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Determinants of Economic Impact of Agricultural Extension:a Review of Farmer Adoption Behavior and Market Linkages

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ABSTRACT

Agricultural extension programs are widely deployed as instruments of rural development, yet their economic impacts vary substantially across contexts, commodities, and farm household characteristics. This paper reviews 82 empirical studies published between 1990 and 2024 to identify the key determinants of extension program effectiveness, with a dual focus on farmer adoption behavior and market linkage quality. We develop an integrated analytical framework that distinguishes between supply-side determinants — program design, delivery modality, agent quality, and targeting strategy — and demand-side determinants — farm household attributes, risk preferences, social networks, and market access conditions — and examine how these dimensions jointly shape the translation of extension contact into measurable economic gains. The evidence reveals that farmer adoption behavior is governed primarily by expected profitability, risk perceptions, capital constraints, and peer effects, while the conversion of adoption-driven productivity gains into income improvements depends critically on output market integration, value chain structure, and price information access. Programs that address adoption barriers and market linkage simultaneously generate income effects two to three times larger than those addressing either constraint in isolation. We document significant heterogeneity in extension effectiveness across wealth strata, gender, agroecological zones, and crop types, and identify the methodological advances — combining experimental variation with structural modeling — needed to disentangle these determinants empirically. The review concludes with evidence-based guidance for designing extension programs that maximize economic impact across diverse smallholder contexts.

INTRODUCTION

Agricultural extension programs operate on a deceptively simple theory of change: inform farmers about superior technologies and practices, and they will adopt them; adoption will raise productivity; productivity gains will translate into income improvements that reduce poverty and enhance food security. Decades of experience and a growing empirical literature have revealed this theory to be incomplete in important ways. Farmers do not always adopt technologies they know about. Those who adopt do not always sustain the practice across seasons. Those who sustain adoption do not always realize income gains commensurate with productivity improvements. And income gains, when they materialize, are not uniformly distributed across farm households. Understanding why these disconnects occur — and under what conditions the full theoretical chain from information to income operates as intended — is the central problem this review addresses.

The heterogeneity of extension impacts across programs, contexts, and beneficiary populations has been recognized since early meta-analyses in the 1990s, but the discipline's response has largely been to document this heterogeneity rather than to explain it systematically. Studies report mean treatment effects and note that impacts vary by gender, wealth, education, and agroecological zone, but rarely develop the theoretical architecture needed to predict which contextual configurations will support high-impact extension and which will not. Without such an architecture, evidence accumulation cannot cumulate into policy-relevant generalizations, and the extensive body of extension evaluation research remains fragmented across regional and commodity literatures.

This paper develops an integrated framework for understanding extension impact heterogeneity organized around two dimensions: farmer adoption behavior and market linkage quality. We conceptualize extension effectiveness as a joint function of the degree to which information delivery triggers behavioral change on the farm (the adoption dimension) and the degree to which farm-level behavioral changes translate into market-mediated income improvements (the market linkage dimension). This two-dimensional structure accommodates the full range of observed impact patterns, from programs that generate knowledge without adoption to programs that generate adoption without income gains, and provides a basis for designing interventions that address the binding constraints for specific beneficiary populations.

We draw on 82 empirical studies across sub-Saharan Africa, South Asia, Southeast Asia, and Latin America, with systematic attention to study design quality, outcome measurement, and the contextual moderators that explain variation in estimated effects. The review makes four contributions. First, it provides a theoretically grounded taxonomy of extension impact determinants organized around the adoption-market linkage framework. Second, it synthesizes quantitative evidence on the magnitude of each determinant's contribution to impact heterogeneity. Third, it evaluates the evidence on how adoption and market linkage barriers interact — including whether addressing both simultaneously is more than the sum of addressing each separately. Fourth, it develops methodological and policy recommendations grounded in the integrated framework.

The paper proceeds as follows. Section 2 presents the analytical framework. Section 3 describes review methodology. Sections 4 and 5 examine supply-side and demand-side determinants of adoption behavior. Sections 6 and 7 examine output market and value chain determinants of income realization. Section 8 analyzes interaction effects between adoption and market linkage. Section 9 examines heterogeneity across farm household characteristics. Section 10 addresses methodological advances needed to study determinants rigorously. Section 11 develops policy implications, and Section 12 concludes.

AN ANALYTICAL FRAMEWORK FOR EXTENSION IMPACT DETERMINANTS

The Two-Dimensional Impact Space

The economic impact of an extension program can be characterized in a two-dimensional space defined by the strength of the adoption response and the quality of market linkages available to adopting farmers. The adoption dimension captures the degree to which extension-induced knowledge change produces durable modification of farming practice. The market linkage dimension captures the degree to which practice change, by improving farm productivity or product quality, can be converted into higher net income through output markets. In a fully functioning system — where extension reliably generates adoption and markets efficiently reward productivity improvements — the two dimensions reinforce each other to produce large, sustainable income effects. In practice, each dimension presents distinct constraints that the other dimension cannot compensate for.

Four archetype positions in this two-dimensional space define canonical patterns of extension program performance. High adoption, high market linkage: extension generates strong adoption responses and adopting farmers access markets that reward their productivity gains with price premiums or volume opportunities; income effects are large and sustained. High adoption, low market linkage: extension successfully stimulates adoption but farm output cannot be effectively marketed due to transaction costs, post-harvest losses, or price volatility; productivity gains do not translate proportionally into income improvements. Low adoption, high market linkage: favorable market conditions exist for productive farmers, but extension fails to generate sufficient adoption to capitalize on these opportunities; income effects are limited by the behavioral response. Low adoption, low market linkage: both adoption and market access are constrained; extension generates minimal economic impact regardless of program quality. Extension evaluation that estimates aggregate mean effects without diagnosing the program's position in this space provides limited actionable guidance for program improvement.

Supply-Side Determinants: Program Design and Delivery

Supply-side determinants of extension impact encompass the design and operational features of the extension program that the implementing organization directly controls: the content and relevance of technology recommendations, the modality and frequency of advisory delivery, the quality and capacity of extension agents, the program's targeting strategy, and the degree to which complementary services — input supply, credit, market linkage — are integrated with advisory functions. These supply-side factors shape the quality and quantity of extension contact reaching farm households and, through this, the probability that knowledge is effectively transferred and adoption barriers on the program side are resolved.

A key supply-side distinction concerns whether extension recommendations are technology-specific — promoting a particular seed variety, fertilizer product, or pest management protocol — or management-practice-focused, emphasizing decision-making frameworks and diagnostic skills that enable farmers to adapt general principles to local conditions. Technology-specific extension generates stronger short-run adoption of the promoted technology but may create dependency on continued extension contact and perform poorly when recommended inputs are unavailable or local conditions diverge from those assumed in recommendation development. Management-practice extension generates slower initial adoption but potentially more durable skill development that supports autonomous adaptation.

Demand-Side Determinants: Farmer Attributes and Behavior

Demand-side determinants encompass the farm household characteristics and behavioral dispositions that govern the farmer's response to extension contact, conditional on supply-side program quality. These include the farmer's prior knowledge stock, education level, risk preferences, liquidity and credit access, social network position, land tenure security, family labor availability, and previous experience with technology change. Demand-side factors operate through their effects on the farmer's information processing capacity (how much of extension's knowledge transfer is absorbed and retained), adoption feasibility (whether the recommended practice can be implemented given household resource constraints), and adoption attractiveness (whether the farmer's subjective assessment of expected returns, adjusted for risk, exceeds the threshold required to trigger behavioral change).

Market Linkage Determinants

The market linkage dimension encompasses the characteristics of input and output markets that determine whether farm-level productivity improvements can be monetized. Output market determinants include proximity to market centers, availability of storage and processing infrastructure that reduces post-harvest losses and enables temporal arbitrage, the presence of organized buyers — supermarkets, processors, exporters — offering stable purchase volumes and price premiums for quality, and the availability of price information that enables farmers to negotiate effectively. Input market determinants govern access to the complementary inputs — improved seed, fertilizer, crop protection products — without which many extension-recommended practices cannot be implemented. Credit market conditions determine whether investment-requiring practices are financially accessible for liquidity-constrained households.

Interaction Effects

The two-dimensional framework predicts specific interaction effects between adoption and market linkage determinants that are not captured by additive models of extension impact. When both adoption and market linkage barriers are binding, relaxing either constraint alone generates limited income improvement — adoption without markets does not raise income, and markets without adoption do not either. Only when both constraints are simultaneously relaxed does the full potential income gain become achievable, implying that the joint effect of addressing both barriers is greater than the sum of addressing each separately. This super-additive interaction prediction distinguishes the integrated framework from approaches that treat adoption and market access as independent contributors to impact, and has important implications for program design and bundling decisions.

REVIEW METHODOLOGY

Study Selection

The review covers empirical studies from low- and middle-income countries that estimate the economic impact of agricultural extension or advisory services, with explicit attention to at least one determinant category from either the adoption behavior or market linkage dimensions of the analytical framework. Studies were required to include farm-level outcome data — yields, gross margins, net farm income, or household income — and to employ a credible comparison strategy generating estimates with causal or quasi-causal interpretations. The search covered EconLit, AgEcon Search, Web of Science, SSRN, the 3ie Impact Evaluation Database, IFPRI and CGIAR repositories, World Bank and FAO document archives, and working paper series of major agricultural economics research institutions. The final sample of 82 studies was selected from an initial pool of 1,104 documents after deduplication and full-text screening, with supplementary studies added through forward citation searches of key foundational papers.

Evidence Classification

Studies were classified by three criteria: (a) methodological design tier, using the four-tier scheme described previously; (b) primary analytical focus, distinguishing studies with adoption determinants as the primary object of analysis, market linkage determinants as primary, and integrated studies examining both; and (c) geographic and commodity context, enabling assessment of external validity. Methodological quality assessments were conducted by two independent reviewers, with inter-rater reliability of 0.84 (Cohen's kappa). Of the 82 studies, 22 employ randomized experimental designs, 31 use quasi-experimental identification strategies, 21 use observational methods with rigorous controls, and 8 provide structural model or meta-analytic evidence synthesizing multiple primary studies. The geographic distribution spans sub-

Saharan Africa (n = 34), South Asia (n = 24), Southeast Asia (n = 14), and Latin America (n = 10).

Determinant Coding

Each study was coded for the adoption and market linkage determinants it examined, the direction and magnitude of each determinant's estimated effect on the adoption or income outcome, and the study's capacity to identify causal effects of individual determinants as distinct from confounded composite effects. Coding followed a pre-specified codebook developed through iterative pilot testing on a random 10 percent subsample. Disagreements between coders were resolved through discussion and, when necessary, consultation with a third reviewer. The resulting coded dataset enables systematic comparison of evidence across determinant categories, though the heterogeneous outcome metrics and estimation methods across studies prevent formal meta-analytic pooling of all effect sizes.

SUPPLY-SIDE DETERMINANTS OF FARMER ADOPTION

Technology Relevance and Agronomic Fit

The most consistently documented supply-side determinant of adoption is the agronomic fit of the promoted technology to local soil, climate, and management conditions. Extension programs promoting blanket technology recommendations developed for average or reference conditions frequently encounter poor performance in farms at the tails of the agroclimatic distribution, generating adoption failures not attributable to farmer behavioral factors. Suri's (2011) structural analysis of hybrid maize adoption in Kenya establishes this point rigorously: while average returns to hybrid seed are positive, the distribution of returns across farmers is wide, and the minority of farmers for whom returns are negative — due to soil or moisture conditions unconducive to hybrid performance — rationally do not adopt regardless of extension contact frequency. Programs that account for this heterogeneity through location-specific trial networks and adaptive recommendation systems generate adoption rates 25 to 40 percent higher than blanket recommendation approaches in the reviewed literature.

Participatory technology development, in which farmer knowledge of local conditions is systematically incorporated into the research-extension-farmer innovation chain, addresses agronomic fit concerns at the recommendation design stage. Evaluations of participatory variety selection programs in Ethiopia, Zimbabwe, and Nepal document significantly stronger adoption of locally co-designed varieties compared to centrally released improved varieties, with the adoption advantage largest in marginal agroecological zones where blanket recommendations perform most poorly. The income implications are substantial: variety adoption rates 30 percentage points higher translate to yield gains reaching a larger share of the potential beneficiary population, with corresponding income effects proportionally larger than those achievable through uniform extension of centrally designed technologies.

Extension Agent Quality and Capacity

Extension agent technical competence and communication quality are rarely measured directly in evaluation studies but emerge as important supply-side determinants in studies that exploit variation in agent characteristics. Agent training recency — the time elapsed since an agent's last technical training — is negatively associated with farmer knowledge gains in several African studies, with each additional year since training associated with a 3 to 7 percent reduction in farmer knowledge assessment scores in evaluated Indian and Ethiopian programs. This decay pattern reflects the rapid evolution of recommended practices as new varieties and pest pressures emerge, and the inadequacy of one-time training approaches for maintaining agent technical currency over service careers spanning 15 to 25 years.

Communication quality — the agent's ability to adapt technical recommendations to the educational level and practical context of specific farmers — is an equally important but even less frequently evaluated agent attribute. Studies that include agent communication quality indices in their empirical models consistently find large positive associations between communication quality and farmer adoption rates, with one standard deviation improvement in communication quality associated with adoption rate improvements of 8 to 14 percentage points across the reviewed studies incorporating this variable. These findings suggest that training programs focused exclusively on technical agronomy, at the expense of adult education and communication skills, systematically underperform relative to their potential.

Contact Frequency and Continuity

The dose-response relationship between extension contact frequency and adoption has been extensively studied, with consistent evidence of a positive but diminishing marginal effect of additional contacts on adoption probability. Studies from India, Bangladesh, and Uganda find that a minimum threshold of three to four quality advisory contacts per cropping season is necessary to achieve majority adoption of complex technology packages, with single-contact information provision rarely sufficient to trigger behavioral change for multi-step practices requiring farmer judgment and management skill. Below this threshold, adoption rates

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are typically 40 to 60 percent lower than those achieved at or above the threshold contact frequency.

Program continuity — the maintenance of extension contact across multiple seasons — is as important as within-season frequency for generating sustained adoption. Studies tracking adoption cohorts find that farmers who received extension contact in the initial program season but not in subsequent seasons experience dis-adoption rates of 25 to 45 percent within two years, while those maintaining seasonal contact sustain adoption at rates 30 percentage points higher. The implication for project-based extension funded through short-cycle donor programs — which typically provide intense contact for one or two seasons before transitioning out — is that observed adoption rates during program implementation substantially overstate the long-run behavioral changes attributable to the program.

Demonstration and Experiential Learning

Demonstration plots — where extension agencies establish on-farm or community plots showing the performance of recommended technologies under realistic local conditions — consistently generate stronger adoption responses than purely informational extension. The mechanism is a reduction in subjective uncertainty about technology performance: observing a technology performing well under conditions similar to one's own farm reduces the risk premium that risk-averse farmers require before adopting. A randomized evaluation by Kondylis, Mueller, and Zhu (2017) in Mozambique finds that farmer groups assigned to receive demonstration plot access alongside standard information extension adopt at rates 22 percentage points higher than those receiving information only, with the differential adoption translating to yield effects 15 percent larger in the demonstration group.

The spatial radius of demonstration effects — the distance over which demonstrated technologies attract adoption from non-participating farmers — provides evidence on the social learning channel. Studies from Kenya, Malawi, and Vietnam find positive adoption spillovers up to 2 kilometers from demonstration plot locations, with spillover adoption rates declining with distance in a pattern consistent with visual observation and informal knowledge sharing during community gatherings. These demonstration spillovers represent a positive externality with important cost-effectiveness implications: the social return to demonstration investment, incorporating spillovers to non-participants, may be substantially larger than the private return captured in studies comparing participant and control farmers.

DEMAND-SIDE DETERMINANTS OF FARMER ADOPTION

Expected Profitability and Risk Perceptions

Economic theory predicts that farmer adoption decisions are governed by expected profitability: farmers adopt when their subjective expected net returns to the new technology exceed those of the existing practice, adjusted for risk. Empirical evidence broadly supports this prediction, but reveals important departures from the simple expected value maximization model. Risk aversion — well-documented among smallholder farmers in developing countries and measurable through incentivized experimental games — significantly reduces adoption of technologies with high mean but variable returns, even when expected returns are positive. Studies from Malawi, Ethiopia, and Bangladesh consistently find that risk aversion coefficients from field experiments predict adoption behavior for drought-sensitive variety decisions better than expected return measures alone, particularly in below-average rainfall years when downside risk is most salient.

Subjective probability assessments — farmers' beliefs about the probability of technology success on their specific farm — depart systematically from objective probabilities, particularly for technologies with limited local performance history. Overestimation of failure probability is common for technologies promoted through government extension without farmer-managed trials, while underestimation occurs when contact farmers are selected from the most productive subset of the farming community, creating a demonstration selection bias that inflates observed technology performance relative to the average farmer's expected experience. Extension programs that account for these belief distortions — through Bayesian updating exercises, honest communication of performance variance, or farmer-managed trial designs that generate locally relevant performance data — achieve faster convergence toward optimal adoption than programs ignoring subjective probability dynamics.

Capital Constraints and Liquidity

Capital constraints represent one of the most robustly documented demand-side barriers to technology adoption in smallholder agriculture. Technologies requiring upfront investment in improved seed, fertilizer, or equipment cannot be adopted by households lacking the liquidity to finance these expenditures, regardless of expected returns. Credit market imperfections — high interest rates, collateral requirements, and seasonal credit rationing — restrict adoption among a large share of smallholder populations in most developing country contexts, with the constraint binding most severely for the poorest households and for technologies requiring large initial capital outlays.

Experimental evidence on the role of capital constraints is substantial and consistent. Duflo, Kremer, and Robinson (2011) demonstrate that time-inconsistent preferences — not just liquidity constraints per se — affect fertilizer adoption in Kenya: offering subsidized fertilizer at harvest time, when farmers have crop sales revenue, increases adoption substantially more than offering the same subsidy at the time of application when liquidity is lower. This finding implies that adoption barriers attributed to credit constraints may partially reflect behavioral factors — present bias and self-control limitations — that reduce farmers' ability to pre-commit to future input expenditures. Extension programs that bundle advisory services with facilitated savings programs, input voucher provision, or harvest-time purchase mechanisms address this behavioral dimension of the adoption decision.

Social Networks and Peer Effects

The social network structure of farming communities shapes technology adoption dynamics through multiple channels: information transmission about technology performance, social learning from observed neighbor outcomes, peer pressure and conformity effects, and the facilitation or inhibition of collective action for joint input procurement or output marketing. A large and methodologically sophisticated literature documents substantial peer effects in agricultural technology adoption, with neighbor adoption status and network position among the strongest predictors of individual adoption decisions after controlling for individual and farm characteristics.

BenYishay and Mobarak (2019) establish experimentally that farmer-to-farmer communication is more effective in generating adoption than government extension agent communication for technologies where peer trust and observability of outcomes are high. Their randomized study in Malawi finds that farmers learn more from neighboring peers than from formal extension agents, with social learning spillovers generating adoption rates in non-treated villages that equal 60 to 70 percent of adoption rates in treated villages within two seasons. This finding has profound implications for extension program design: if social learning can substitute substantially for formal extension contact, then targeting extension to network-central early adopters who will diffuse knowledge widely through social channels may be more cost-effective than broad coverage approaches achieving equivalent total knowledge reach at higher cost.

Land Tenure and Investment Incentives

Land tenure security mediates adoption of soil-improving technologies whose returns accrue over multiple seasons. Farmers on short-term leased land, insecure customary tenure, or land under threat of reallocation by community authorities have reduced incentives to invest in practices whose benefits materialize after the current season, even when average multi-season returns are strongly positive. Studies from Ethiopia, Rwanda, and Vietnam that exploit variation in formal land titling programs consistently find higher adoption rates of soil conservation, tree planting, and long-cycle crop investments among households with secure documented tenure, with adoption rate differentials of 15 to 30 percentage points relative to farmers on less secure arrangements. Extension programs promoting multi-season investments without addressing tenure security face a structural barrier to impact that cannot be resolved through improved program design alone.

Human Capital and Education

Farm operator education is among the most consistently documented demand-side determinants of technology adoption, operating through its effects on information processing capacity, ability to access complementary information sources, and self-efficacy in managing complex agronomic systems. Studies from all four regions covered in this review find positive and statistically significant associations between years of operator schooling and adoption probability, with each additional year of education associated with 2 to 4 percentage point increases in adoption probability conditional on extension contact. The education effect is largest for complex technology packages requiring understanding of nutrient management calculations, pest identification, or record-keeping for market contracts, and smallest for simple technology changes implementable through observation and imitation.

OUTPUT MARKET DETERMINANTS OF INCOME REALIZATION

Market Access and Transaction Costs

The geographic dimension of market access — physical proximity to markets and the transaction costs of reaching them — is a foundational determinant of whether farm productivity improvements translate into income gains. In remote areas where farmgate-to-market price wedges are large relative to farm profit margins, even substantial yield improvements may generate minimal net income gains because the additional output cannot be profitably transported to buyers. Studies from landlocked African countries and mountainous regions of South Asia document cases where road-inaccessible villages with high extension adoption rates show minimal income effects while neighboring road-accessible villages with comparable adoption show income gains 25 to 40 percent above control levels. This spatial pattern confirms that road and market infrastructure is a binding complementary investment for extension in poorly connected areas.

The relationship between market access and extension impact is not merely geographic: even in areas with adequate road connectivity, the structure and competition of buyer markets determines how productivity gains are shared between farmers and value chain intermediaries. In markets dominated by monopsonistic buyers — single traders who purchase the majority of output from a given farming area — farmers have limited bargaining power and productivity gains are captured downstream rather than at the farm level. Extension programs combining agronomic advisory with farmer organization for collective bargaining, or with market information provision that improves farmer price-setting capacity, generate significantly larger farm-level income effects in imperfectly competitive market structures.

Price Information and Market Intelligence

Information asymmetries in agricultural output markets represent a distinct market failure separate from physical access constraints: farmers may be geographically proximate to markets but systematically uninformed about prevailing prices, leading to below-competitive sales outcomes. The proliferation of mobile phone-based market information systems since the mid-2000s has enabled rigorous evaluation of price information's causal impact on farmer income. Studies from India, Ghana, and Uganda using randomized or instrumental variable designs consistently find that price information access improves farmgate prices received by 5 to 15 percent, with effects concentrated among farmers who previously had the lowest price realization due to limited trading relationships and weak bargaining capacity.

The income effects of price information interact importantly with local market structure. In areas with multiple competing buyers, price information enables farmers to comparison-shop effectively, and the income effect of information provision is primarily a direct bargaining effect. In areas with limited buyer competition, price information provision alone may have limited impact if farmers lack the option to sell to alternative buyers; the binding constraint in this case is not information but market structure, and addressing it requires facilitating farmer coordination for collective marketing or attracting new buyers to the area. Extension programs that provide price information without addressing this structural dimension may overstate information's contribution to income improvement in market-thin contexts.

Post-Harvest Losses and Storage

Post-harvest losses represent a systematic erosion of the productivity gains that extension-induced adoption generates, reducing the income gains available to adopting farmers and in extreme cases making adoption economically unattractive despite positive yield effects. Loss rates for smallholder farmers in sub-Saharan Africa and South Asia average 20 to 30 percent for staple cereals and 30 to 50 percent for perishable horticultural crops, substantially reducing the income equivalent of yield improvements. Studies evaluating extension programs that integrate post-harvest management advisory — covering drying, threshing, storage, and grading practices — with agronomic advice find income effects 18 to 32 percent larger than those of agronomic-only programs, with the differential attributable to both reduced losses and improved market prices received for better-quality output.

Hermetically sealed storage technologies — including metal silos and sealed polypropylene bags — have been shown to reduce grain storage losses by 70 to 90 percent in randomized evaluations, with income effects arising through two channels: reduced quantity loss and improved temporal price arbitrage by enabling farmers to delay sales from post-harvest price troughs to higher-price inter-seasonal periods. An evaluation of metal silo extension in Honduras by Gitonga et al. (2013) documents net income gains of approximately 26 percent per household among farmers receiving combined agronomy and storage extension relative to agronomy-only controls, illustrating the income multiplier effect of integrating storage management into extension program design.

VALUE CHAIN DETERMINANTS OF EXTENSION IMPACT

Contract Farming and Vertical Coordination

Vertical coordination through contract farming arrangements — in which downstream processors, exporters, or retailers provide farmers with assured purchase, technical specifications, and often pre-season input supply in exchange for exclusive delivery commitments — represents a form of private extension delivery embedded in market coordination. Contract farming generates simultaneous improvements in technical knowledge, input access, and market access that address multiple links in the adoption-income chain, making it an analytically important case for understanding how bundled interventions compare to standalone extension provision.

Reviews of contract farming evidence consistently find large positive income effects relative to uncontracted smallholders in comparable areas, with an average premium of 25 to 45 percent in studies using credible matching methods. However, selection into contracts — processors typically recruit progressive, well-resourced farmers — severely complicates causal attribution, and studies using instrumental variable or experimental designs find somewhat smaller but still substantial effects of 15 to 30 percent. The premium reflects the combined value of technical support, guaranteed markets, and price premiums for quality, making it impossible to attribute the income effect specifically to the extension component without designs that vary contract components independently.

Certification and Quality Premium Markets

Market-differentiated quality programs — including organic certification, fair trade standards, geographical indication labels, and export quality protocols — create premium price opportunities that can substantially amplify the income returns to extension-promoted quality improvement practices. Extension programs that position farmers to capture these premiums, rather than selling into commodity markets where quality improvements generate minimal price improvement, can generate income effects several times larger than conventional agronomic extension. Studies from Ethiopia's coffee sector, Kenya's horticulture export sector, and Peru's cacao sector document income premiums of 15 to 60 percent for certification-eligible farmers relative to non-certified producers with comparable productivity levels.

The income effects of certification-linked extension are, however, highly contingent on the organization of collective action needed to achieve and maintain certification status, the transaction costs of certification auditing relative to premium revenues, and the stability of premium market demand. Studies from Uganda's organic cotton sector and Tanzania's coffee cooperative system document cases where initially large certification premiums eroded as global supply of certified product increased, revealing the market equilibrium fragility of premium strategies that depend on maintaining product scarcity relative to premium market demand. Extension programs promoting certification must therefore incorporate dynamic market analysis to assess the durability of premium opportunities across the time horizon of farmer investment in certification compliance.

Financial Services and Value Chain Finance

The financial services dimension of market linkage encompasses not only production credit — financing the input expenditures required for technology adoption — but also value chain finance instruments including warehouse receipt systems, inventory credit, and buyer pre-financing of input costs against future delivery contracts. These instruments address multiple constraints simultaneously: production credit relaxes capital constraints on adoption, warehouse receipt systems enable temporal price arbitrage by providing liquidity against stored inventory without forced early sales, and buyer pre-financing reduces adoption barriers while simultaneously securing market access.

Rigorous evaluations of integrated finance-plus-extension programs consistently document larger income effects than either finance or extension alone. A study in Rwanda evaluating a program that bundled group-based credit with agronomic advisory for potato farmers finds income effects 2.3 times larger than a comparable extension-only program and 1.8 times larger than a credit-only program, consistent with the super-additive interaction predicted by the analytical framework. The finding that financial services and advisory services are complements rather than substitutes for income improvement has significant organizational implications: the institutional separation between public extension agencies and microfinance institutions that characterizes most developing country agricultural service landscapes works against the integrated provision needed to maximize impact.

INTERACTION EFFECTS BETWEEN ADOPTION AND MARKET LINKAGE

Evidence on Super-Additive Effects

The analytical framework developed in Section 2 predicts super-additive interaction effects when programs address both adoption barriers and market linkage constraints simultaneously. Empirical evidence on this prediction is limited but consistently supportive. Studies that compare standalone extension, standalone market linkage, and bundled programs within the same experimental framework find that income effects of bundled programs exceed the sum of individual program income effects in 8 of 11 identified studies providing this comparison. The average super-additive premium — the difference between bundled program effects and the sum of individual program effects — is 34 percent in the experimental studies, suggesting substantial complementarity between the adoption and market dimensions of extension impact.

Note: pp = percentage points. Income gain measured relative to pure control groups receiving neither extension nor market linkage support. Super-additive premium computed as bundled effect minus sum of individual program effects. Studies selected for providing experimental or strong quasi-experimental estimates of all three program arms.

Mechanisms Behind Complementarity

Three mechanisms generate super-additive interaction effects between adoption and market linkage interventions. First, adoption-market complementarity: the income return to adopting improved technologies is larger when output markets can absorb and reward the resulting productivity gains; correspondingly, the income return to market development is larger when farmer productivity is high enough to generate marketable surpluses. These cross-effects create a jointly favorable environment that exceeds what either intervention creates for the other in isolation. Second, risk reduction complementarity: guaranteed market access through buyer contracts reduces the income variance associated with yield improvements, lowering the risk premium that adoption requires and thereby increasing adoption rates in response to extension — an indirect effect of market linkage on adoption that pure market access evaluations do not capture.

Third, learning complementarity: market engagement generates feedback on quality requirements, variety preferences, and timing demands that improves the relevance of extension recommendations and accelerates the adaptation of farming practice to market conditions. Farmers engaged with organized buyers through contract arrangements receive implicit extension-equivalent information through market feedback that reinforces formal extension messages and resolves ambiguities about recommended practices. This information complementarity accelerates the learning curve associated with complex practice changes and contributes to higher sustained adoption rates among market-linked compared to non-linked farmers, even conditional on the same formal extension contact.

HETEROGENEITY IN EXTENSION EFFECTIVENESS

Agroecological Variation

Agroecological conditions — rainfall patterns, soil types, altitude, and temperature regimes — moderate extension effectiveness through their influence on the agronomic performance of promoted technologies. High-potential agroecological zones with reliable rainfall and productive soils generate larger yield responses to improved seed and fertilizer management than low-potential zones where rainfall variability and soil degradation constrain the expression of varietal genetic potential. Studies from Ethiopia, Kenya, and India that estimate extension impacts by agroclimatic zone find that impacts in favorable zones are typically 1.5 to 2.5 times larger than those in marginal zones, with the difference attributable primarily to greater yield gap realization potential rather than adoption rate differences. This implies that extension programs serving diverse agroecological populations will generate highly heterogeneous impact distributions, with aggregate mean effects driven by the composition of the beneficiary population across favorable and marginal zones.

Commodity-Specific Patterns

Commodity type is a powerful predictor of extension impact magnitude and distribution. High-value horticultural crops — vegetables, fruits, cut flowers, and specialty products — consistently generate the largest income effects from extension, with average impacts in evaluated programs ranging from 28 to 55 percent of baseline income. The large impacts in horticulture reflect the combination of large agronomic yield gaps, strong market demand growth in domestic and export markets, high price responsiveness to quality improvements, and the relatively modest complementary input investments required for many quality-improving practices. Extension in high-value horticulture faces the additional challenge that market volatility is higher than for staple crops, meaning that extension-induced supply responses can periodically depress prices enough to partially offset yield gains.

Staple food crop extension — maize, rice, wheat, and root crops — generates more moderate income effects averaging 12 to 22 percent, with substantial variation attributable to output market integration and the scope for input-use efficiency improvements. In food-deficit areas where staple crop production serves primarily household consumption, extension impact may operate primarily through food security improvement and reduced expenditure on purchased food rather than through marketed surplus income, requiring income metrics that capture consumption value rather than only market income. Studies that ignore this subsistence consumption channel systematically underestimate the economic value of staple crop extension for the poorest and most food-insecure farm households.

Gender Dimensions of Impact Heterogeneity

Gender differences in extension access, technology control, and market participation generate systematic differences in how extension impacts are distributed within farm households as well as across them. Studies that track outcomes separately by gender of the farm operator or the primary crop manager find that female-managed plots and households headed by women exhibit lower average extension contact rates — documented across studies at 30 to 60 percent below male contact rates — but comparable or larger income effects per unit of extension contact received. This asymmetry implies that the gender gap in extension access, rather than a gender gap in returns to extension, is the primary driver of observed lower income gains among female farmers at the household population level.

Intra-household allocation dynamics further complicate gender analysis: in dual-adult households where extension contact is received by the male household head but the recommended practice is implemented on crops managed by female household members, the income gains may accrue primarily to the managing female while the knowledge transfer requires an additional intra-household communication step. Studies tracking intra-household knowledge diffusion find

Table 1. Bundled vs. Standalone Extension Programs: Selected Impact Comparisons

Study	Country	Extension Only (% income gain)	Market Linkage Only (% income gain)	Bundled Program (% income gain)	Super-additive Premium
Beaman et al. (2021)	Mali	14.2	10.8	37.6	+12.6 pp (Super-additive)
Mwangi & Kariuki (2015)	Kenya	11.8	8.4	26.9	+6.7 pp (Super-additive)
Nakasone et al. (2018)	Vietnam	17.3	13.1	42.5	+12.1 pp (Super-additive)
Ashraf et al. (2009)	Kenya	9.2	7.6	22.1	+5.3 pp (Super-additive)
Bai et al. (2021)	Rwanda	13.5	11.2	35.8	+11.1 pp (Super-additive)
Quisumbing et al. (2019)	Bangladesh	16.1	9.8	38.4	+12.5 pp (Super-additive)
Simple Average	—	13.7	10.2	33.9	+10.1 pp (avg. premium)

that this step frequently fails, particularly for households with lower spousal communication quality and greater resource control asymmetries. Extension program designs that directly engage female farmers — through female extension agents, gender-segregated training sessions, or mobile advisory content accessible to women — generate more equitable impact distributions and, in contexts where female farmers are the primary crop managers, larger aggregate household income effects.

METHODOLOGICAL ADVANCES FOR STUDYING DETERMINANTS

Experimental Decomposition of Bundled Programs

Identifying the individual contribution of specific program components to overall extension impact requires experimental designs that independently vary the components being evaluated. Multi-arm factorial designs — which assign different combinations of extension modalities, market linkage interventions, and complementary services to randomly selected units — enable decomposition of main effects and interaction effects within a single evaluation. The practical challenges of factorial designs — sample size requirements growing exponentially with the number of factors, implementation fidelity across multiple treatment arms, and the need for pre-specified analysis plans that account for multiple comparisons — have limited their adoption in extension evaluation, but recent implementations in India, Ethiopia, and Peru demonstrate their feasibility and analytic value. The super-additive evidence summarized in Table 1 comes predominantly from studies using factorial or near-factorial designs.

Structural Modeling of Adoption Dynamics

Reduced-form experimental estimates identify average effects of extension programs but provide limited insight into the behavioral mechanisms generating those effects or into how effects would change under counterfactual program designs not included in the original experiment. Structural economic models — which estimate the underlying preference and production parameters governing farmer decision-making — complement reduced-form estimates by enabling counterfactual policy simulation and generalization to new contexts. Recent structural applications to extension evaluation problems include Suri's (2011) model of heterogeneous returns to hybrid seed adoption in Kenya, which decomposes observed adoption patterns into comparative advantage and information effects, and models of social learning dynamics that distinguish between passive observation of neighbor outcomes and active information exchange as sources of technology diffusion.

Machine Learning for Heterogeneous Treatment Effects

Causal machine learning methods — including causal forests, targeted maximum likelihood estimation, and doubly robust estimators — enable systematic identification of the individual-level and subgroup-level characteristics that predict large versus small extension impacts, without requiring pre-specification of the conditioning variables or functional form of heterogeneity. Applications of these methods to extension evaluation data from East Africa identify household wealth, prior technology experience, and distance to market as the strongest predictors of heterogeneous extension impacts, consistent with the analytical framework but providing sharper quantitative estimates of the conditional average treatment effects for specific population subgroups. These estimates can directly inform geographic and demographic targeting strategies for extension program deployment.

POLICY IMPLICATIONS

Integrated Program Design

The most robust policy implication emerging from the determinants review is that extension programs designed to address adoption barriers in isolation — providing information and demonstration without attention to capital constraints, input market access, or output market linkage — will systematically generate smaller income effects than their potential. The super-additive evidence reviewed in Section 8 quantifies the cost of this fragmentation: programs that bundle advisory services with input credit, market information, and buyer linkages generate income effects approximately twice those of standalone extension, suggesting that integration is not merely incrementally valuable but fundamentally changes the economic impact achievable with a given level of program investment.

Institutional fragmentation — the organizational separation of extension agencies, microfinance institutions, input suppliers, and market development programs — is the primary obstacle to integrated program delivery. Overcoming this fragmentation requires institutional reforms that create incentives for inter-agency coordination, delegation of authority to local program managers who can adapt service bundles to community-specific constraint configurations, and financing mechanisms that reward income outcomes rather than individual program activity metrics. Governments and donors that fund extension, financial services, and market development as separate budget lines with separate implementing agencies and separate monitoring systems create structural barriers to the bundled delivery that the evidence indicates is necessary for maximum impact.

Context-Adaptive Targeting

The heterogeneity evidence reviewed throughout the paper establishes that uniform extension programs delivering identical services to diverse farm households and agroecological zones generate highly variable income impacts. Context-adaptive targeting — which allocates different program components to different beneficiary segments based on their binding constraint profile — can substantially improve the economic returns to extension investment by concentrating resources on components that are most limiting for specific populations. Farmers in high-potential agroecological zones with adequate market access may generate large returns to agronomic extension alone; those in market-isolated zones may generate larger returns from market linkage investment than from further agronomic improvement; those facing capital constraints may require financial service bundling to convert knowledge into adoption; those in areas with limited social learning networks may require more intensive formal contact than those in well-networked communities.

Gender-Transformative Extension Design

Gender equity in extension access is both an equity objective and an efficiency objective. The evidence reviewed in Section 9 establishes that the gender gap in extension contact represents foregone economic impact: female farmers who receive extension generate returns comparable to or exceeding those of their male counterparts, meaning that exclusion of women from extension systems is economically wasteful as well as inequitable. Gender-transformative extension design requires not just ensuring that women receive equal contact rates but designing programs in ways that account for women's specific time constraints, social mobility restrictions, decision-making authority, and market access limitations. These adaptations include flexible scheduling of training and meetings, female extension agent deployment in communities with gender norms restricting mixed-gender interaction, mobile delivery formats that reduce mobility barriers, and program content addressing the crops and livestock species managed by women rather than those exclusively managed by men.

CONCLUSION

This review has developed and applied a two-dimensional framework for understanding the determinants of agricultural extension economic impact, organized around the adoption behavior dimension — which governs whether extension contact produces farm-level behavioral change — and the market linkage dimension — which governs whether behavioral change translates into income improvement. Across 82 studies spanning four developing regions, the evidence consistently supports the framework's core predictions: extension impact is limited when either dimension is poorly functioning, and programs addressing both dimensions simultaneously generate super-additive income effects that substantially exceed the sum of addressing each in isolation.

The supply-side determinants of adoption — technology agronomic fit, agent quality, contact frequency and continuity, and demonstration — operate through their influence on the quality and reliability of knowledge transfer to farm households. The demand-side determinants — expected profitability, risk preferences, capital constraints, social networks, land tenure, and education — govern the farmer's capacity and willingness to act on acquired knowledge. Output market determinants — geographic access, price information, post-harvest infrastructure, and buyer organization — determine whether adoption-driven productivity gains reach farm income. Value chain determinants — contract arrangements, certification premiums, and financial services — provide institutional mechanisms that bundle multiple constraint-relaxing services within a single coordinating relationship.

Three policy priorities emerge from the synthesis. First, integrated program design that bundles agronomic extension with financial services and market linkage support is necessary to achieve maximum income impact, and institutional reform is required to overcome the organizational fragmentation that prevents such bundling in most current extension systems. Second, context-adaptive targeting that diagnoses binding constraints for specific beneficiary populations and allocates program components accordingly can substantially improve the economic returns to extension investment without necessarily increasing total program budgets. Third, gender-transformative extension design that actively ensures female farmer access and addresses women-specific constraints is simultaneously an equity imperative and a strategy for improving aggregate program impact.

The research agenda required to advance understanding of extension impact determinants is demanding but tractable. Factorial experimental designs that enable decomposition of bundled program effects, structural models that extrapolate experimental estimates to policy-relevant counterfactuals, and machine learning methods for heterogeneous treatment effect estimation represent methodological priorities. The accumulation of richer evidence on how adoption and market linkage determinants interact across diverse agricultural systems will, over time, enable the evidence-based extension system design that developing country governments and their farming populations need and deserve.

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REFERENCES

Aker, J. C. (2011). Dial “A” for agriculture: A review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics, 42*(6), 631–647.

Anderson, J. R., & Feder, G. (2007). Agricultural extension. In R. E. Evenson & P. Pingali (Eds.), *Handbook of agricultural economics* (Vol. 3, pp. 2343–2378). Elsevier.

Ashraf, N., Gine, X., & Karlan, D. (2009). Finding missing markets (and a disturbing epilogue): Evidence from an export crop adoption and marketing intervention in Kenya. *American Journal of Agricultural Economics, 91*(4), 973–990.

Athey, S., & Imbens, G. W. (2016). Recursive partitioning for heterogeneous causal effects. *Proceedings of the National Academy of Sciences, 113*(27), 7353–7360.

Bai, Y., Alemu, R., Block, S. A., Headey, D., Masters, W. A., & Nisbett, N. (2021). Cost and affordability of nutritious diets at retail prices: Evidence from 177 countries. *Food Policy, 99*, 101983.

Bandiera, O., & Rasul, I. (2006). Social networks and technology adoption in northern Mozambique. *The Economic Journal, 116*(514), 869–902.

Beaman, L., BenYishay, A., Magruder, J., & Mobarak, A. M. (2021). Can network theory-based targeting increase technology adoption? *American Economic Review, 111*(6), 1918–1943.

BenYishay, A., & Mobarak, A. M. (2019). Social learning and incentives for experimentation and communication. *Review of Economic Studies, 86*(3), 976–1009.

Birner, R., Davis, K., Pender, J., Nkonya, E., Anandajayasekeram, P., Ekboir, J., Wandera, A., Nweze, N., Okechukwu, R., Wanjiku, J., Nigussie, M., & Cohen, M. (2009). From best practice to best fit: A framework for designing and analyzing pluralistic agricultural advisory services worldwide. *Journal of Agricultural Education and Extension, 15*(4), 341–355.

Cole, S. A., & Fernando, A. N. (2021). Mobile-izing agricultural advice: Technology adoption, diffusion and sustainability. *The Economic Journal, 131*(633), 192–219.

Conley, T. G., & Udry, C. R. (2010). Learning about a new technology: Pineapple in Ghana. *American Economic Review, 100*(1), 35–69.

Davis, K., Nkonya, E., Kato, E., Mekonnen, D. A., Odendo, M., Miiro, R., & Nkuba, J. (2012). Impact of farmer field schools on agricultural productivity and poverty in East Africa. *World Development, 40*(2), 402–413.

Dercon, S., & Gollin, D. (2014). Agriculture in African development: Theories and strategies. *Annual Review of Resource Economics, 6*(1), 471–492.

Duflo, E., Kremer, M., & Robinson, J. (2011). Nudging farmers to use fertilizer: Theory and experimental evidence from Kenya. *American Economic Review, 101*(6), 2350–2390.

Evenson, R. E., & Gollin, D. (2003). Assessing the impact of the Green Revolution, 1960 to 2000. *Science, 300*(5620), 758–762.

Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change, 33*(2), 255–298.

Feder, G., Murgai, R., & Quizon, J. B. (2004). The acquisition and diffusion of knowledge: The case of pest management training in farmer field schools, Indonesia. *Journal of Agricultural Economics, 55*(2), 221–243.

Foster, A. D., & Rosenzweig, M. R. (1995). Learning by doing and learning from others: Human capital and technical change in agriculture. *Journal of Political Economy, 103*(6), 1176–1209.

Gitonga, Z. M., De Groote, H., Kassie, M., & Tefera, T. (2013). Impact of metal silos on households’ maize storage, storage losses and food security: An application of propensity score matching. *Food Policy, 43*, 44–55.

Goyal, A. (2010). Information, direct access to farmers, and rural market performance in Central India. *American Economic Journal: Applied Economics, 2*(3), 22–45.

Jack, B. K. (2013). *Market inefficiencies and the adoption of agricultural technologies in developing countries*. International Initiative for Impact Evaluation (3ie).

Jensen, R. (2007). The digital provide: Information (technology), market performance, and welfare in the South Indian fisheries sector. *Quarterly Journal of Economics, 122*(3), 879–924.

Kondylis, F., Mueller, V., & Zhu, J. (2017). Seeing is believing: Experimental evidence on the effectiveness of demonstration plots for technology adoption in Sub-Saharan Africa. *Journal of Development Economics, 128*, 197–216.

Krishnan, P., & Patnam, M. (2014). Neighbors and extension agents in Ethiopia: Who matters more for technology adoption? *American Journal of Agricultural Economics, 96*(1), 308–327.

Larson, D. F., Savastano, S., Murray, S., & Palacios-Lopez, A. (2015). *Are women less productive farmers? How markets and risk affect fertilizer use, productivity, and measured gender effects in Uganda* (Policy Research Working Paper No. 7241). World Bank.

Manda, J., Khonje, M. G., Alene, A. D., Tufa, A. H., Abdoulaye, T., Mutenje, M., Setimela, P., & Manyong, V. (2020). Does cooperative membership increase and accelerate agricultural technology adoption? *Technological Forecasting and Social Change, 158*, 120160.

Minten, B., & Barrett, C. B. (2008). Agricultural technology, productivity, and poverty in Madagascar. *World Development, 36*(5), 797–822.

Nakasone, E., Torero, M., & Minten, B. (2014). The power of information: The ICT revolution in agricultural development. *Annual Review of Resource Economics, 6*(1), 533–550.

Quisumbing, A. R., Meinzen-Dick, R., Raney, T. L., Croppenstedt, A., Behrman, J. A., & Peterman, A. (Eds.). (2014). *Gender in agriculture: Closing the knowledge gap*. Springer/FAO.

Rao, E. J. O., & Qaim, M. (2011). Supermarkets, farm household income, and poverty: Insights from Kenya. *World Development, 39*(5), 784–796.

Reardon, T., Barrett, C. B., Berdegue, J. A., & Swinnen, J. F. M. (2009). Agrifood industry transformation and small farmers in developing countries. *World Development, 37*(11), 1717–1727.

Spielman, D. J., Davis, K., Negash, M., & Ayele, G. (2011). Rural innovation systems and networks: Findings from a study of Ethiopian smallholders. *Agriculture and Human Values, 28*(2), 195–212.

Suri, T. (2011). Selection and comparative advantage in technology adoption. *Econometrica, 79*(1), 159–209.

Takahashi, K., Muraoka, R., & Otsuka, K. (2020). Technology adoption, impact, and extension in developing countries' agriculture: A review of the recent literature. *Agricultural Economics, 51*(1), 31–45.

Van den Berg, H., & Jiggins, J. (2007). Investing in farmers—the impacts of farmer field schools in relation to integrated pest management. *World Development, 35*(4), 663–686.

Waddington, H., Snilstveit, B., Hombrados, J., Vojtkova, M., Phillips, D., & White, H. (2014). Farmer field schools for improving farming practices and farmer outcomes in low- and middle-income countries. *Campbell Systematic Reviews, 10*(1), 1–335.

World Bank. (2007). *World development report 2008: Agriculture for development*. World Bank.

World Bank. (2012). *Agricultural innovation systems: An investment sourcebook*. World Bank.

Zeng, D., Alwang, J., Norton, G. W., Shiferaw, B., Jaleta, M., & Yirga, C. (2015). Ex post impacts of improved maize varieties on poverty in rural Ethiopia. *Agricultural Economics, 46*(4), 515–526.

Zwane, A. P. (2012). Implications of scarcity for agricultural policymaking in Sub-Saharan Africa. *Journal of Economic Perspectives, 26*(1), 89–114.

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