colombia	1	3%
Honduras	1	3%
Peru	5	15%
South Asia	**7**	21%
India	6	18%
Pakistan	1	3%
Sub-Saharan Africa	**17**	52%
Benin	2	6%
Ethiopia	1	3%
Ghana	1	3%
Kenya	4	12%
Mozambique	1	3%
Niger	4	12%
Swaziland	1	3%
Uganda	3	9%
Total	**33**	100%

Because one of the studies included separate impact evaluations in three different countries (Honduras, Swaziland, and Cambodia), the total number of studies in this table appears higher than the actual number of studies (33 vs. 31).

4.4 COUNTRY WEALTH

Country Wealth Designation	Number of Systematic Review Studies	Percentage
Low income	12	36%
Lower middle income	15	45%
Upper middle income	6	18%
Total	33	100%

Table 3Table 3, below, displays the studies according to country wealth designation based on the World Bank's categorization. Almost half of all the studies discussed in the narrative section of the systematic review studies and 5 of the 12 meta-analysis studies examined lower-middle-income countries. Only 19 percent of the studies examined upper-middle-income countries. The rest were close to equally split between low-income and lower-middle-income countries.

Table 3. Studies by Country Wealth Designation

Country Wealth Designation	Number of Systematic Review Studies	Percentage
Low income	12	36%
Lower middle income	15	45%
Upper middle income	6	18%
Total	33	100%

Because one of the studies included separate impact evaluations in three different countries, the total number of studies in this table appears higher than the actual number of studies (33 vs. 31).

4.5 TIMING OF PUBLICATION OF STUDIES

Figure 2, **Error! Reference source not found.**below, depicts the number of systematic review studies published or made available to SI during the search period (2000 – present). Although the timeframe began in 2000, the SI research team did not find any relevant studies published earlier than 2005. The number of studies steadily increased, peaking in the year 2012. Studies seemed to taper off slightly after that, though this might simply be the time it takes for studies to be publicly posted.

Figure 2. Number of Studies included in the Systematic Review by Year Published

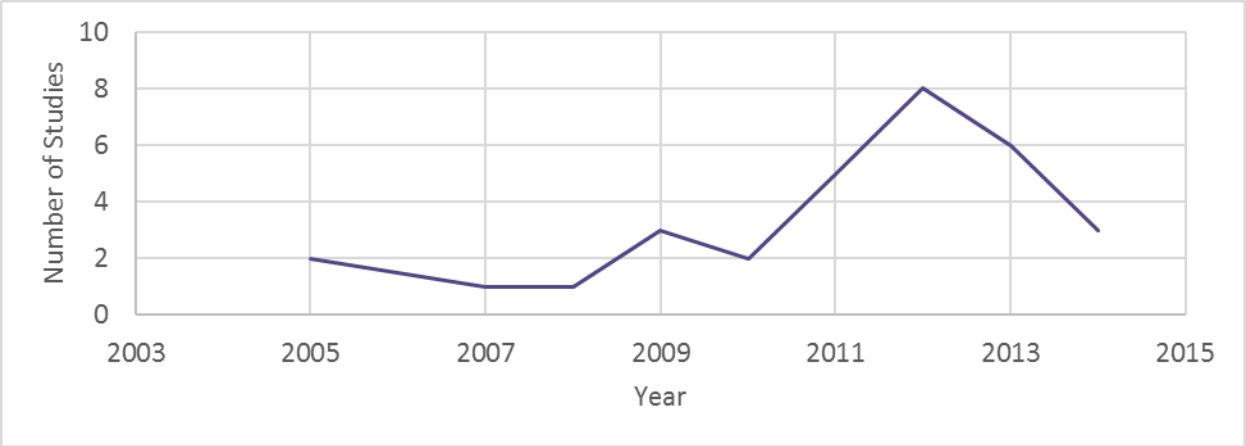


Table 4, below,**Error! Reference source not found.** displays the outcomes, findings, locations, and years of publication of each of the studies. The largest number of papers reported on income, followed closely by farm productivity. Fewer papers reported on price dispersion, and very few reported on the remaining outcomes, including input use, crop loss and changes in cropping pattern.

Table 4. Studies by Outcome

Study Name	Location	Intervention Type	Income	Price Dispersion	Production/ Yield	Input Use	Crop Loss	Change in Crop Type	Statistical Design
Adjovi 2013	Benin	Access Device	Increase *						Cross-sectional
Aker 2009 (M-A)	Niger	Infrastructure		Decrease ***					DiD
Aker 2010	Niger	Infrastructure		Decrease ***					DiD
Aker 2011	Niger	Service			Increase Non-significant				RCT
Aker 2012 (M-A)	Niger	Service	Increase Non-significant		Positive **				RCT
Al-Hassan 2013	Ghana	Service	Non-significant						PSM
Arodokoun 2011	Benin	Access Device	Increase ***		Decrease Non-significant				IV
Ashraf 2005 (M-A)	Kenya	Service	Increase Non-significant			Decrease Non-significant			RCT
Beuermann 2011 (M-A)	Peru	Access Device	Increase *		Decrease Non-significant				DiD
Beuermann 2012	Peru	Infrastructure	Increase ***						DiD
Camacho 2011	Colombia	Service	Increase *	Decrease ***			Decrease **		RCT
Campenhout 2013	Uganda	Service	Increase ***		Decrease Non-significant				DiD
Casaburi 2013	Kenya	Service			Increase **				RCT
Chong 2005 (M-A)	Peru	Access Device	Increase ***						IV
Cole 2012	India	Service				Increase **		Increase *	RCT
Fafchamps 2012 (M-A)	India	Service	Decrease Non-significant	Increase Non-significant					RCT
Fu 2012	India	Service							DiD
Goyal 2010 (M-A)	India	Service	Increase ***	Decrease **					DiD

Houghton 2009	Swaziland	Access Device	Increase ***						IV
Houghton 2010	Cambodia	Access Device	Increase ***						IV
Houghton 2011	Honduras	Access Device	Increase **						IV
Jehan 2014	Pakistan	Access Device			Increase ***				
Jensen 2007 (M-A)	India	Infrastructure	Increase **	Decrease ***	Increase ***		Decrease ***		DiD
Kiiza 2012	Uganda	Access Device			Increase ***	Increase *			PSM
Kirui 2012	Kenya	Service	Increase ***						PSM
Kizito 2012 (M-A)	Mozambique	Service	Increase **						IV
Labonne 2009 (M-A)	Phillippines	Access Device	Increase **						IV
Machado 2011	Peru	Access Device	Increase **						PSM
Mitra 2013	India	Service	Increase Non-significant						RCT
Muto 2008	Uganda	Infrastructure	Increase Non-significant						IV
Nakasone 2013 (M-A)	Peru	Service	Increase *		Increase Non-significant				RCT
Ogutu 2014	Kenya	Service			Increase ***				PSM
Tadesse 2014 (M-A)	Ethiopia	Service	Increase *						IV

Note: ***, ** and * represent statistical significance of the results at 1, 5 and 10% levels, respectively. Non-significant represents that results were not statistically significant at the 10% level.

PSM = Propensity Score Matching; DiD = Difference-in-Difference; IV = Instrumental Variable; CTV= Continuous Treatment Variable; RD= Regression Discontinuity Design

M-A = Study was additionally included in meta-analyses

5 FINDINGS: NARATIVE ANALYSIS

The research team presents the findings from the narrative analysis conducted for this systematic review, below, by outcome. In discussing effects, the research team categorized study findings as statistically significant if the study author stated that results were significant at a 90 percent confidence interval level.

5.1 MARKET-PRICE DISPERSION OUTCOMES

Five out of six authors found that ICT interventions decreased crop price dispersion with statistical significance. These findings were particularly dramatic in cases where the farmers were working with perishable goods and/or when the farmers had access the necessary means (eg. transportation) to act on the information they received through the intervention.

As shown in Figure 3, researchers found six studies that discussed price dispersion as an outcome of ICT interventions. Each of these studies examined one of the two types of interventions: 1) service interventions that provided access to direct information on the prices of different crops at different locations and/or markets and 2) interventions that allowed farmers the ability to communicate through ICT.

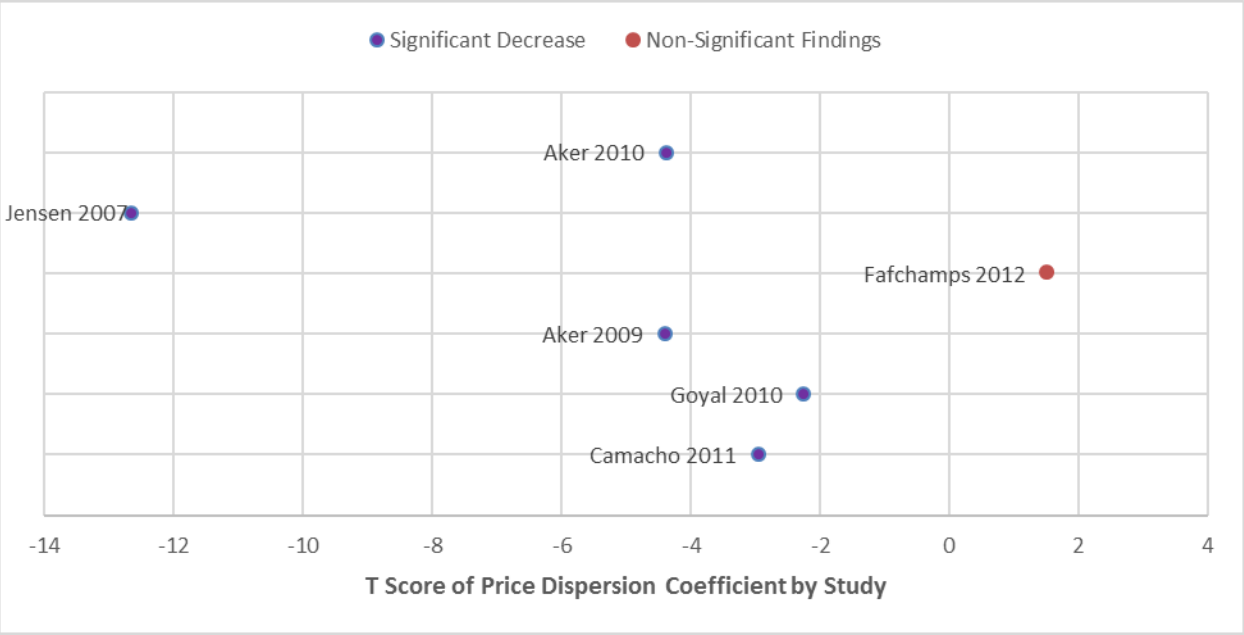
The first includes service programs that provide direct information on the prices of different crops at different locations and/or markets that are accessible to the farmer in real time or with a slight lag. The second includes any access to mobile phones or public payphones that would enable farmers to communicate across the region in order to obtain price information or arrange sales' deals.

All six market-price dispersion studies analyzed the impacts of ICT on price dispersion using multivariate regressions. Displayed below, in Figure 3**Error! Reference source not found.** are scatter plots of the t-statistics obtained from each of the six studies.[6] It is not standard practice to compare t-statistics directly across different studies because study designs and populations vary greatly, but the statistics help to display findings from the individual studies. An absolute value of t-

[6] In statistics, the *t*-statistic is a ratio of the departure of an estimated parameter from its notional value and its standard error. It is the calculated difference represented in units of standard error. It is used in statistical hypothesis testing, and in the computation of confidence intervals. The greater the magnitude of the t-statistic (it can be either positive or negative), the greater the evidence for rejecting the null hypothesis that there is no significant difference between two groups. Also, the larger the absolute value of the t-value, the smaller the p-value, and the greater the evidence against the null hypothesis. Mostly, a t-statistic value of two and above translates to a smaller p-value. The key property of the *t*-statistic is that it is a pivotal quantity. Therefore, while defined in terms of the sample mean, its sampling distribution does not depend on the sample parameters, and thus it can be used regardless of what these may be.

statistics of about two or above on the positive side or two or below on the negative side indicates a significant variation in means between two groups (such as beneficiary and comparison groups). Therefore, the chart provides a good depiction of the findings for each of the six studies. The plots should be considered as a descriptive display of the significance of the results rather than a quantitative metric of the results. Nonetheless, it is clear that in five out of the six studies assessed, ICT intervention groups significantly varied from control or comparison groups and were highly correlated with lower price dispersion, suggesting farmers with better access to information through ICT interventions are better able to obtain competitive prices.

Figure 3. Strength of Findings on ICT's Impact on Price Dispersion



T statistics are not directly comparable across studies, but they show whether findings are significant within each study. This scatterplot shows that 5 out of 6 authors found ICT to lower price dispersion with statistical significance.

The results were the strongest in Jensen's (2007) study of fish markets in Kerala, South India. Jensen found that prior to the development of mobile-phone infrastructure, fishermen were most often selling fish only in their own local markets. Because fish are highly perishable, any fish not sold were thrown back into the water at the end of the day. A market with few fish would experience high prices, while a neighboring market only twenty minutes away that had too many fish could experience very low prices. In the low-price market, excess fish would go to waste even though there likely would have been buyers in the high-price market. As mobile-phone coverage was introduced in different regions of Kerala, Jensen found that price dispersion rapidly decreased. The fishermen that purchased phones were able to make sales deals quickly where their fish were most valuable. This produced more efficient fish allocation, overall, such that the price dispersion decreased. This was also a particularly unique case because the villages in which fish were sold were close enough in proximity that many fishermen were able to travel by boat from one market to another with minimal barriers. In other contexts, there may be more barriers to travel, which could likely prevent such efficient reallocation from taking place, even with mobile phones.

Aker (2009 & 2010) found similar, though less dramatic, results in the grain markets in Niger. Both of Aker's studies used quasi-experimental designs to observe changes in markets as they gained access to mobile-phone coverage.[7] While there is most likely some endogeneity in terms of which regions receive mobile phone coverage, mobile coverage is a better indicator than household mobile phone ownership since the latter is a self-selected group. Additionally, the exact timing of the introduction of mobile phone coverage is exogenous, which provides a better experimental setting.

Two additional researchers employed experimental designs to similarly show that use of ICT significantly reduced price dispersion in Colombia and India. Camacho (2011) examined the impacts of providing weather and price information through SMS, and Goyal (2010) examined an intervention that involved the use of internet kiosks to provide price information to soybean farmers. Both authors found that the interventions lowered price dispersion.

Collective quantitative impacts are addressed through the meta-analysis on price dispersion and reported in later sections of this review below.

5.2 FARMER INCOME

Of the authors who examined farmer income, 75% (18 out of 24) found that ICT interventions increased farmer income with statistical significance. Findings tended to be dramatic in cases where the farmers were in a monopsony or other situation in which the middlemen buying crop had more power than the farmers. Interventions that provided market information services were helpful inasmuch as the farmers had the transportation means to act on the information.

In the studies analyzed narratively for this systematic review, ICT programs that could effectively improve farmer income are discussed under two mechanisms: 1) interventions that can increase farmers' production through use of better farming practices, and 2) interventions that can improve farmers' ability to negotiate better prices for their inputs and outputs. Interventions that focused on increasing the use of better farming practices primarily provided information on weather and/or new agricultural techniques in order to increase productivity or quality of produce, thus leading to higher yields and more income for farmers. Programs that focused on improving the ability of farmers to negotiate better output prices provided farmers with information on output prices and market locations.

[7] While there is most likely some endogeneity in terms of which regions receive mobile phone coverage, mobile coverage is a better indicator than household mobile phone ownership since the latter is a self-selected group. Additionally, the exact timing of the introduction of mobile phone coverage is exogenous, which provides a better experimental setting.

SI researchers reviewed a total of 22 studies that examined impacts of ICT on farmers' income, one of which contained three separate impact evaluations in different countries (Houghton, 2009), resulting in a total of 24 country-level findings. Of those 24 findings, 18 (75%) found that ICT programs helped increase income with statistical significance at least at the 10% level. Most of these studies focused on examining effects of information provision on prices to increase incomes. The other 25% of authors found that there was no statistically significant impact on income.

The increase in farmer incomes was particularly large in Goyal's (2013) study of soybean farmers in central India. The market in the study area was a case of monopsony, in which the many soybean farmers sold at the farm gate to the same large corporate processor, called ITC Limited. The intervention provided farmers with information on soybean prices at various locations before ITC offered the farmers its price. Although the farmers were still not able to negotiate with ITC, the price information better equipped them to sell elsewhere if they were not satisfied with ITC's price offering. For example, if prices were higher in another market that was readily accessible to the farmer, they could choose to sell there instead of selling to ITC.

Campenhout (2013) studied an ICT intervention that included the provision of information on crop prices and transportation costs as well as agricultural extension services on improved farming practices. The intervention was designed to provide information on prices, demands, transportation options, and farming practices because it was found that price information alone was often not enough to improve farmers' incomes. Farmers also required additional information on demand and costs of transportation, especially to distant markets. He found that the package of interventions significantly increased farmers' incomes.

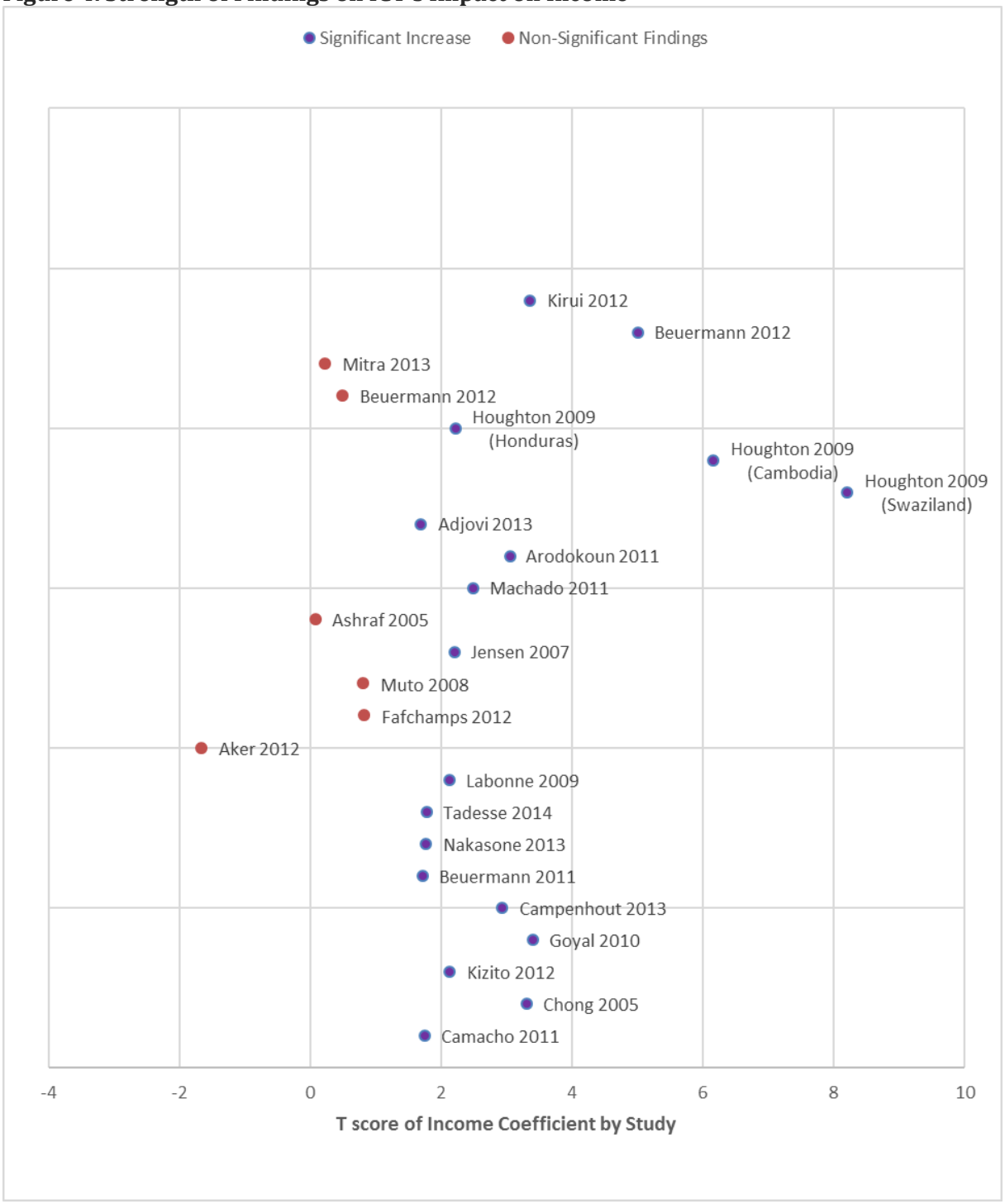
Houghton (2009) used an instrumental variables design to show that use of mobile phones appeared to increase ownership of assets in Cambodia, Swaziland, and Honduras. The assets he examined included cattle, pigs, and land, all of which are known indicators of income and wealth. While included in the narrative portion of the systematic review, these results, though significant, were excluded from the meta-analysis because the form of measurement (cattle, pigs and land) was too inconsistent with the other measures of income which were in currency. These would not have been comparable.

Among the 25% of authors that found no impact on income, there was no single common barrier. However, five out of six of these studies were on interventions related to market information services. A common problem with these types of interventions is that they only provide information on prices. If farmers do not have access to transportation, they do not have the means to take advantage of the information because they cannot sell elsewhere. Additionally, a common problem is that impacts on income can take a long time to materialize, but evaluations are typically completed shortly after the intervention. This can make it difficult for researchers to detect changes.

Figure 4, below, displays a scatter plot of the individual t-statistics found in the regression analysis of each study. As previously mentioned, the plots should be considered as a descriptive display of the significance of the results rather than a quantitative metric of the results. This chart should be

considered as a descriptive depiction rather than a quantitative conclusion. Summary statistics will be addressed later in the meta-analysis section of this report.

Figure 4. Strength of Findings on ICT's Impact on Income



T statistics are not directly comparable across studies, but they show whether findings are significant within each study. This scatterplot shows that 18 out of 24 authors found that ICT increased income with statistical significance.

5.3 INPUT USE

Two of the three studies that examined the effects of ICT on input use found that ICT programs significantly increased the use of specific inputs. Generally, interventions that provide agriculture extension services or hotlines for advice are known to have the most impact on input use.

Cole (2012) found that an agricultural advice hotline significantly increased the intensity of use of pesticides. Prior to the hotline, the farmers' main source of information on pesticide was the input dealers. The hotline provided objective information on the inputs such as pesticide. Kiiza (2012) reported that use of improved seeds was significantly higher among farmers in Uganda who used various ICT devices (primarily radios) to obtain agricultural information. Ashraf (2005) found that DRUMNET, an ICT program designed to connect local farmers with exporters in Kenya had no significant impact on farmers' overall expenditures on inputs, (including fertilizer, seeds, and pesticides). For those studies that did find an effect, however, the inputs likely helped to improve farming practices and, thus, led to increased use of pesticides, improved seeds, or other agricultural tools, which may have contributed to increases in farm income through better farming practice. In this way, input use is an intermediate outcome that could lead to better income in the long run.

5.4 PRODUCTION/YIELDS

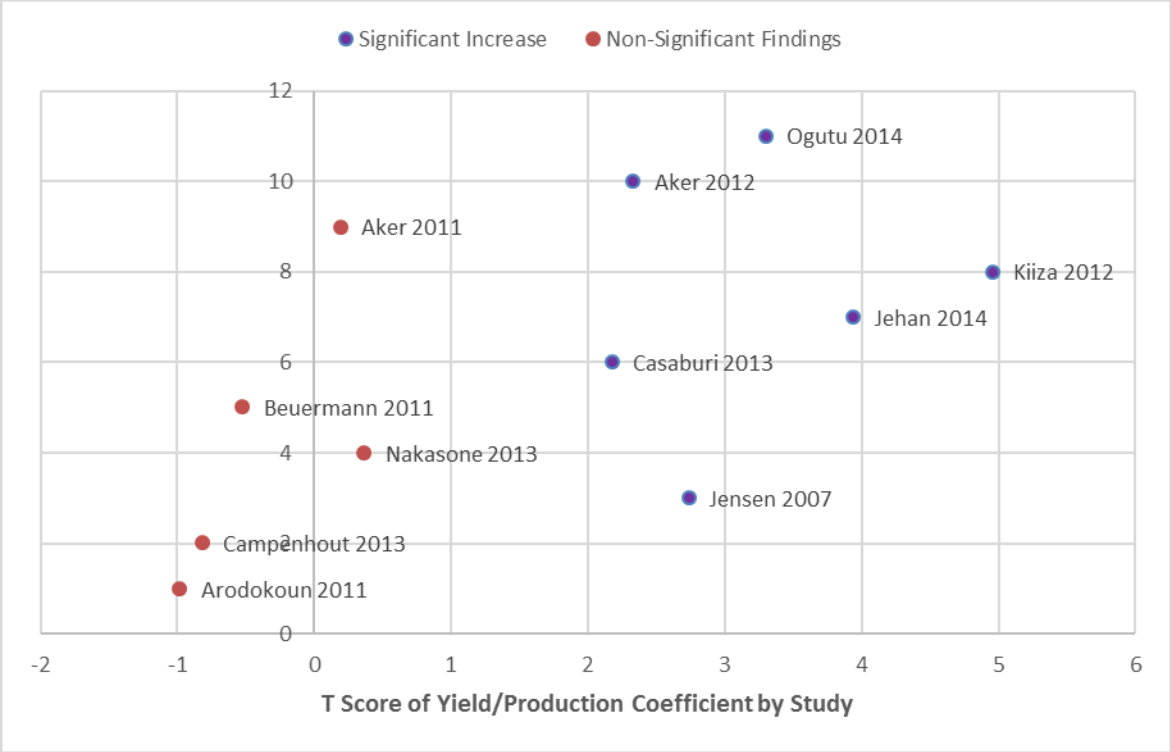
Six out of eleven authors found that ICT significantly increased farmer yields/production. These interventions were related to increasing mobile phone coverage, improving access to phones, or disseminating information on modern farming technology via SMS.

For example, several of the interventions that provided farmers with market information via SMS resulted in increases of total quantities of crops produced as shown in Figure 5, below. This was the case in Casaburi's (2013) study in Kenya. However, Campenhout (2013) found that a Uganda-based ICT intervention that provided agricultural extension services and price information via smartphones did not have a significant impact on quantities produced, although it did appear to increase farm incomes. Additional research is needed to explore the reason for these differing findings. **Error! Reference source not found.** below depicts the t-statistics for each of the studies that reported on yields.

The other five authors examining yield, found no significant impacts. There didn't appear to be any common trends among these studies. However, one possible explanation for the lack of findings is that few interventions are designed to directly address production. Most provide market information, intended to improve farmers' sales and prices. In the long run, this might lead farmers to increase production if they are making better sales, but may not be detected in a short-term evaluation. There were however, a few studies that focused on providing farming information intended to benefit production. Campenhout's was one such study. Interestingly however, Campenhout found that the intervention, which involved agriculture extension services via mobile

device, increased income, but had no significant impact on production in Uganda. More research is needed on what makes agriculture extension services via ICT more impactful.

Figure 5. Strength of Findings on ICT's Impact on Yield/Production



T-statistics are not directly comparable across studies, but they show whether findings are significant within each study. This scatterplot shows that 6 out of 11 authors found that ICT increased yields/production with statistical significance.

5.5 CROP LOSSES/WASTE

Both Jensen (2007) and Camacho (2011) found that ICT interventions decreased crop waste significantly by improving sales efficiency and enabling farmers to better protect their crops.

After receiving mobile coverage, loss from wasted fish was mostly eliminated among the fishermen in Kerala, India since they were able to sell most of their catch. In this particular study the reduction of waste was the mechanism by which fishermen increased their incomes (Jensen, 2007). Camacho (2011) reported that the ICT-based intervention that provided farmers with information on prices and weather via SMS significantly reduced crop loss in Colombia since weather information enabled farmers to better prepare for inclement weather and hence reduce waste.

5.6 CHANGES IN CROPPING PATTERNS

Researchers only found one study that explicitly addressed the impacts of ICT on changes in cropping patterns. Cole (2012) found that a mobile-phone-based agricultural advice hotline increased the number of farmers growing cumin, a particularly profitable crop.

Cumin is particularly profitable but requires careful farming practices. With increased accessibility to farming information, more farmers were able to grow cumin because they could easily obtain farming advice when needed. It was not clear in the study, however, whether the advisers specifically encouraged farmers to grow cumin or whether farmers were more willing to pursue it because of the additional support. Nonetheless, it is likely that the crop's profitability combined with increased farmer access to information might have encouraged more farmers to grow the crop (an intermediate outcome) and could have also led to increases in farm income.

5.7 OTHER INTERMEDIATE OUTCOMES

Although the focus of the report is on the previously stated outcomes, SI noted other important outcomes cited by researchers. A few of these are discussed below, as they might function as intermediate outcomes for farmers to achieve higher-level outcomes such as income.

Two authors—Kirui (2012) and Adjovi (2013)—discussed outcomes related to agricultural commercialization. Kirui (2012) defined commercialization in this case as the ratio of the value of sales to the value of total production and found that the ICT intervention resulted in a significant increase in commercialization. It is indicative of how well the farmer is able to sell and whether the farmer grows primarily for business or for subsistence. Commercialization could also be a potential pathway to higher income.

Although very few researchers discuss it, exports could also function as intermediary outcomes, as they often serve as a mechanism to increase income. Only Ashraf (2005) in examining the DRUMNET program in Kenya discussed the role of exports. DRUMNET included a program to help connect rural farmers to middlemen who could export their crops. Unfortunately, the study was unable to effectively address the question of ICT interventions on export sales, as the DRUMNET program ultimately failed because farmers did not receive the support they needed to meet the legal requirements to export crops. Many farmers struggled to obtain an export license, which DRUMNET did not help them acquire. An important takeaway of this paper is that while exporting could be a valuable mechanism for increasing income, international trade is complex and requires more planning and a more comprehensive intervention. Based on the literature, many rural farmers only sell their crops at the gate to local middlemen (World Food Programme 2015). Generally, only larger farms or farmer cooperatives export crops, while small-scale rural farmers are generally subsistence farmers or sell locally. Additional research on ways of increasing crop exports using ICT could be very informative for policy-makers.

Although few authors explicitly measure it, one of the frequently stated benefits of ICT programs is that they are relatively cheap to implement. A number of studies examined interventions in which

services were provided via ICT channels to one beneficiary group and via non-ICT channels to another treatment group. This allowed for a side by side comparison of the value of providing the service via ICT or in-person. Aker (2011) examined the benefits of a mobile cash transfer as compared with a cash transfer in the same amount given in person in Niger. She found that the transfers distributed via mobile phone were significantly cheaper for the implementing agency. Additionally, the recipients had much lower transaction costs, as they did not need to travel or spend time picking up the transfer. ICT thus reduced the costs of implementing the intervention for both the donor and the recipient. Aker also suggested that those receiving the transfer via phone instead of in person had better welfare outcomes, such as greater diversity in diet. Although there was no nutritional component to the intervention, it is possible that the farmers receiving mobile cash transfers had more time to spend on productive activities, which may have led to the better nutrition outcomes. Another possibility is that those receiving mobile transfers spend money differently than those receiving cash transfers. Additional research is needed to investigate this theory. The lower transaction costs for both recipients and implementing partners could be a mechanism for higher income down the line.

Another intermediate outcome is food security and disaster preparedness. One of the most common functions of ICT interventions is that they can be used for disaster preparedness. For example, individuals can use phones to communicate in emergency situations. Additionally, receiving weather information in advance of impending natural disasters provides farmers with valuable lead time during which they can take precautions to protect crops and capital assets. This in turn can improve income and prevent farmers from falling into poverty traps due to economic shocks. Although SI did not examine protection against these types of systematic shocks, the research team did come across a few papers that discussed the topic. Camacho (2011) suggests that one of the benefits of an intervention that provided weather information was that it reduced crop loss by allowing farmers time to prepare for inclement weather. After a natural disaster in Niger, Aker (2011) found that compared with a hard cash transfer, a mobile cash transfer provided farmers with better food security in terms of diversity of diet. Neither intervention contained any nutrition-focused components. Aker suggested that the farmers receiving mobile transfers may have achieved better outcomes because they spent less time collecting the cash transfer and could therefore spend more time on productive activities. Al Hassan (2013) similarly found that an intervention that provided farmers with training on how to use mobile phones to access market price information led to greater food security. Food security is an important result related with well-being. Additional research on whether ICT impacts food security could be highly informative.

5.8 GAPS IN THE LITERATURE

In conducting this systematic review, SI found a number of gaps in the existing body of research on the impacts of ICT interventions on income and price dispersion. Based on the systematic review, very few papers addressed crop loss, input use, and change in crop type. Additional literature gaps are discussed below.

5.8.1 Outcomes with Limited Studies

As mentioned in the above section as well as in the meta-analyses section, below, SI found that there were very limited numbers of studies on some of the key outcomes of interest for ICT interventions—such as crop-price dispersion, input use, crop loss, and changes in cropping patterns. Additional studies examining the effects of ICT interventions on these outcomes could prove very beneficial to policy makers. Further, studies on the effects of ICT interventions for yields are mixed; in about half of the cases, yield increased, and in the other half there was no effect. Additional research into possible moderators or situations in which ICT interventions result in increased yields and those where they don't would be incredibly useful.

5.8.2 Length of Study Periods

Most impact evaluations are done over short time frames that rarely exceed a few years. This is a problem in studying agriculture because crop cycles are slow, and it can take a long time to realize outcomes, especially outcomes related to income. Additional research on the long-term effects of ICT might reveal even greater impacts on beneficiaries, or in the minimum, would allow researchers to examine the sustainability of results from ICT interventions.

5.8.3 Increased Frequency of Information

One benefit of ICT interventions is that they allow extension workers, implementing partners, and others focused on farmer capacity building more frequent and often timely interaction with farmers due to the reduced transaction costs of providing the information remotely. For instance, extension workers who were once able to visit each of the farmers in their regions just twice per year could send information to farmers almost daily through mobile phones. The theory is that this allows the extension workers to alert farmers when it is time to plant, apply pesticides, harvest, etc. Frequent interactions also allow extension workers and implementing partners to ensure farmers retain the information on which they are trained. However, the increased frequency of capacity-building events through ICT is not an oft-studied area. More information about the benefits of multiple capacity-building interactions via ICT could prove useful to policy makers.

5.8.4 Sex-Disaggregated Data

One initial goal of the review was to track the percentage of beneficiaries in each study that were female so as to disaggregate findings by sex. This became difficult because very few of the researchers provided sex or gender information for beneficiaries in their descriptive statistics. While many of authors mentioned that regressions controlled for the sex of the respondent, few discussed sex-disaggregated findings or addressed deeper questions about the role of sex in the success of interventions.

While a handful of studies did present sex-related findings, the findings were mixed, further suggesting the need for future research into this topic. At baseline, several studies found that women did not participate in the market as actively as men, and they tended to have lower baseline outcomes. For example, Houghton (2009) found that women in Swaziland generally owned fewer

cattle than their male counterparts. Campenhout (2013) found that female-headed households sold less produce on the market in Uganda. In terms of the impact of interventions based on gender, findings varied. Chong (2005) found that the mobile phone intervention in Peru had similar impacts regardless of whether the household was headed by a man or a woman. But, Aker (2012) found that women gained greater benefits from mobile-phone access in Niger than men receiving the same intervention. On the other hand, Kiiza (2012) found that female-headed households that used ICT devices for information attained smaller gains than male-headed households that did the same. The discrepancies in findings may suggest that differential sex- and gender-based impacts are highly contextual, highlighting the need for more research on the topic to understand the heterogeneous impacts of ICT interventions. Additional research on this could help decision makers better assess potential differences between the sexes/genders and, thus, better target each appropriately.

5.8.5 Geographical Coverage

As discussed in the descriptive statistics, studies were clustered in a few specific countries. Countries that had more readily available data may be over-represented, while countries with less data may be under-represented. The research team found no studies on the Middle East or Central Asia, for instance. Experimental design studies were also seen to be conducted within a couple of countries, most notably, India and Kenya. To really understand what makes ICT interventions work, researchers need more studies worldwide on each of the outcomes.

5.8.6 Language of Publication

Lastly, despite searching for studies in four different languages, SI found that almost all impact evaluations on the effect of ICT interventions on agricultural outcomes were written in English. Increasing the number of impact evaluations published in other languages could make them more useful to local policymakers. The excessive publications in English may indicate that researchers are presenting to the academic community that generally use English more often than local policy-makers in the countries where evaluations are conducted.

6 FINDINGS: META-ANALYSES

6.1 PRICE DISPERSION SUMMARY STATISTICS

Three studies were available for inclusion in the meta-analysis on price dispersion. These studies are included in Table 5, below, along with their effect sizes expressed in standard deviations as Cohen's d values and confidence intervals:

Table 5. Price Dispersion Meta-Analysis Statistics

Study	Standardized Difference in Means (D Values)	Standard Error	Lower Limit	Upper Limit
Aker 2009	-0.276	0.032	-0.339	-0.213
Goyal 2010	-0.300	0.052	-0.403	-0.197
Jensen 2007	-5.595	0.162	-5.913	-5.277
Summary Statistic	**-2.041**	**0.771**	**-3.550**	**-0.531**

Interpretation of Cohen's d value can be a little bit ambiguous. Unlike t-statistics, which have a definitive interpretation related to standard deviation, Cohen's d values have no such direct interpretation. As a rough rule of thumb, Cohen suggested the following interpretation:

- 0.8 = large effect
- 0.5 = moderate effect
- 0.2 = small effect

For the purposes of the discussion in this report, SI researchers have used this interpretation. It should be noted however, that this approach might not be always appropriate since in certain fields, a Cohen's d value of 0.2 may in fact be considered very large for some types of interventions such as those related to primary education reading outcomes. For this reason, researchers additionally discuss the confidence interval of the Cohen's d values to determine whether they are significantly different from zero.

CMA generated the forest plot depicted in Figure 6, below,**Error! Reference source not found.** which shows changes to crop-price dispersion due to ICT interventions. The plots reflect effect sizes as the standardized mean differences, calculated using the methodology discussed in Appendix 5. These figures are shown in Table 5. The confidence intervals are based on an inverse weighting of the pooled standard deviation within each study. This means that the more precise outcome measurements were weighted more heavily than those that were less precise. As specified in the Campbell Collaboration method, all forest plots and meta-analyses were based on random effects models due to the high degree of heterogeneity.

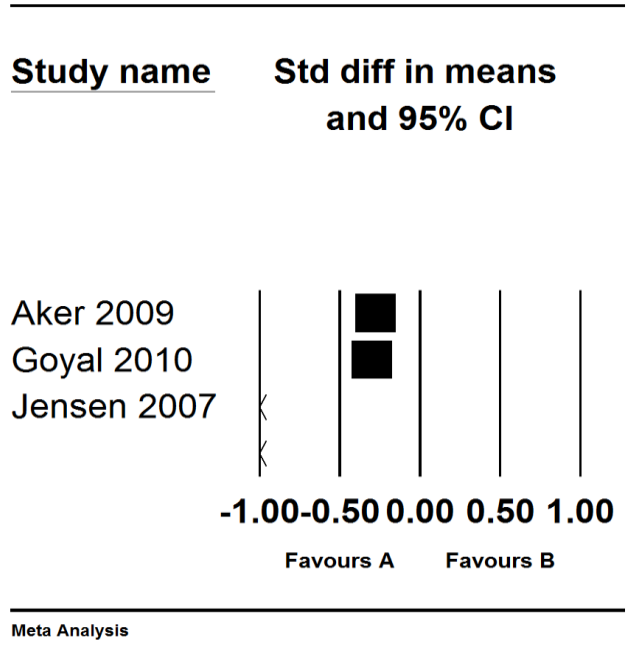
Overall, the ICT interventions appeared to lower price dispersion very significantly with an effect size of -2.041 and a small confidence interval band that does not encompass zero. All three of the

studies display negative effect sizes with confidence intervals that do not include zero. Results are strongest in Jensen's study which has an effect size of -5.595. Jensen suggests that this is due to the very high perishability of fish, which makes the good much more susceptible to price discrepancies than more durable goods like grain and soybeans, which are the topics of the other two studies.

The impact was less extreme in Aker's study of the grain market in Niger. The reason for this smaller effect may be because grain is storable. Farmers may have had some capacity to hold the grain while searching for better prices, transport grain to a different market, or wait for a better time to sell. While this may not always be the case because farmers may need to sell immediately in order to manage cash flows or due to poor storage and/or transportation infrastructure, grain farmers are unlikely to have the same level of time urgency as fishermen. Goyal's (2010) findings were similar in magnitude to Aker's. Interestingly, Goyal's study examined soybeans, which likely have similar qualities (such as storability to grains). The intervention provided farmers with internet kiosks to access regional soybean prices. This better equipped them to set prices for their crops.

Due to the very small number of studies with sufficient information to include in the price dispersion meta-analysis, the team has refrained from analyzing the moderators for price dispersion.

Figure 6. Price Dispersion Forest Plot



6.2 INCOME SUMMARY STATISTICS

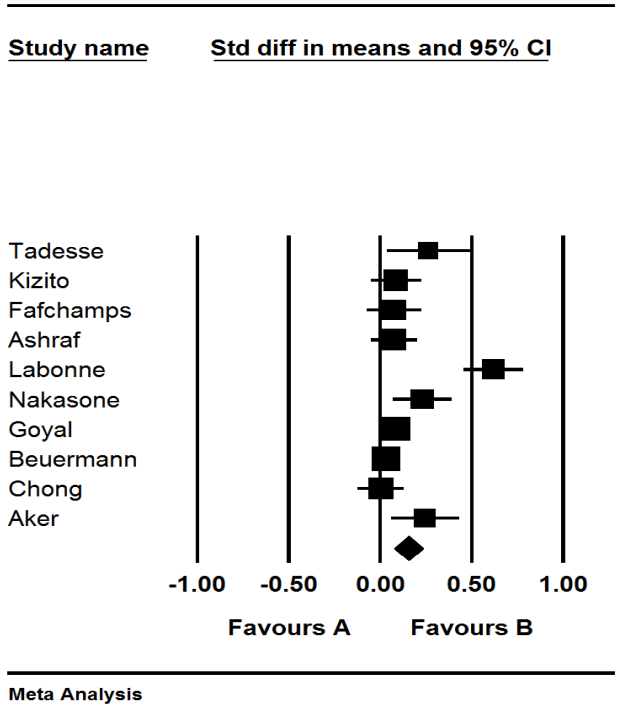
SI found ten studies that met the criteria for meta-analysis of income-related ICT-intervention outcomes. These studies are listed in Table 6 along with their effect size and confidence intervals:

Table 6. Income Meta-Analysis Statistics

Study	Standardized Difference in Means (D Values)	Standard Error	Lower Limit	Upper Limit
Tadesse 2014	0.263	0.115	0.038	0.488
Kizito 2012	0.089	0.069	-0.049	0.223
Fafchamps 2012	0.076	0.075	-0.071	0.222
Ashraf 2005	0.074	0.064	-0.051	0.199
Labonne 2009	0.619	0.082	0.458	0.780
Nakasone 2013	0.230	0.082	0.069	0.390
Goyal 2010	0.088	0.022	0.045	0.131
Beuermann 2011	0.033	0.019	-0.003	0.070
Chong 2005	0.003	0.063	-0.121	0.127
Aker 2012	0.245	0.094	0.061	0.428
Summary Statistic	**0.153**	**0.041**	**0.073**	**0.223**

The research team used CMA to generate the forest plot depicted in Figure 7**Error! Reference source not found.**, which shows changes in farmer agricultural incomes due to ICT interventions. The overall summary statistic for effect size was 0.153, which may be seen as insignificant or, by other interpretations, could be considered a small positive change in incomes due to the intervention. The confidence interval for the summary statistic ranged from 0.073 to 0.223. Because this interval does not encompass zero, SI researchers conclude that, on average, ICT programs have a very small but positive impact on farmer income. Part of the reason for this small effect size could be the limited time period over which most of these studies are conducted. True changes in income often take more than a few years. However, to know whether the short time frames are resulting in underestimated results, further research is needed.

Figure 7. Income Forest Plots

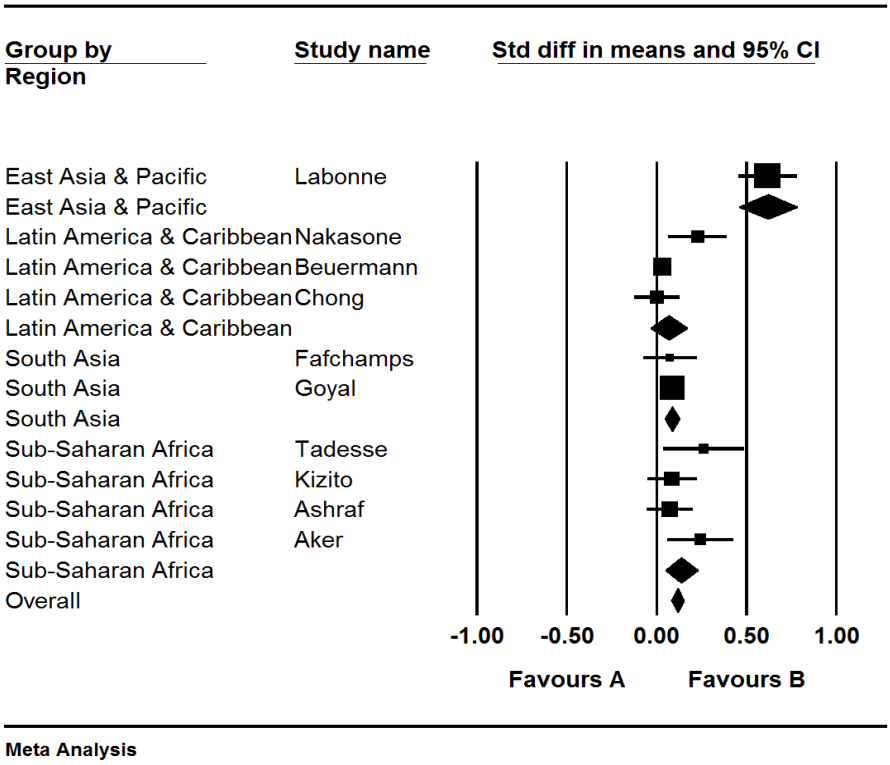


6.3 HETEROGENEOUS IMPACTS ON INCOME BASED ON MODERATORS

Because the contexts of the different studies vary widely, SI researchers expected heterogeneous impacts. As such, the team applied moderators to the meta-analysis to see how they affect the impact of ICT interventions on incomes.

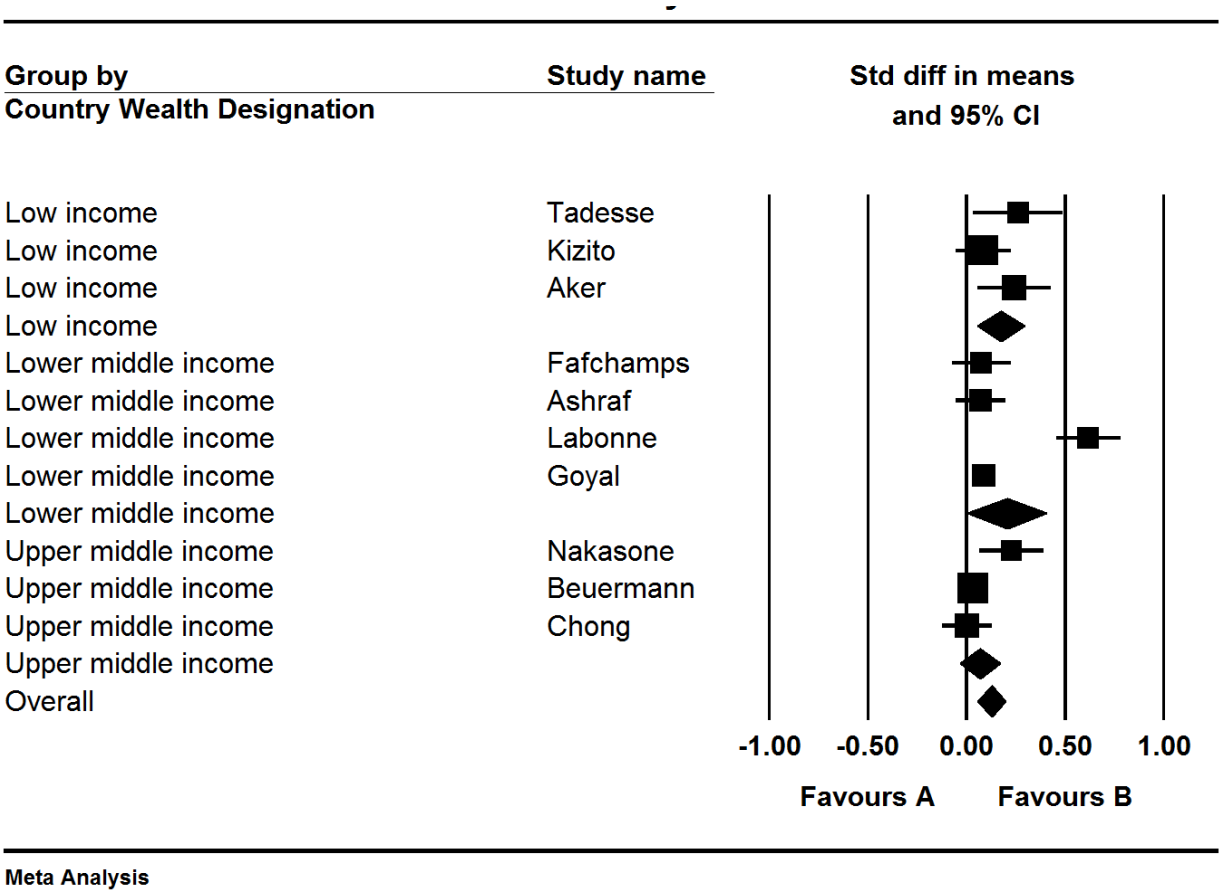
Based on **Error! Reference source not found.**Figure 8, below, ICT interventions appear to have had the largest impacts in Sub-Saharan Africa (d value of 0.139) and South Asia (Cohen's d value of 0.088) (the diamonds represent the overall results for each region). Although the impact looks large for East Asia and the Pacific as well, this observation carries less weight since there was only one study from that region. Interestingly, all three regions had positive effect sizes and confidence intervals that did not encompass zero. The same is true of the overall summary statistic, indicating that ICT programs likely cause positive impacts on farmers' income in all four regions.

Figure 8. Income Meta-Analysis by Region



As shown in Figure 9, below, all three country economic levels included in the study were associated with positive effect sizes. The Cohen's d value for upper-middle-income countries, however, is the lowest and has a confidence interval that includes zero. This indicates that it is harder to infer an impact for upper-middle-income countries. Low-income and lower-middle-income countries experienced positive returns from ICT interventions. Interestingly, the impact is highest in lower-middle-income countries, with a Cohen's d value of 0.206, representing a moderate increase. Impacts are also large in low-income countries at 0.175 and lowest in upper-middle-income countries (Cohen's d value of 0.069). Additional research is needed to determine the causes for this differential impact. One possibility is that low-income and lower-middle-income countries have a greater information gap to begin with, such that ICT interventions are more powerful in these regions.

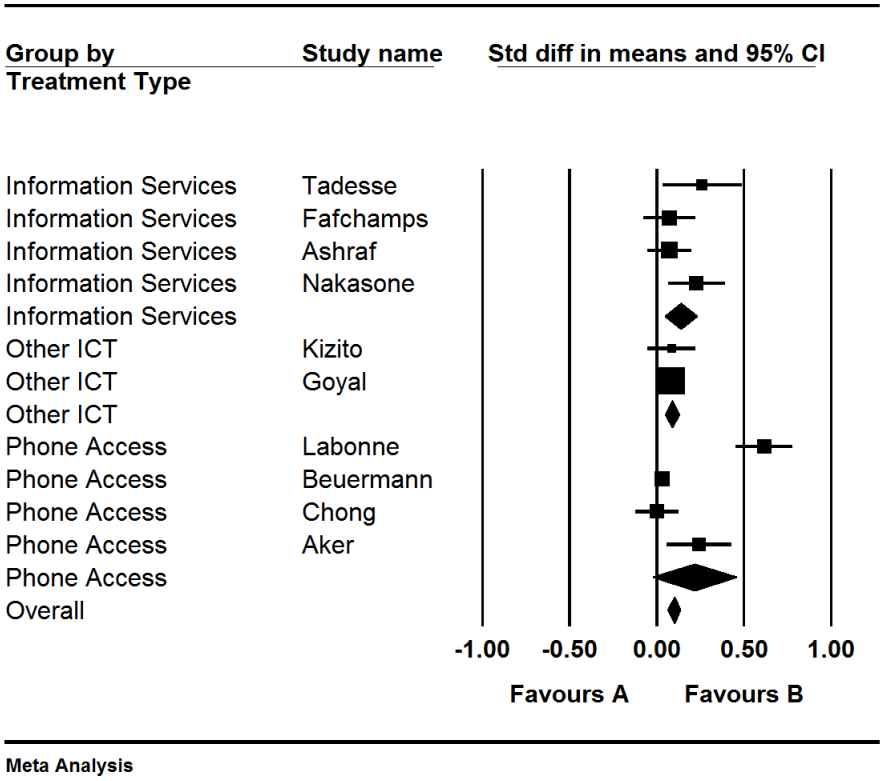
Figure 9. Income Meta-Analysis by Economic Status



As shown in Figure 10, below, interventions that provided information services to farmers appear to have had the largest consistent impact of all ICT interventions, with a Cohen's d value of .139. Phone access, either via mobile phones or landlines, had a larger Cohen's d value of .217, but the results were inconsistent. The error bar of this result was very large and encompassed zero. Other ICT devices, such as internet kiosks, had the smallest Cohen's d value of .088.

SI also tested the impact of several other continuous variable moderators on income. These included the percentage of the country's government budget spent on agriculture, the country's state of fragility, and the level of international funding in the country, as defined in the methodology. However, the research team found that none of these moderators significantly influenced the effect of ICT interventions on income. To verify these results, the team regressed income using each of these variables individually and collectively, and none of the models demonstrated any significant impact of these moderators.

Figure 10. Income Meta-Analysis by Treatment Type

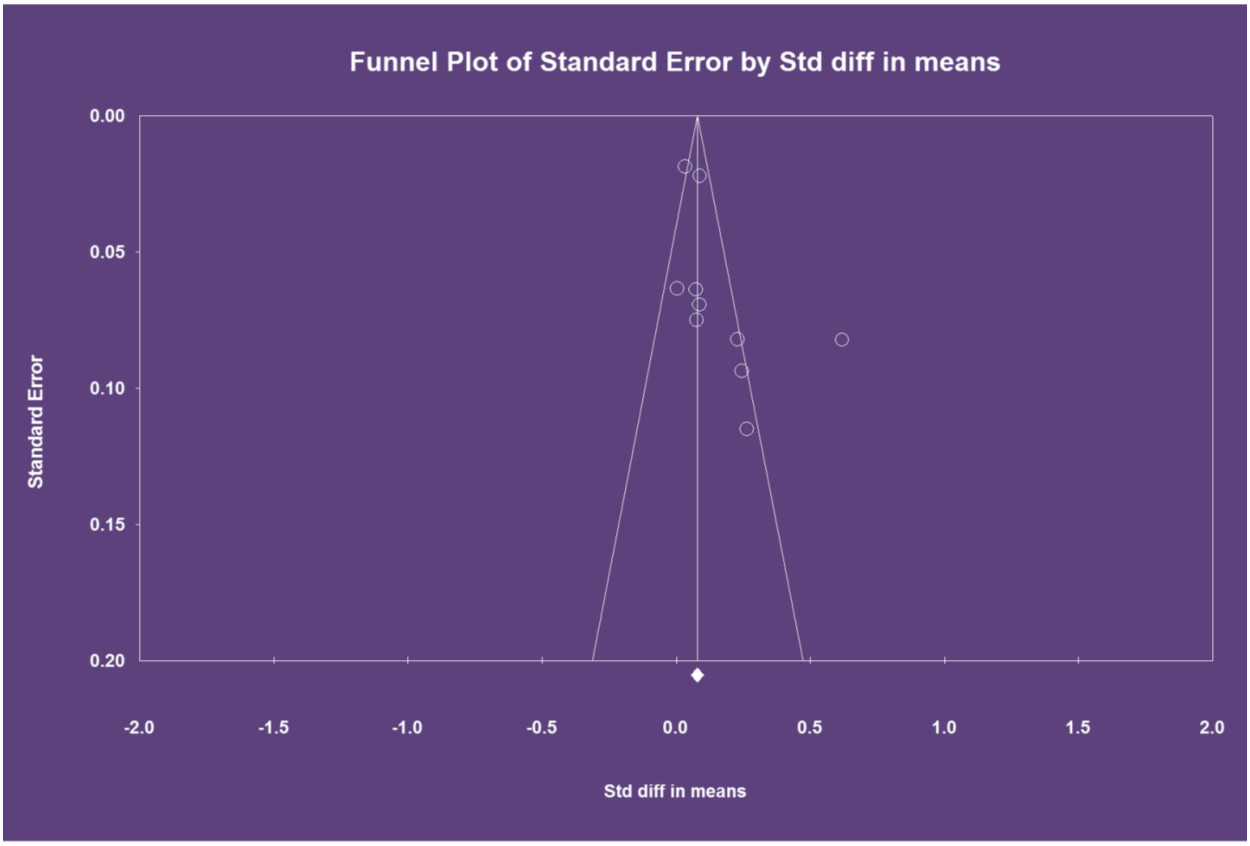


6.4 PUBLICATION BIAS

In order to identify possible publication bias, Figure 11, below, displays a funnel plot of the results from the studies included in meta-analysis on income (publication bias could not be assessed for price dispersion because of the limited number of studies available for this outcome). Based on the image, there seems to be an asymmetry in which there are few published studies with low standard errors and results that are lower than the summary statistic, suggesting that there may be systematic bias in the results SI presents in this paper. It appears that this systematic review may be missing studies with a small sample size and less significant results.[8] As such, it is possible that SI researchers have overestimated the effects of ICT interventions on farmer income.

[8] Publication bias arises when deviation occurs between what research is published among what is available to be published. While bias towards rigor and some specific outcomes are desirable, preference for results showing a significant finding leads to bias in the published literature. Statistically significant results have been shown to be three times more likely to be published compared to papers with insignificant results, although not all statistically significant studies are of high relevance for policy makers.

Figure 11. Funnel Plot of Studies on Income



This hypothesis is further strengthened by the information provided in Table 7, below, which shows that the studies with the smallest sample sizes also have the greatest effect sizes, suggesting a publication bias against publishing small studies with low or insignificant effect sizes.

In order to investigate whether publication bias threatens the integrity of the findings, we applied Duvall and Tweedie's Trim and Fill to impute the lack of studies with small sample size and small effect size. Using the assumption of random effects, the Trim and Fill function suggested that there were no missing papers, and the findings were not brought into question due to publication bias. This means that much of the variability in study findings may be attributed to actual differences in the effect size in different populations. While publication bias is still possible, the imputations suggest that it is not so large as to significantly bias the findings of this study.

Table 7. Sample and Effect Sizes for Studies with Impact Outcomes

Study	Sample Size	Effect Size (Cohen's d)	Standard Error	Lower Limit	Upper Limit
Aker 2012	460	0.245	0.094	0.061	0.428
Tadesse 2014	545	0.263	0.115	0.038	0.488
Nakasone 2013	600	0.230	0.082	0.069	0.390
Labonne 2009	621	0.619	0.082	0.458	0.780
Kizito 2012	654	0.089	0.069	-0.049	0.223
Fafchamps 2012	713	0.076	0.075	-0.071	0.222
Chong 2005	986	0.003	0.063	-0.121	0.127
Ashraf 2005	1,566	0.074	0.064	-0.051	0.199
Goyal 2010	8,276	0.088	0.022	0.045	0.131
Beuermann 2011	11,495	0.033	0.019	-0.003	0.070
Summary Statistic	**-**	**0.153**	**0.041**	**0.073**	**0.223**

7 CONCLUSIONS

Overall, the studies examined in this review show that ICT interventions do indeed have the potential to improve farmers' livelihoods, including by improving intermediate outcomes such as yields and adoption of modern farming practices and by directly affecting the larger impacts, such as helping to increase farmer income and decrease crop price dispersion.

ICT interventions consistently appear to decrease crop price dispersion. While the overall impact was moderate, it was particularly large for perishable goods. It is likely that impacts could increase over time as farmers become more and more familiar with their local markets.

Further, ICT interventions appear to have small-to-moderate impacts on farmer incomes, and these impacts hold regardless of region, country economic status, and state fragility. With respect to these moderators, however, impacts appeared larger in the regions of South Asia and Sub-Saharan Africa and in low-income and lower-middle-income countries than in upper-middle-income countries. In terms of types of interventions, those interventions that provided phone access appeared to have the largest impact, although with high variability in results. By contrast, interventions that provided market information services had consistently positive impacts. The impacts of other ICT devices such as radio and internet kiosks were relatively smaller.

Both income and price dispersion impacts tended to be largest when there was an existing information gap that was addressed by the intervention and when farmers had the capacity to sell in different markets. Farmers can only benefit from price information if they also have the ability to sell in different markets. Information helped improve the farmers' ability to sell to the highest bidders or alternatively to better negotiate with local buyers. For this reason, ICT services that provided comprehensive information on both transportation as well as market prices had greater impacts than those that did not.

In addition to the direct impacts discussed here, other benefits of ICT interventions include potential cost savings for both the donor and the recipient, ease of distributing information to farmers more frequently, and improved food security and disaster preparedness amongst farmers. Additional research is needed to shed light on the full benefits of these additional outcomes.

8 POLICY IMPLICATIONS

ICT interventions work to expand agricultural markets, but, ICT is not a one size fits all solution. The review findings and conclusions suggest that interventions focused on increasing access to mobile phones or making information available via mobile phones or other ICT mechanisms could be effective in achieving intended outcomes to expand agricultural markets. However, this conclusion comes with one large caveat: the magnitude of effects varies by the context, including geographical location, gender, and wealth status, among others, and ICT may not work universally. All of the studies included in in this systematic review highlighted the fact that the impacts of ICT interventions are highly contextual and that in order to be successful, interventions should be customized to suit the particular needs of the farmers, as well as the larger, economic, political, legal, and social environment in which they operate. While this review shed some light on the potential contexts in which ICT interventions might seek to improve farmer livelihoods, there is more work to be done to understand where ICT interventions work best. For instance, the review found that in some contexts, the enabling environment needs to be improved for ICT to work effectively. However, there are other contextual factors that need to be studied further, including farmer wealth, access to storage facilities, etc. In other words, this study should not be taken to say that ICT interventions will work everywhere. Lessons from the review that are of policy relevance are discussed below:

8.1 POLICY MAKERS SHOULD FOCUS ICT INTERVENTIONS WHERE INFORMATION GAPS EXIST AND PROVIDE COMPREHENSIVE ACCESS TO INFORMATION AND MARKETS

ICT programs that provide information are highly effective only where information is asymmetric, incomplete, or lacking, and only if farmers can act on it. While additional research is needed, studies included in this review suggest that ICT interventions had the greatest impact in lower-middle-income countries, followed closely by low-income countries, while results were insignificant and very low in upper-middle-income countries that have a relatively smaller information gap. Also, the intervention that Fafchamps studied in India that provided information on both prices and transportation costs was very useful because it increased farmers' capacity to explore markets as their capacity to reach and sell to the highest buyer and/or negotiate with local middlemen. Information services that take on this comprehensive approach are very useful.

ICT devices, alone, have the potential to be very useful, but the results are less predictable. This is likely because while devices like phones may increase availability of information on prices, farmers can only take advantage of this information if they have the capacity to travel and sell in other markets. Indeed, this capacity to travel depends on several factors such as the specific context, the economic conditions of the farmer, and the existing transportation infrastructure in the country. Combining price information with improved infrastructure, information about transportation, and

access to economical transportation is more likely to impact farmer livelihoods in countries or areas where this infrastructure is less developed or does not already exist.

8.2 POLICY MAKERS SHOULD IMPROVE LICENSING AND LEGAL PROCEDURES TO ENCOURAGE EXPORTS

Lack of adequate and timely information, delays, and complicated procedures in a country to obtain licenses to export could affect exports even if ICT can help produce exportable crops and secure lucrative export markets, as evidenced in a study by Ashraf (2005) of Kenya's DRUMNET service, which provided farmers with connections to export produce. Since exporting requires a lot more preparation and coordination than selling locally, this program was very complicated. Farmers were encouraged, through the ICT intervention, to change their crop selection in order to meet international demands over domestic demands. Farmers were concerned that the exporting middlemen would later refuse to buy the produce, leaving the farmers without an option to then sell their crops locally. The administrators of the intervention allayed these concerns and encouraged farmers to participate. Ultimately in order to export, the farmers needed to obtain a special license. The farmers were ill-informed about export licensing and did not have the money or means to obtain licenses on time. Thus, many farmers were unable to sell or export their crops and ultimately, Ashraf found no significant income effects attributable to the project. This may account for the lack of statistically significant findings in this paper. Any intervention in which exporting crops is a viable option should carefully examine any political and legal requirements as these are crucial to the success of the intervention.

8.3 POLICY MAKERS SHOULD CUSTOMIZE INTERVENTIONS FOR SPECIFIC BENEFICIARIES

One of the unfortunate long-term effects of the DRUMNET intervention is that it ultimately built distrust among farmers of international aid because the intervention did not address the specific context and needs (Ashraf 2005). This is particularly detrimental because it may prevent farmers from taking advantage of programs in the future that could truly be beneficial. The DRUMNET intervention is not the only intervention that has failed due to a gap or faulty assumption in the program theory of change. For this reason, it is essential that any ICT interventions are tailored to the specific needs of the population in question and that they carefully examine the entire value chain—including by involving local government officials and experts and beneficiaries in the process of determining each of the steps necessary in the theory of change. This will help ensure programs avoid oversights that act to diminish program effects and also cause more harm than good for farmers.

8.4 POLICY MAKERS SHOULD WORK TO IMPROVE ELECTRONIC LITERACY

In order to benefit from most ICT interventions, the population needs to have some minimum level of education and/or electronic literacy. Many of the successful interventions involved sending information via SMS. This requires that participants have basic literacy. Other programs such as the internet kiosks (Goyal, 2010) require that participants have a basic knowledge of how to operate a

computer. Interventions should take the population's literacy level into consideration, and provide ICT functional education or training to fill in any gaps in the necessary knowledge.

APPENDIX 1: SEARCH WEBSITES

WEBSITES:

Google, Google Scholar, CGIAR, World Bank IEG, World Bank Agricultural/Economic Office, World Bank Rural Development Research, USAID DEC, FFPr, FFP, UNDP, DfID, FAO, University of Nebraska-Lincoln, Kansas State University, Florida State University, Michigan State University, University of Northern Colorado, AGRIS, CARIS, IFAD, WFP, WTO, FEWSNET, FAS, UNCTAD, SourceOECD, CIP, IFPRI, SAARC, AIARD, Tuskegee University, Arkansas Tech University, Florida State University, Cornell University, University of Minnesota Twin Cities, University of California-Davis, University of Massachusetts-Amherst, Tufts University, University of Wisconsin-Madison, University of Florida, Rutgers State University, Texas A&M, Penn State, MCC, 3ie, JPAL, and IPA.

PEER REVIEWED JOURNALS:

i. Information Technologies and International Development
ii. Electronic Journal of Information Systems in Developing Countries
iii. Information Technology for Development
iv. African Journal of Information and Communication
v. International Journal of Education and Development Using Information and Communication Technology
vi. Asian Journal of Communication
vii. International Journal on Advances in ICT for Emerging Regions
viii. African Journal of Information & Communication Technology
ix. International Journal of Information Communication Technologies and Human Development
x. World Development
xi. Journal of International Development

APPENDIX 2: SEARCH TERMS

Keywords used for the searches will follow PICOS format (Population, Intervention, Comparison, Outcomes, Study design). Combinations (or permutations) of the keywords will then be used to identify relevant studies. Further, searches will be conducted through the reference lists and bibliographies of relevant studies.

POPULATION SEARCH TERMS:

South and South East Asia
Eastern Europe
Middle East
Latin America
Africa
NIS countries (developed countries will not be searched)
Rural population and farm households
Farmers
Agribusinesses

STUDY DESIGN SEARCH TERMS:

Impact Evaluation
Propensity Score Matching
Randomized Controlled Trial
Instrumental Variables
Difference in Differences
Evaluations

INTERVENTION SEARCH TERMS:

Mobile Phone
Agriculture
ICT
Market Information Systems
MIS

COMPARISON SEARCH TERMS:

Control
Group
Comparison Group
Treatment Group
Comparator
Counterfactual

OUTCOMES SEARCH TERMS:

Income
Profits
Markets
Sales
Prices
Adoption

APPENDIX 3: SEARCH DETAILS BY SITE

No.	Website/Data base	# of combinations searched	Notes
1	JPAL	1	As there were limited numbers of studies on J-PAL, we used filters to find the relevant studies. Used J-PALs database (http://www.povertyactionlab.org/evaluations) to search for relevant studies. Following two filters were selected to find relevant studies: 1)"Agricultural Technology Adoption Initiative" under Research Initiatives. 2) "Completed" under status filter. There were 7 completed studies, while 28 were on-going.
2	IFAD	88	No filters were used while searching. Results on first page only are documented.
3	UNCTAD	12	No filters were used while searching. Results on first page only are documented. Not even a single result was relevant. Results were technical reports, conference notes, press releases, etc.
4	Journal of International development	146	No filters were used and results only on the first page were documented.

No.	Website/Data base	# of combinations searched	Notes
5	FAS	12	No filters were used while searching. Results on first page are only documented. Not even a single result was relevant. Results were alerts, updates or quarterly reports.
6	FEWSNET	12	No filters were used while searching. Results on first page are only documented. Not even a single result was relevant. Results were alerts, updates or quarterly reports (about food security).
7	Google Scholar	159	Following filters were used in google scholar while searching the articles: 1) articles were selected instead of "case law" and "my library"; 2) date range was selected from 2002 - until date; and 3) sort by relevance. Only first 20 results for each query were analyzed.
8	World Bank	44	Filters were used to select only “agriculture” related studies. Results on first 4 pages were documented/analyzed.
9	3ie	128	No filters were used, Results on first 5 pages were documented/analyzed.
10	IFPRI	131	No filters were used, Results on first 5 pages were documented/analyzed.
11	Journals FFPR	37	Following filters were used “agriculture” and “evaluation.”

APPENDIX 4: CALCULATING COHEN'S D

In statistics, Cohen's d is calculated as follows:

$$d = \frac{\bar{X}_T - \bar{X}_C}{s_{pooled}}$$

Where:

d represents Cohen's d

$\overline{X}$ represents the mean for the indexed group

T represents the treatment (beneficiary) group

C represents the comparison group

The numerator in the above equation represents the average difference between the beneficiary and comparison groups attributed to treatment.

Since almost all of the studies included in the meta-analysis used regressions with various controls to analyze data and display results, the research team used the regression coefficients for the numerator. In cases where there were multiple regression models, the team selected the author's primary model (where specified). If the primary model was not specified, as a general practice, researchers used the model with the maximum number of controls in order to minimize bias.

The denominator in the above equation is generally calculated using the following equation:

$$s_{pooled} = \frac{s_T^2(n_T - 1) + s_C^2(n_C - 1)}{n_T + n_c - 2}$$

Where:

n represents the number of observations in the specified group

s represents the standard deviation of the outcome variable for the indexed group.

However, individual standard deviations were not available for the beneficiary and comparison groups in some papers. In such cases, researchers used the overall standard deviation as a close proxy.

APPENDIX 5: THEORY OF CHANGE ON PRICE DISPERSION

Economic theory states that if markets are competitive and efficient, the prices and quantities of goods sold will be at equilibrium in supply of and demand of goods that is economically optimal for the market At this equilibrium, under the assumptions of multiple sellers and buyers that can buy or sell from anyone across markets of homogenous goods and have perfect information on demand and supply, a similar price may exist for a homogenous good across the markets. But, if information is not perfect, market inefficiencies occur, leading to wide price dispersions across markets as seen in many developing countries. High price dispersion could create arbitrage opportunity. By providing farmers with information about prices ICT interventions can overcome information barriers, enabling farmers to better market their produce and attain better prices. Importantly, interventions targeting price dispersion assume that there is in fact a solvable information barrier that creates a market failure. If the market is already efficient, or if the barriers are not related to information and/or communication, ICT interventions cannot be expected to affect price dispersion.

APPENDIX 6: STUDY DESIGN FINDINGS

Experimental Design Studies

Most of the experimental studies included in the narrative and meta-analysis portions of this systematic review consisted of evaluations of the impacts of market-information-service interventions, usually via mobile phone and/or SMS. A few examined mobile phone access by randomly assigning phones to some participants. The ICT interventions provided information ranging from market prices to weather updates to better agricultural practices or input recommendations.

Many of the studies said that the services provided through ICT-based interventions were similar to non-ICT-based interventions previously offered by donors or local governments. As such, in a few cases, the studies provided a side-by-side comparison of the impacts of information services provided through ICT channels and similar interventions provided through non-ICT channels, also comparing both against a control group. All three groups were randomly assigned. For example, a study of potato farmers in West Bengal, Mitra (2013) examined two treatment interventions that provided price information. In the first treatment group, the price information was written and posted on a board centrally-located in the village, and in the second, the information was sent via SMS. Both of these treatments were administered by the researchers with the support of the International Food Policy Research Institute (IFPRI), The International Growth Center (IGC) and the London School of Economics (LSE). Aker's 2011 study examined the impacts of mobile cash transfers as compared to hard cash transfers, both assigned randomly to villagers in Niger during a food crisis as part of a pilot program implemented by a nonprofit called Concern Worldwide. Cole (2012) compared traditional agricultural extension services to a hotline providing similar services via phone. Working with a nonprofit called Development Support Center, Cole randomly assigned two treatment groups, one that received text message information along with traditional agricultural extension services and one that received only the text message service. These studies examined not only the overall impact of providing information, but also the added impact of providing this information via ICT as opposed to through traditional methods such as in-person agricultural extension services and word of mouth. A couple of studies (Mitra, 2013; Aker, 2011) also examined the cost effectiveness of the ICT versus non-ICT interventions.

Quasi-Experimental Design Studies

Among the 20 quasi-experimental design studies, the most common interventions focused on access to or ownership of mobile phones. Because access to phones and outcomes related to such ownership are both endogenous, authors used quasi-experimental methods to isolate the impact of ICT. Most often, authors used the timing of phone coverage as the exogenous event to isolate impacts since coverage is typically phased into a country one region at a time. For example, in studying Kerala's fish markets in India, Jensen (2007) examined three different regions to identify price changes at the time when each region first received mobile coverage, using the regions that did not yet have covereage as the comparison at that time. Muto (2008) similarly used a phased approach for mobile phone coverage in Uganda, while Beuermann (2011) does the same for government-issued public phones in Peru. In a slight variation on this approach, Aker (2010) looked at market pairs in Niger, comparing price dispersion between two markets in which both

local communities had cell-phone coverage (and were potentially able to communicate with each other) and pairs in which at least one market was in a community without cell-phone coverage. All of these studies used the exogeneity of the timing of the intervention to identify ICT impacts, usually using difference-in-differences analysis.

Despite the success of these studies, identifying ICT impacts becomes more complex when mobile-phone ownership is involved (assuming the phones were not given to participants as part of the intervention). Since phone owners self-select by choosing to own a phone (as opposed to coverage areas, which are designated by some third party), the intervention becomes very much endogenous and complicates examination of the impacts of ICT. For example, authors including Ogutu (2014), Kiiza, Kirui (2012), and Al-Hassan (2013) used propensity-score matching (PSM) to overcome this endogeneity issue but fell short in capturing many unobservable characteristics that affect decisions to purchase a phone through proxy indicators, but other authors such as Tadesse (2014), Kizito (2012), Labonne (2009), Houghton (2009), and Chong (2005), used instrumental variables to discern impacts of ICT through owning or using a phone. For example, Houghton (2009) creates an instrumental variable representing an individual's likeliness of owning a mobile phone based on unobservable characteristics. This serves as a better measure than mobile-phone ownership, because phone owners are self-selected and therefore highly endogenous.

In addition to examining cell-phone coverage and mobile-phone ownership, a few of the systematic review papers examined ICT programs not related to mobile phones. A couple of examples included Goyal's (2010) paper on internet kiosks that provided price information and Kiiza's (2012) study, which included various technologies, especially radio.

Similar to studies using experimental designs studies, a few quasi-experimental design studies also examined interventions related to providing market information. For example, Campenhout (2013) used a difference-in-differences design to assess the impacts of a project implemented by Grameen Foundation that provided farmers with local information about crop prices and transportation. The systematic review also includes a couple of studies that examined the impacts of mobile-money-transfer applications. These include Aker's study in Niger (2011) and Kirui's study in Kenya (2012).

Gaps in the Literature: Clustering of Studies by Country and Study Design

There was a noticeable trend of studies clustering in a few specific countries, which may be indicative of gaps in the literature. Countries with less readily available data may be systematically excluded from study, for instance. To further investigate this possibility, Table 8 breaks down the studies by both study design and country. As shown in the table, studies using difference-in-differences or experimental designs appeared to cluster in a few countries. The studies that used an instrumental variables design varied widely in terms of both country and region. Of the nine studies that used a difference-in-differences approach, three were based in India, each with a different author. This may reflect greater availability of data in this country, greater use of ICT interventions or access to ICT in this country, or simply may be a coincidence. It is particularly interesting that the experimental designs are clustered in a few countries, given that experimental designs generally cannot be done with pre-existing data. Of the nine experimental designs, two took place in Kenya and three in India. This suggests that there may be a research gap in the locations of experimental design studies as well. In terms of outcomes, the experimental designs collectively examined all six of the listed outcomes, with little clustering around any particular one.

Table 8. Studies by Study Design and Country

Because one of the studies included separate impact evaluations in three different countries, the total number of studies in this table appears higher than the actual number of studies (33 vs. 31).

Country by Study Design	Number of Studies Included in the Systematic Review	Percent of Studies
Instrumental Variables	**9**	**100%**
Cambodia	1	11%
Ethiopia	1	11%
Honduras	1	11%
Mozambique	1	11%
Peru	1	11%
Philippines	1	11%
Swaziland	1	11%
Uganda	1	11%
Benin	1	11%
Difference-in-Differences	**8**	**100%**
Peru	2	25%
Uganda	1	13%
India	3	38%
Niger	2	25%
Propensity Score Matching	**5**	**100%**
Ghana	1	20%
Kenya	2	40%
Peru	1	20%
Uganda	1	20%
Experimental Designs	**9**	**100%**
Colombia	1	11%
India	3	33%
Kenya	2	22%
Peru	1	11%
Niger	2	22%
Cross-Sectional/Panel	**2**	**100%**
Pakistan	1	50%
Benin	1	50%
Total	**34**	**100%**

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