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BEYOND SUBSIDY VOLUME: INSTITUTIONAL QUALITY AS THE TRANSMISSION INFRASTRUCTURE OF SUSTAINABLE AGRICULTURAL TRANSFORMATION. A CRITICAL MECHANISTIC REVIEW

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ABSTRACT

Public agricultural support is often evaluated by expenditure, coverage, or average treatment effects, yet similar instruments generate sharply different productivity, welfare, and environmental outcomes across agricultural systems. This critical mechanistic review asks where that divergence is produced. Synthesizing recent peer-reviewed empirical studies, meta-analyses, systematic reviews, and comparative policy research, we conceptualize institutional quality as the transmission infrastructure linking policy design to targeting, delivery, complementary services, farmer response, and multidimensional outcomes. Five mechanisms recur across settings: administrative capability and accountability; land and property institutions; market and financial coordination; knowledge, extension, and digital systems; and collective organizations. Evidence from input-support programmes in sub-Saharan Africa, the European Union's agricultural support architecture, and emerging-economy reforms shows that institutions do not merely add to subsidy effects; they alter targeting, additionality, investment horizons, technology uptake, market participation, and environmental leakage. The synthesis also rejects a simple 'strong institutions equal good outcomes' interpretation: capable administrations can efficiently implement incentives that remain environmentally misaligned, while land formalization, credit, or digital tools can underperform when complementary constraints bind. We propose a policy-transmission framework with observable failure signatures for diagnosing where support loses effectiveness and identify mechanism-specific priorities for future causal research.

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Introduction

Why similar support generates different outcomes

Agricultural support is frequently discussed as if the instrument itself—fertilizer subsidy, direct payment, price support, insurance subsidy, environmental payment or innovation grant—contains its own development effect. That framing is analytically incomplete. Public support first has to pass through a sequence of institutional operations: beneficiaries must be identified; eligibility rules must be interpreted consistently; inputs, payments or services must arrive on time; markets and complementary services must exist; farmers must perceive the intervention as credible enough to change behaviour; and the resulting private response must align with the public objective. A failure at any stage can attenuate, redirect or reverse the intended effect. Cross-country evidence is consistent with this transmission view: the productivity association of public agricultural spending is stronger where governance indicators are more favorable, while more recent production-function estimates also find systematic, though heterogeneous, links between institutional conditions and agricultural output (Soko et al., 2023; Lin et al., 2024).

The same logic helps reconcile apparently contradictory subsidy findings. In Ghana, a review of the Planting for Food and Jobs programme documents implementation and targeting problems alongside gains in access and output, while a staggered difference-in-differences study of Tanzania's input-voucher programme finds no clear average productivity increase and substantial heterogeneity by treatment cohort and farm size (Pauw, 2022; Karata, 2024). Experimental evidence from Ethiopia shows that input vouchers and index insurance affect production and welfare through different risk and liquidity channels rather than through a single 'subsidy effect' (Wong et al., 2020). Malawi evidence further shows that farm-input support can interact with non-agricultural public services, including early-health and nutrition programmes, to shape child nutrition outcomes (Mwale et al., 2022). These studies shift the relevant question from whether subsidies 'work' to which institutional bottleneck determines the conversion of a particular instrument into a particular outcome.

Environmental evidence makes the same point from another direction. Global modelling finds that the climate implications of agricultural support depend on what commodities and practices the support induces, not simply on the amount transferred (Laborde et al., 2021; Springmann and Freund, 2022). Within the European Union, subsidy allocation is heavily associated with emissions-intensive animal products, demonstrating that high administrative capacity does not itself guarantee environmental alignment (Kortleve et al., 2024). Conversely, agri-environmental schemes can improve biodiversity under suitable design, but meta-analytic and farm-level evidence shows heterogeneous effects, opportunity-cost constraints and spillovers between enrolled and non-enrolled land (Marja et al., 2024; Bonev, 2024). Institutional quality therefore needs to be decomposed into functions rather than treated as an undifferentiated label for 'good governance'.

Scope, evidence base and contribution

This article is a critical mechanistic review rather than a systematic review with a preregistered search protocol. It prioritizes peer-reviewed empirical studies, meta-analyses, systematic or scoping reviews and comparative policy research published mainly from 2020 onward. Evidence was selected for its ability to identify a transmission mechanism between policy support and farm-level or system-level outcomes: targeting and accountability; tenure and investment; market and financial coordination; information and technology adoption; collective organization; environmental conditionality; or digital monitoring. The rebuilt reference base intentionally excludes the older citations used in the previous manuscript version and emphasizes recent work from high-quality agricultural economics, development, environmental and food-systems journals.

The central contribution is a policy-transmission framework that treats institutional quality as infrastructure for converting public resources into outcomes. The framework makes three distinctions. First, an instrument has a proximal target—such as lowering an input price, stabilizing revenue, changing a land-management practice or rewarding an ecological result—that is analytically separate from distal outcomes such as productivity, income, resilience or biodiversity. Second, institutional mechanisms can mediate effects by changing delivery and can moderate effects by changing the return to the same delivered benefit. Third, institutional strength is objective-specific: an administration can deliver payments accurately yet still implement incentives that promote resource-intensive production. This distinction is crucial for avoiding the tautological claim that successful policies succeed because institutions are strong. These distinctions are integrated in the policy-transmission architecture illustrated in Fig. 1.

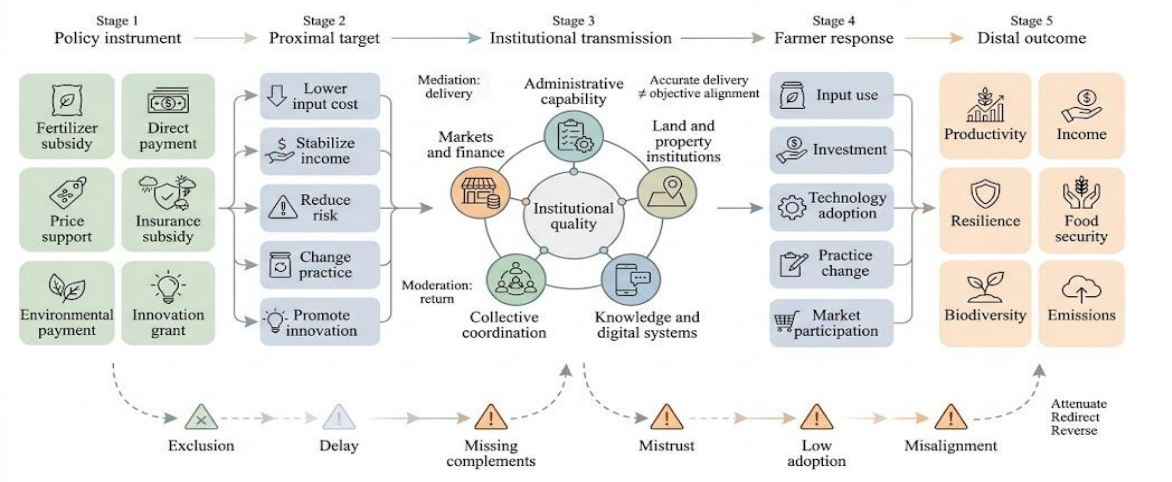


Figure 1. Institutional transmission of agricultural support: why similar policy instruments generate divergent outcomes.

Public support affects outcomes through proximal targets, institutional transmission functions, and farmer responses rather than through a direct "subsidy effect". Institutional quality mediates delivery and moderates the return to delivered support, while failures at different stages can attenuate, redirect, or reverse intended effects.

From Policy Instrument to Outcome: A Transmission Framework

Policy archetypes and their institutional dependencies

Four broad policy archetypes recur in the contemporary evidence. Input and credit support seek to relax liquidity or input-access constraints; price and income instruments seek to alter expected returns or income risk; insurance and risk-management instruments transfer or pool production risk; and agri-environmental or result-based payments condition support on practices or measured outcomes. Each archetype places a different burden on institutions. Input subsidies require accurate beneficiary registries, procurement integrity, timely last-mile distribution and functioning input markets. Credit and insurance require information on borrowers, losses and covariate risk; the insurance literature repeatedly identifies basis risk, trust, liquidity and understanding as constraints on demand and performance (Ali et al., 2020; Kramer et al., 2022). Result-based environmental payments require the hardest measurement problem because payment eligibility depends on credible indicators of environmental outcomes (Elmiger et al., 2023; Hagemann et al., 2025).

Direct and area-based payments create a different institutional exposure: part of the transfer can be capitalized into land values or rents, changing who ultimately captures support. A synthesis of capitalization studies shows that agricultural subsidies can be reflected in land prices, so nominal incidence on farm operators need not equal economic incidence (Ciaian et al., 2021). Distributional analysis of CAP payments likewise shows that evaluation depends on the unit of analysis and the pre-transfer income distribution, not merely on payment shares (Piet and Desjeux, 2021). Farm-level modelling of the 2013 CAP reform further illustrates how changes in payment design can alter production and income effects unevenly across farm types and regions (Espinosa et al., 2020).

This instrument-specific view also clarifies why 'repurposing' support is not a simple budgetary switch. Environmental performance depends on the mapping from payment rule to behavior, the counterfactual behavior without payment, the monitorability of the targeted outcome and the possibility of leakage to other parcels or activities. Reviews of payments for environmental services and agri-environmental schemes find that additionality, targeting, contract design and monitoring are central to effectiveness (Wunder et al., 2020; Tyllianakis and Martin-Ortega, 2021). Contemporary EU evidence adds that institutional and interest structures can constrain the translation of broad food-system strategies into policy change even when sustainability goals are explicit (Candel and Daugbjerg, 2025).

Institutional quality as transmission infrastructure

For the purposes of this review, institutional quality is defined operationally as the reliability of five functions: (i) administrative targeting and accountability; (ii) definition and enforcement of land and resource rights; (iii) coordination of input, output, finance and risk markets; (iv) production and delivery of usable knowledge and data; and (v) collective coordination among farmers and between farmers and other actors. These functions are separable. A country can have competent payment administration but weak extension, or formal land records but poor access to finance. Treating them separately makes empirical hypotheses testable and prevents national governance indices from substituting for actual implementation mechanisms.

The framework therefore follows a six-stage chain: policy design → targeting and delivery → complementary services and institutions → farmer response → economic, social and environmental outcomes → feedback and redesign. At the targeting stage, leakage, capture or exclusion can alter who receives support. At the complementarity stage, absent credit, extension, storage or market access can lower the marginal return to a delivered subsidy. At the behavioral stage, information, trust, expectations and risk determine whether farmers change practice. At the outcome stage, production responses can create externalities—for example fertilizer or livestock emissions—unless environmental incentives are aligned. At the feedback stage, monitoring determines whether a programme learns from heterogeneity rather than reproducing it. The six-stage transmission chain and its stage-specific failure pathways are synthesized in Fig. 2.

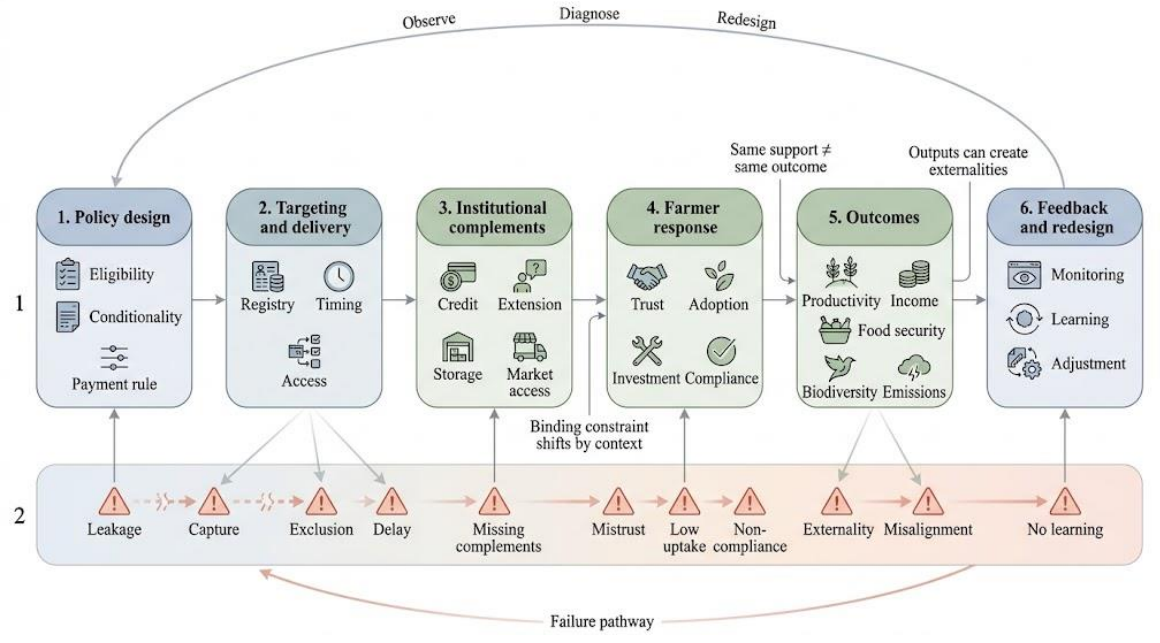


Figure 2. Six-stage policy-transmission chain and stage-specific pathways of policy failure.

Agricultural support is converted into outcomes through a sequence of analytically distinct stages: policy design, targeting and delivery, institutional complements, farmer response, outcomes, and feedback/redesign. At each stage, specific failures can emerge, including leakage, exclusion, missing complements, low uptake, externalities, and failure to learn, thereby reducing policy-conversion efficiency.

Table 1. Policy instruments as transmission problems: proximal responses, institutional dependencies and observable failure signatures.

Policy instrument	Proximal response	Institutional dependency	Failure signature	Illustrative evidence
Input/seed/fertilizer voucher	Lower effective input price; higher use	Registry quality, procurement, timely distribution, extension, output market	High redemption but weak yield/income response; exclusion or late delivery	Pauw (2022); Karata (2024); Wong et al. (2020)
Credit or finance support	Relax liquidity constraint; enable investment	Lender information, contract enforcement, repayment capacity, market return	Borrowing rises but adoption/productivity does not; adverse selection	Nakano and Magezi (2020); Ali et al. (2020)
Insurance subsidy	Reduce downside risk; stabilize investment	Risk data, basis-risk management, claims administration, trust	Low renewal; weak behavioral response; innovation effects vary	Kramer et al. (2022); Chemeris et al. (2022)
Area/direct income payment	Raise/ stabilize farm income	Land records, eligibility rules, payment system	Capitalization into land rents; incidence differs from nominal recipient	Ciaian et al. (2021); Piet and Desjeux (2021)
Agri-environmental practice payment	Adopt specified management action	Verification, advisory services, credible contracts	Enrollment without ecological additionality; low uptake when opportunity costs are high	Hasler et al. (2022); Schaub et al. (2023)

Result-based environmental payment	Deliver measured ecological outcome	Outcome indicators, monitoring, risk-sharing, appeals	Threshold gaming; high monitoring cost; farmer bears uncontrollable ecological risk	Elmiger et al. (2023); Schaub et al. (2025b); Hagemann et al. (2025)
Digital conditional transfer/monitoring	Target, verify or personalize support using data	Connectivity, data governance, interoperability, human support	Digitally invisible farmers excluded; unchallengeable classification errors	Meemken et al. (2024); Porciello et al. (2022)

Institutional Mechanisms Governing Policy Conversion Efficiency

Administrative capability, targeting and accountability

Administrative capacity affects both extensive and intensive margins of policy delivery. Beneficiary registries, procurement, payment systems, appeals, audit trails and local implementation determine who enters a programme, how much support arrives and when it arrives. These mechanisms are especially consequential where public budgets are large relative to local administrative capacity. The Ghana and Tanzania subsidy studies show that average programme labels conceal differences in implementation intensity, targeting and beneficiary composition (Pauw, 2022; Karata, 2024). Cross-country evidence linking institutional quality to the productivity effect of public agricultural spending provides complementary macro-level evidence, but it cannot by itself identify which administrative component is causal (Soko et al., 2023).

Targeting is not only a technical problem. Distribution can be shaped by political access and organized interests. Evidence from Russian agricultural subsidization documents redistributive patterns and office-holding incentives consistent with political-economy channels in programme allocation (Kvartiuk and Herzfeld, 2021, 2023). The relevant general lesson is not that subsidy capture is universal, but that the incidence of support is endogenous to institutional arrangements. For empirical evaluation, administrative records on application, eligibility, approval, payment timing and appeals are therefore more informative than expenditure totals alone. A mechanistic review should distinguish programme rules from realized delivery.

Accountability also determines the feasibility of more conditional instruments. Practice-based payments need verification that specified actions occurred; result-based payments need credible measurement of ecological outcomes. Reviews of result-based schemes identify monitoring costs, indicator selection, farmer risk and advisory support as recurrent constraints (Elmiger et al., 2023; Hagemann et al., 2025). A Swiss quasi-experimental evaluation finds that increases in result-based payments improved biodiversity for plots near the eligibility threshold, showing that carefully

defined administrative thresholds can generate measurable responses but also create discontinuous incentives (Schaub et al., 2025b).

Land and property institutions: security is a channel, not an endpoint

Land institutions can influence the return to subsidies by changing investment horizons, collateral possibilities, rental-market participation and the perceived risk of losing future benefits. Yet recent causal evidence rejects a deterministic relationship between formalization and investment. A randomized trial of tenure security finds that improved formal security does not automatically translate into broad investment responses, and a 2025 synthesis of counterfactual evaluations concludes that tenure interventions tend to improve perceived security and some investment outcomes while productivity, credit and welfare effects remain mixed (Huntington and Shenoy, 2021; Huntington and Lisher, 2025). The mechanism therefore depends on whether insecure tenure is actually the binding constraint.

Studies across Malawi, Zambia, China and Vietnam show why the distinction matters. Gendered land rights can change investment responses within customary systems; title can affect performance of large land-based investments; land certification can reduce misallocation; and tenure security can be associated with agricultural investment, but magnitudes and channels vary by setting (Deininger et al., 2021; Ali and Deininger, 2022; Gao et al., 2021; Bellemare et al., 2020). In China's apple sector, tenure security interacts with market-oriented farmland allocation, again indicating that property rights and market institutions are complements rather than substitutes (Li et al., 2021).

Two cautions are important. First, perceived security and formal documentation are not interchangeable: awareness and actual enforcement may differ (Vu and Goto, 2020). Second, stronger private rights can create environmental trade-offs when higher expected returns increase incentives to clear or intensify land; evidence linking land rights, productivity and deforestation illustrates this possibility (Abman and Carney, 2020). In Ghanaian cocoa landscapes, the relationship between tenure security and sustainable land management is also conditional rather than monotonic (Asaaga et al., 2020). Thus, a land reform can improve the investment channel without guaranteeing the environmental channel.

Markets, finance and value-chain institutions

A production subsidy creates durable income gains only if additional output can be financed, stored, transported and sold on acceptable terms. Meta-analysis of entry into high-value markets identifies credit, assets and cooperative membership among recurrent determinants of participation, while evidence from Eastern Africa links market access with dietary diversity and food security (Ola and Menapace, 2020; Usman and Haile, 2022). Research on developing-country value chains further emphasizes market power, contracting, quality standards and coordination costs rather than treating commercialization as a frictionless consequence of higher production (Macchiavello et al., 2022).

Aggregation institutions can reduce these frictions, but they are not automatically inclusive. A global scoping review of aggregation models finds multiple pathways—cooperatives, producer companies, contract arrangements and other intermediaries—with benefits that depend on governance, service bundles and buyer relationships (Abraham et al., 2022). Broader evidence on 'inclusive business' similarly shows that value-chain inclusion can redistribute risks and returns in ways not captured by participation rates alone (German et al., 2020). This matters for subsidy evaluation because a programme can increase physical output while leaving farm-gate bargaining conditions unchanged.

Finance and insurance operate as complementary institutions when policy-induced investments require working capital or when risk suppresses adoption. A randomized microcredit intervention in Tanzania increased technology adoption and productivity through access to capital, illustrating how financial constraints can be binding independently of input prices (Nakano and Magezi, 2020). Insurance evidence is more conditional: demand is sensitive to basis risk, liquidity and trust, and subsidized insurance can affect innovation and yield resilience but may also change incentives in ways that require careful design (Ali et al., 2020; Chemeris et al., 2022). The implication is that 'credit access' or 'insurance availability' should be measured as a mechanism—terms, timing, information and claims performance—not as a binary institutional attribute.

Knowledge, extension and digital systems

Technology support fails when farmers receive an input without the knowledge required to use it profitably under local conditions. Meta-analyses of agricultural technology adoption show substantial heterogeneity associated with technology traits, information, context and study design (Ruzzante et al., 2021; Schulz and Börner, 2023). Evidence from West Africa also shows that exposure to technology programmes can influence adoption, while field research demonstrates that the identity and credibility of the information source affects uptake (Bambio et al., 2022; Arslan et al., 2022). In this mechanism, extension is not a generic 'complementary service'; it changes perceived returns, uncertainty and implementation quality at the farm level.

Digitalization can reduce information and monitoring costs but can also move the bottleneck. Reviews of digital agricultural services in low- and middle-income countries identify uneven evidence on sustained welfare effects and recurrent constraints in connectivity, affordability, literacy and business models (Porciello et al., 2022; Choruma et al., 2024). A recent African review similarly notes a large gap between the number of digital initiatives and evidence of widespread smallholder use or impacts on food security and environmental outcomes (Njuguna et al., 2025). Research on digital farming adoption emphasizes that technologies diffuse through farm characteristics and system interactions rather than through technical availability alone (Shang et al., 2021).

The institutional challenge becomes sharper when digital tools are used to determine eligibility or compliance. Remote sensing, machine learning and platform data can make sustainability monitoring more scalable, but the same systems can create data asymmetries, exclusion and

surveillance risks (Meemken et al., 2024). Economic analysis of AI-based agriculture similarly highlights fixed costs, data, interoperability, skills and uncertain returns as determinants of adoption (Khanna et al., 2024). Digitalization therefore changes the feasible frontier of targeting and verification, but only where governance covers data access, contestability and human support. Broader reviews of digital futures reach the same conclusion: digital tools are enabling infrastructure, not substitutes for institutions (MacPherson et al., 2022; McGrath et al., 2023).

Collective organizations and local coordination

Collective institutions affect the transaction costs of both public programmes and markets. A large scoping review of farmers' organizations finds more consistent evidence for income effects than for yield or product-quality effects, suggesting that aggregation often works through market access, services and bargaining rather than agronomy alone (Bizikova et al., 2020). Cooperative or group structures can also serve as channels for extension, credit and programme enrollment, but internal governance determines whether benefits reach smaller or less-connected members. This mechanism is especially important where public agencies cannot cost-effectively transact with many dispersed smallholders.

Collective institutions are also relevant to environmental support because ecological outcomes frequently cross parcel boundaries. Contract design research shows that coordination, risk allocation and the scale of the ecological target affect participation and performance (Bredemeier et al., 2022). Systematic evidence on agri-environmental participation further finds that advice, attitudes, opportunity costs, contract flexibility and local context shape enrollment; simple information nudges do not have uniform effects (Schaub et al., 2023). The 2026 multi-country farmer experiment under the CAP's green architecture similarly finds that behavioural messages had mixed effects, with some combinations affecting stated adoption while stand-alone interventions often did not (Barreiro-Hurle and Rommel, 2026). Taken together, these mechanisms operate as an interdependent institutional system in which the binding constraint can shift across policy settings, as synthesized in Fig. 3.

Administrative capability, land and property institutions, markets and finance, knowledge and digital systems, and collective coordination interact as an institutional bundle rather than as isolated determinants. Policy-conversion efficiency depends on complementarity across these mechanisms, while a weak or missing component can become the binding constraint that limits investment, adoption, commercialization, and sustainability-related outcomes.

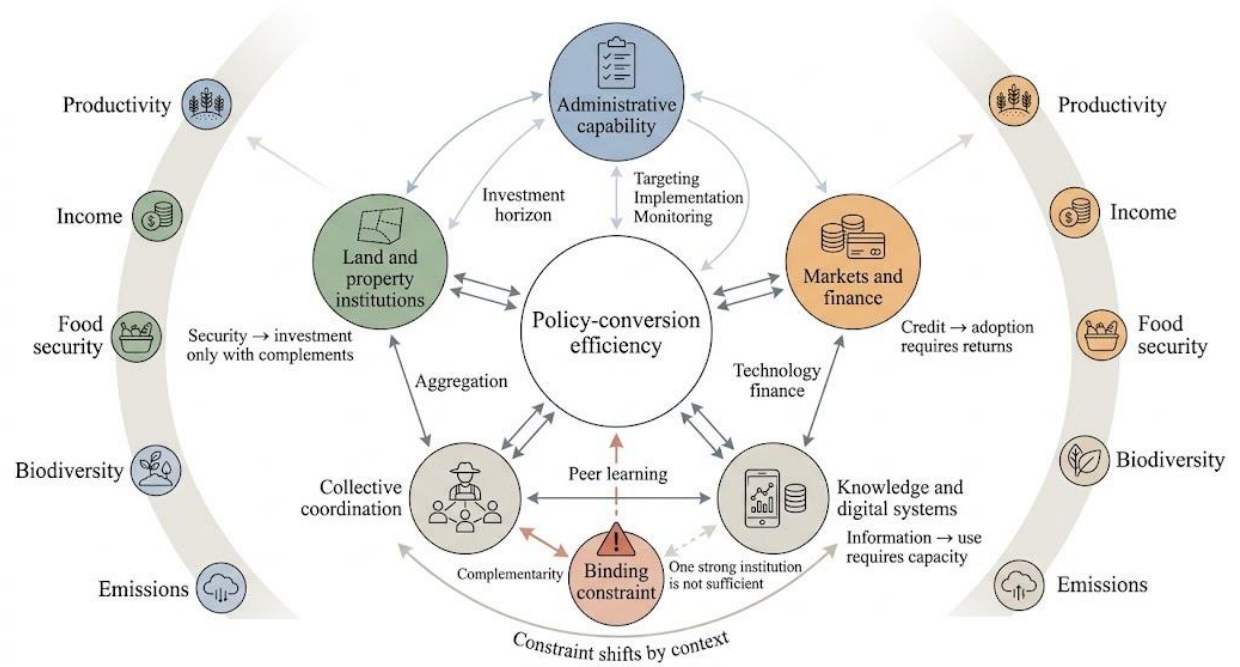


Figure 3. Institutional complementarity and binding constraints governing agricultural policy–conversion efficiency.

Table 2 complements this synthesis by linking each institutional mechanism to measurable diagnostics and characteristic policy–conversion failures.

Table 2. Institutional mechanisms, measurable diagnostics and characteristic policy–conversion failures.

Institutional mechanism	Transmission role	Observable diagnostic	Typical failure signature	Evidence base
Administrative capability	Converts formal rules into actual targeting, timing and payment	Application-to-payment time; error/appeal rates; geographic coverage	Leakage, exclusion, delayed inputs, cohort heterogeneity	Soko et al. (2023); Pauw (2022); Karata (2024)
Land/property institutions	Sets investment horizon and governs transfer/use rights	Perceived security; dispute rate; rental activity; investment by tenure status	Formal title with weak investment response; exclusion; land-use externality	Huntington and Shenoy (2021); Deininger et al. (2021); Abman and

				Carney (2020)
Market/finance institutions	Turns higher production capacity into profitable exchange and investment	Farm-gate margins; credit terms; storage/transport access; buyer concentration	Output grows but net returns do not; rationed credit; weak bargaining power	Ola and Menapace (2020); Macchiavello et al. (2022); Abraham et al. (2022)
Knowledge/extension systems	Changes information, perceived returns and correct use of technologies	Contact quality; source credibility; knowledge retention; repeat adoption	Input received but incorrectly used; adoption stops after support	Arslan et al. (2022); Ruzzante et al. (2021); Schulz and Börner (2023)
Digital/data institutions	Lower targeting and monitoring cost; enable adaptive advice	Connectivity; data completeness; interoperability; appeal pathways	Digital divide; algorithmic exclusion; data concentration	Porciello et al. (2022); Meemken et al. (2024); Njuguna et al. (2025)
Collective organizations	Aggregate demand/output, lower transaction costs, coordinate public goods	Service bundle; member participation; internal accountability	Benefits captured by better-connected members; weak representation	Bizikova et al. (2020); Bredemeier et al. (2022)

Comparative Evidence Across Agricultural Policy Regimes

Input-support programmes in low-income and smallholder systems

Input-support programmes remain a useful stress test for the transmission framework because their proximal objective—reduce the effective price of seed, fertilizer or another input—is relatively simple, whereas their distal objectives are not. Ghana's programme review documents simultaneous benefits and implementation weaknesses, and Tanzania's quasi-experimental evaluation finds that average productivity effects can disappear once timing and heterogeneous treatment are considered (Pauw, 2022; Karata, 2024). Experimental evidence from Ethiopia shows that a voucher and rainfall insurance solve different constraints, so bundling or sequencing can matter (Wong et al., 2020). These findings are inconsistent with evaluating programme quality by redemption rates alone.

The African technology literature further indicates that subsidies are most likely to raise productivity when farmers face a genuine adoption barrier and when complementary conditions make the technology profitable. A broad synthesis of agricultural technology in Africa emphasizes credit, risk, learning, infrastructure and market access as joint constraints (Suri and Udry, 2022). Microcredit evidence from Tanzania and multi-country technology-exposure evidence from West Africa support this complementarity interpretation (Nakano and Magezi, 2020; Bambio et al., 2022). Where these complements are missing, subsidy-induced input use can be real without being transformative.

The welfare endpoint can also differ from the production endpoint. Malawi evidence shows that input-support effects on child nutrition depend partly on complementary health and nutrition programmes (Mwale et al., 2022). This is an important warning against causal overextension: higher fertilizer use or maize output does not automatically imply improved nutrition, resilience or poverty reduction. A credible evaluation therefore specifies the outcome chain and tests the links rather than moving directly from programme participation to a broad claim of 'agricultural transformation'.

High-income support: CAP, risk management and environmental conditionality

High-income agricultural systems illustrate a different institutional problem: administrative capacity is relatively strong, but objectives are numerous and sometimes internally inconsistent. The CAP combines income support, sectoral instruments and agri-environmental measures. Farm-level analyses of direct-payment reform show heterogeneous economic effects, while distributional studies demonstrate that income support and land ownership patterns affect incidence (Espinosa et al., 2020; Piet and Desjeux, 2021). Environmental research adds that a large share of support remains connected to emissions-intensive production, so implementation competence cannot compensate for misaligned incentive design (Kortleve et al., 2024).

Agri-environmental evidence is more nuanced than either blanket success or blanket failure. A review of European agri-environmental policy identifies design, targeting, monitoring and transaction costs as central constraints (Hasler et al., 2022). Meta-analysis finds that arthropod diversity gains can coexist with yield trade-offs or win-wins depending on context and management (Marja et al., 2024). Farm-level work shows both direct and spillover effects of biodiversity schemes (Bonev, 2024), while result-based programmes increasingly attempt to pay for ecological outcomes rather than prescribed actions (Elmiger et al., 2023). Recent causal evidence from Switzerland and Germany indicates that thresholds and payment gradients can measurably change biodiversity outcomes, making incentive architecture an institutional design variable rather than a cosmetic feature (Schaub et al., 2025b; Schaub et al., 2025a).

Risk-management programmes have another information burden. Insurance must price risk, verify losses and maintain farmer trust. Reviews of developing-country insurance find that subsidies alone do not eliminate basis-risk, liquidity and understanding constraints, while evidence from crop-insurance subsidies in higher-income settings shows potential interactions with innovation and

resilience (Kramer et al., 2022; Chemeris et al., 2022). These programmes therefore depend on data institutions in addition to fiscal capacity.

Emerging economies: China and India as contrasting institutional configurations

China illustrates how subsidy redesign can alter environmental behavior when implemented through a broader structural setting. A difference-in-differences study of a new agricultural subsidy reports lower chemical-fertilizer use, with machinery adoption and farm scale acting as mediating channels (Fan et al., 2023). Separate modelling of fertilizer-policy reform shows that nitrogen-pollution reductions and food-security outcomes depend on the precise structure of fertilizer incentives rather than on a simple withdrawal of support (Wang et al., 2023). These studies support a mechanism-based interpretation: policy effects operate through changes in relative prices, production scale, technology and management, all of which are institutionally conditioned.

Land institutions are also central to China's transformation. Evidence on certification and farmland allocation indicates that secure or more transferable rights can reduce misallocation and improve productivity in some settings (Gao et al., 2021; Li et al., 2021). Yet the wider land literature cautions against treating formal title as sufficient, because investment and welfare responses vary with profitability, enforcement and complementary services (Huntington and Lisher, 2025). Thus, the analytically important contrast is not 'formal versus informal' tenure, but whether a rights system provides credible investment horizons and supports efficient exchange without excluding vulnerable users.

India's price-support debate illustrates a different transmission issue: formal support prices and realized procurement access are not equivalent. Evidence reviewing minimum support prices shows that the policy's practical incidence depends on crop, region, procurement and market access rather than on the announced price alone (Gupta et al., 2021). More broadly, the supply- and demand-side development literature emphasizes that public support interacts with markets, infrastructure and rural non-farm demand; focusing only on farm-gate incentives can miss the general-equilibrium pathway through which agricultural growth affects development (de Janvry and Sadoulet, 2020).

Cross-regime synthesis: five failure signatures

Across regimes, five recurring failure signatures are observable. First, delivery failure appears as late, incomplete or unequally distributed support. Second, complementarity failure appears when supported inputs or technologies are used but their marginal productivity remains low because finance, extension, irrigation or markets are missing. Third, incidence failure appears when nominal recipients are not the ultimate beneficiaries because support is capitalized into land values, captured by more connected actors or offset by market power. Fourth, behavioral failure appears when farmers do not adopt, comply or persist because risk, trust, information or opportunity costs dominate the incentive. Fifth, objective-alignment failure appears when a programme achieves its proximate output target while worsening another outcome, such as emissions or biodiversity. Figure 4 locates

these recurrent failure signatures within contrasting policy-regime configurations, while Table 3 anchors the comparison in study-level empirical evidence.

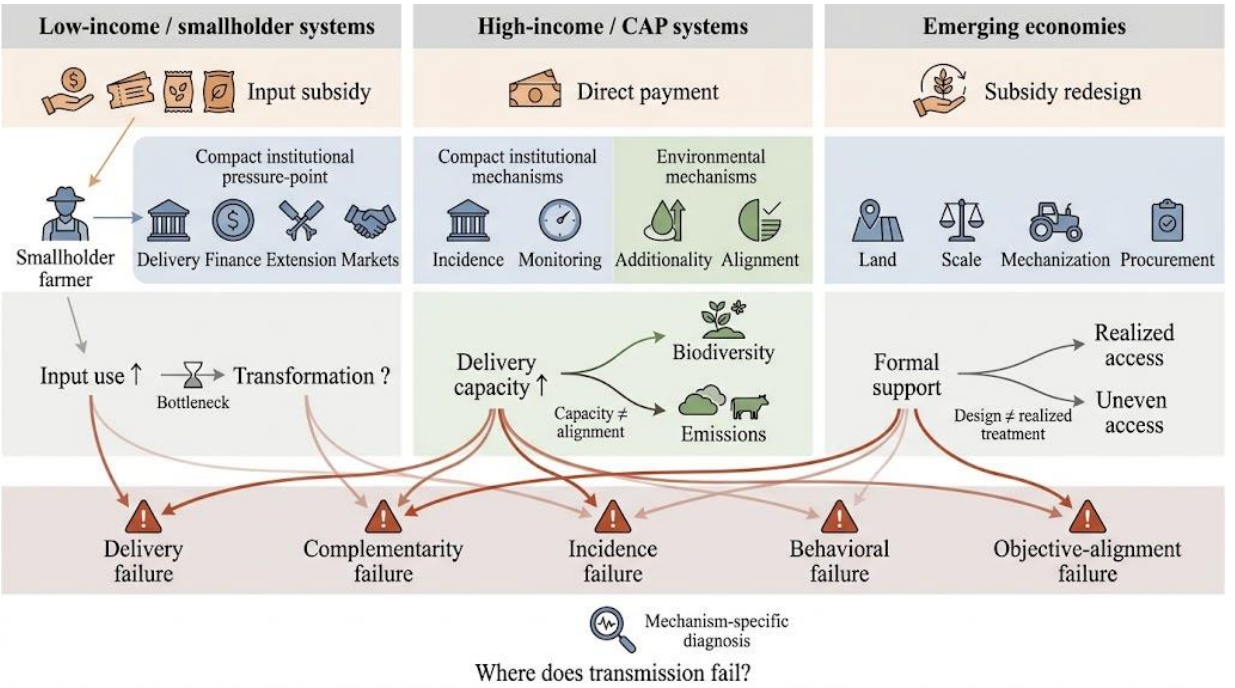


Figure 4. Cross-regime heterogeneity in agricultural policy transmission and recurrent failure signatures.

Low-income and smallholder systems, high-income support architectures, and emerging economies face different institutional bottlenecks despite using overlapping forms of agricultural support. These configurations generate different combinations of delivery, complementarity, incidence, behavioral, and objective-alignment failures, emphasizing the need to diagnose where the policy-transmission process breaks down.

These signatures also show why cross-country institutional indices are useful but insufficient. They can identify broad associations and heterogeneity (Lin et al., 2024), but they rarely identify the stage at which the policy chain fails. Programme-level evidence is required to determine whether a low response reflects targeting, delivery, risk, knowledge, market access or a nonbinding constraint. A mechanistic review therefore gives greater inferential weight to studies that observe a concrete transmission stage, use quasi-experimental or experimental variation, or synthesize mechanism-specific evidence than to studies that correlate aggregate spending with aggregate outcomes.

Table 3. Comparative empirical evidence interpreted through the policy–transmission framework.

Setting / instrument	Identification or evidence type	Institutional condition observed	Supported finding	Mechanistic interpretation
Ghana input support	Programme review	Targeting, implementation and fiscal/market context	Benefits coexisted with implementation weaknesses	Delivery quality and complementary conditions determine conversion beyond input distribution (Pauw, 2022)
Tanzania NAIVS	Staggered difference-in-differences	Rollout timing and beneficiary/farm-size heterogeneity	No clear average productivity gain; effects varied by cohort and farm size	Average treatment effects can mask targeting and implementation heterogeneity (Karata, 2024)
Northern Ethiopia vouchers + rainfall insurance	Experimental evidence	Liquidity and risk constraints addressed separately	Different instruments affected production/welfare through different channels	Instrument bundles should be interpreted by the constraint each component relaxes (Wong et al., 2020)
EU direct payments	Farm-level policy simulation/evaluation	Eligibility, farm structure and payment design	Economic effects varied across farms and regions	Administrative uniformity does not imply homogeneous incidence

				(Espinosa et al., 2020)
EU biodiversity schemes	Meta-analysis + farm-level evaluation	Management context, enrollment and spillovers	Biodiversity gains coexist with yield trade-offs and spillovers	Ecological scale and opportunity cost matter for additionality (Marja et al., 2024; Bonev, 2024)
Switzerland/Germany result-based payments	Quasi-experimental evaluations	Outcome thresholds and payment gradients	Biodiversity response depended on threshold design	Monitoring and incentive function are causal design components (Schaub et al., 2025b; Schaub et al., 2025a)
China subsidy/fertilizer reform	Difference-in-differences + policy modelling	Farm scale, mechanization and input-price incentives	Redesigned support reduced fertilizer use in one study; broader reforms show food–nitrogen trade-offs	Support can induce input-saving behavior when the policy changes the relevant production margin (Fan et al., 2023; Wang et al., 2023)
India minimum support prices	Policy evidence synthesis	Procurement access differs by crop and region	Announced support and realized access are not equivalent	Implementation reach is part of the treatment (Gupta et al., 2021)

Sustainability, Climate Risk and Digital Conditionality

Environmental leakage and climate externalities

The sustainability question is not whether support is environmentally 'good' or 'bad' in the abstract, but which production margin it changes. Global analyses show that agricultural subsidies can alter greenhouse-gas emissions through commodity composition, production levels and trade; alternative reform packages therefore produce different health, climate and economic effects (Laborde et al., 2021; Springmann and Freund, 2022). EU evidence that support is concentrated in emissions-intensive animal-product systems reinforces the need to trace the commodity pathway of payments (Kortleve et al., 2024). In China, by contrast, a redesigned subsidy was associated with reduced fertilizer use, demonstrating that support can also induce input-saving responses when its design changes the relevant margin (Fan et al., 2023).

Environmental externalities also expose spatial leakage. If a conservation payment changes management only on enrolled land, production or pressure may shift elsewhere. Farm-level evidence of spillovers from biodiversity schemes shows why evaluations need a whole-farm or landscape counterfactual rather than a treated-parcel comparison alone (Bonev, 2024). Land-rights evidence adds another leakage mechanism: stronger rights can raise investment incentives but can also increase returns to land conversion, linking productivity and deforestation in some settings (Abman and Carney, 2020). Sustainability therefore depends on the interaction between private incentives, ecological scale and monitoring boundaries.

Result-based incentives, monitorability and farmer risk

Result-based payments are conceptually attractive because they link public expenditure more directly to the public good. Their institutional burden is correspondingly high. Indicators must be ecologically meaningful, observable at acceptable cost, resistant to manipulation, and sufficiently under farmer control that participation is not dominated by uncontrollable weather or ecological noise. Reviews of indicator design and result-based schemes repeatedly identify this monitorability-risk trade-off (Elmiger et al., 2023; Hagemann et al., 2025). Contract design must also address heterogeneity in opportunity costs and uncertainty, otherwise a scheme can be ecologically precise but unattractive to farmers (Schaub et al., 2023).

Recent evaluations show that small design details can matter. Swiss evidence indicates that payment increases affected biodiversity mainly for plots close to the eligibility threshold, and German evidence finds that multiple ecological thresholds can outperform a single threshold for bird diversity (Schaub et al., 2025b; Schaub et al., 2025a). These studies do not establish a universal superiority of result-based payments; rather, they demonstrate that the slope, threshold and observability of the payment function are causal components of policy design. Hybrid contracts may therefore be interpreted as risk-sharing devices that combine minimum actions with outcome-contingent rewards, not merely as compromises between two policy philosophies.

Participation itself remains a behavioral outcome. A systematic review finds that training, advice, profitability, implementation effort and contract flexibility are among the more consistently related factors in voluntary agri-environmental participation, whereas many attitudinal variables have context-dependent effects (Schaub et al., 2023). A large pre-registered farmer experiment under the CAP's current green architecture likewise finds that informational framing produces mixed and combination-specific effects rather than a uniform nudge response (Barreiro-Hurle and Rommel, 2026). The implication is that communication can alter uptake at the margin, but cannot substitute for credible payments, manageable risk or administratively workable contracts.

Adaptive and digital monitoring without digital exclusion

Climate risk increases the value of adaptive institutions because optimal practices and expected returns change with weather, prices and technology. Cross-country evidence from West Africa associates bundled climate-smart practices with higher productivity and food security, while a China-focused meta-analysis shows that adaptation behavior is conditioned by multiple economic, informational and institutional factors (Tabe-Ojong et al., 2023; Huang et al., 2024). Co-produced climate information can improve the uptake of climate services when information is locally usable rather than merely available (Chiputwa et al., 2020). These findings support a dynamic view of institutions as systems that learn, update and communicate rather than static rulebooks.

Digital monitoring may expand this adaptive capacity. Remote sensing, smartphones and machine learning can lower the cost of observing land use, crop condition and some environmental proxies, allowing more frequent feedback and potentially more targeted payments (Meemken et al., 2024). Yet digital evidence also identifies persistent divides in connectivity, skills, affordability and platform access (Porciello et al., 2022; Barbier, 2023). In smallholder African settings, reviews emphasize that access to a tool does not guarantee repeated use, profitable decisions or equitable benefit distribution (Choruma et al., 2024; Njuguna et al., 2025).

This creates a new institutional failure signature: digital conditionality can improve measurement while excluding farmers who cannot generate acceptable data. The relevant design questions are therefore who owns the data, how errors are appealed, whether low-connectivity farmers have an alternative channel, and whether algorithms are auditable. The digital-transition literature treats interoperability, advisory capacity and governance as part of the technology system itself (MacPherson et al., 2022; Ma, 2023). AI adoption research reinforces this point by showing that data, fixed costs, complementarities and uncertainty determine economic uptake (Khanna et al., 2024).

Design Implications and Research Agenda

Match instrument complexity to institutional capacity

The evidence supports a neutral diagnostic principle: the information and enforcement burden of an instrument should be made explicit before its expected benefits are compared. Untargeted input support can be administratively simple but weakly aligned with distributional or environmental

objectives. Targeted transfers require registries and verification. Insurance requires risk and loss information. Result-based environmental payments require ecological measurement and credible attribution. Moving toward a more conditional instrument can improve targeting in theory while reducing realized coverage or increasing transaction costs if the supporting institutions are absent. Table 4 converts this principle into measurable prerequisites rather than a ranking of instruments.

A second implication is that minimum institutional bundles are mechanism-specific. Technology support is more likely to convert into productivity when knowledge, finance and markets are jointly available; meta-analyses show that adoption depends on both technology traits and context (Ruzzante et al., 2021; Schulz and Börner, 2023). Commercialization depends on market coordination and aggregation rather than production alone (Ola and Menapace, 2020; Abraham et al., 2022). Long-horizon land investments depend on tenure security, but recent impact-evaluation evidence shows that secure rights alone do not guarantee productivity or credit effects (Huntington and Lisher, 2025). The analytical unit should therefore be the bundle around a specific causal channel, not an omnibus index of institutional quality.

Third, institutional capacity and objective alignment must be evaluated separately. Highly capable systems can deliver a payment exactly as specified while the payment still induces environmentally costly production. The CAP evidence on emissions-intensive support and the global modelling literature make that distinction concrete (Kortleve et al., 2024; Laborde et al., 2021). Conversely, a modest programme can produce locally valuable outcomes when it resolves a binding constraint and is coupled with complementary services. This is why the proposed framework avoids treating institutional quality as a normative score and instead asks what function is required for what outcome.

Table 4. Instrument–institution matching: prerequisites and monitoring variables for mechanism-specific evaluation.

Policy objective	Instrument feature to evaluate	Minimum institutional prerequisite	Core monitoring indicator	Key evidence / unresolved trade-off
Raise input adoption	Targeting and subsidy depth	Registry + reliable supply + extension	Timeliness, redemption, incremental input use, yield response	Technology effects are context-dependent; avoid equating redemption with productivity (Ruzzante et al., 2021; Suri and Udry, 2022)

Stimulate long-term investment	Eligibility tied to land/user status	Credible tenure and dispute resolution + profitable investment options	Investment by tenure group; rental response; disputes	Tenure security often helps but is not sufficient for productivity/credit effects (Huntington and Lisher, 2025)
Increase commercialization	Link support to aggregation/market access	Transport, storage, contracting, finance, collective governance	Farm-gate margin, rejection rate, marketed share, buyer concentration	Participation can rise without balanced value capture (German et al., 2020; Macchiavello et al., 2022)
Improve resilience	Insurance/risk transfer + adaptive information	Risk data, claims integrity, trusted advisory system	Renewal, basis risk, investment under shocks, post-shock recovery	Subsidy cannot compensate for poor product quality or information (Kramer et al., 2022; Chiputwa et al., 2020)
Deliver biodiversity	Practice vs. result-based payment; threshold slope	Ecological indicators, verification, advisory support, risk sharing	Additionality, species/habitat response, leakage, transaction cost	Results depend on indicator and incentive architecture, not only payment size (Elmiger et al., 2023; Schaub et al., 2025a; Schaub et al., 2025b)
Enable digital targeting/monitoring	Data source, algorithm and appeal process	Connectivity, interoperability, data rights, offline alternative	Coverage gaps, false classifications, appeals, differential uptake	Digital monitoring can reduce cost while creating new exclusion and governance risks (Meemken et al., 2024; Khanna et al., 2024)

Sequencing, complementarity and policy learning

Sequencing matters when one institution raises the return to another. Secure land rights may have little effect where profitable technologies, credit or market access are absent; credit may have little effect where technologies are low-return; extension may have little effect where farmers cannot finance adoption. Evidence from land reforms, microcredit and technology adoption demonstrates these interactions across settings (Huntington and Shenoy, 2021; Nakano and Magezi, 2020; Arslan et al., 2022). Because multiple constraints can bind simultaneously, evaluations that estimate only the average effect of a single component can understate the value of a complementary package or overstate a component that happened to be introduced in a favorable institutional environment.

The same logic applies to environmental programmes. A result-based payment requires indicators and monitoring, but participation also depends on opportunity costs, advice and perceived risk. Reviews of agri-environmental contracts and participation show that ecological targeting and farmer acceptability are jointly determined (Bredemeier et al., 2022; Schaub et al., 2023). Digital monitoring can reduce verification costs but needs contestability and alternative access channels (Meemken et al., 2024). Institutional learning therefore requires programme data that link design, delivery, behaviour and outcomes over time rather than periodic reporting of expenditure and enrollment only.

Research and innovation systems are a long-run complement often omitted from subsidy debates. R&D effects can emerge with long and uncertain lags, and estimates of those lags materially affect measured returns (Alston et al., 2023). Mission-oriented innovation research further emphasizes coordination among public research, private actors and users rather than a linear pipeline from laboratory to farm (Klerkx and Begemann, 2020). Resource-efficiency research similarly shows that technologies need economic incentives and system integration to improve outcomes across food, energy and water dimensions (Miao and Khanna, 2020). A review of policy support that ignores these slower institutional assets will systematically favor instruments with immediate, measurable transfers.

Research priorities: causal mechanisms, distribution and measurement

Three research gaps are especially important. First, causal identification should move from 'institutional quality × spending' interactions toward mechanism-specific variables. Cross-country panel studies are useful for establishing broad regularities, but governance indicators are aggregated, persistent and endogenous (Soko et al., 2023; Lin et al., 2024). Programme studies can instead exploit administrative thresholds, staggered rollouts, randomized information, registry reforms or digital-payment transitions to isolate targeting, monitoring, trust or delivery mechanisms. The strongest recent examples already use discontinuities, randomized trials and modern staggered difference-in-differences designs (Huntington and Shenoy, 2021; Karata, 2024; Schaub et al., 2025b).

Second, distribution needs to be treated as an outcome mechanism. Average farm income can rise while landowners capture part of a transfer, larger farms are more likely to be treated, or digitally connected farmers enter first. Evidence on capitalization, subsidy targeting, farmer organizations and digital divides show multiple routes to heterogeneous incidence (Ciaian et al., 2021; Karata, 2024; Bizikova et al., 2020; Barbier, 2023). Future evaluations need heterogeneity by farm size, tenure status, gender, connectivity and market position, but also tests of why that heterogeneity arises. Merely reporting subgroup coefficients does not identify the institutional mechanism.

Third, outcome measurement must match the policy claim. Productivity requires physical or value productivity, not input redemption; resilience requires performance under shocks, not only mean income; food security requires consumption or access measures, not only cereal output; biodiversity requires ecological indicators, not enrollment; and climate mitigation requires net emissions across possible leakage channels. Recent work on policy indicators, digital sustainability monitoring and result-based biodiversity measurement provides practical foundations for this shift (Brooks, 2023; Meemken et al., 2024; Elmiger et al., 2023). A compact research template is to report the instrument, institutional prerequisite, proximal response, distal outcome, counterfactual, distributional incidence and externalities in the same causal chain. Figure 5 integrates these elements into an adaptive mechanism-based cycle for policy diagnosis, evaluation, learning and redesign.

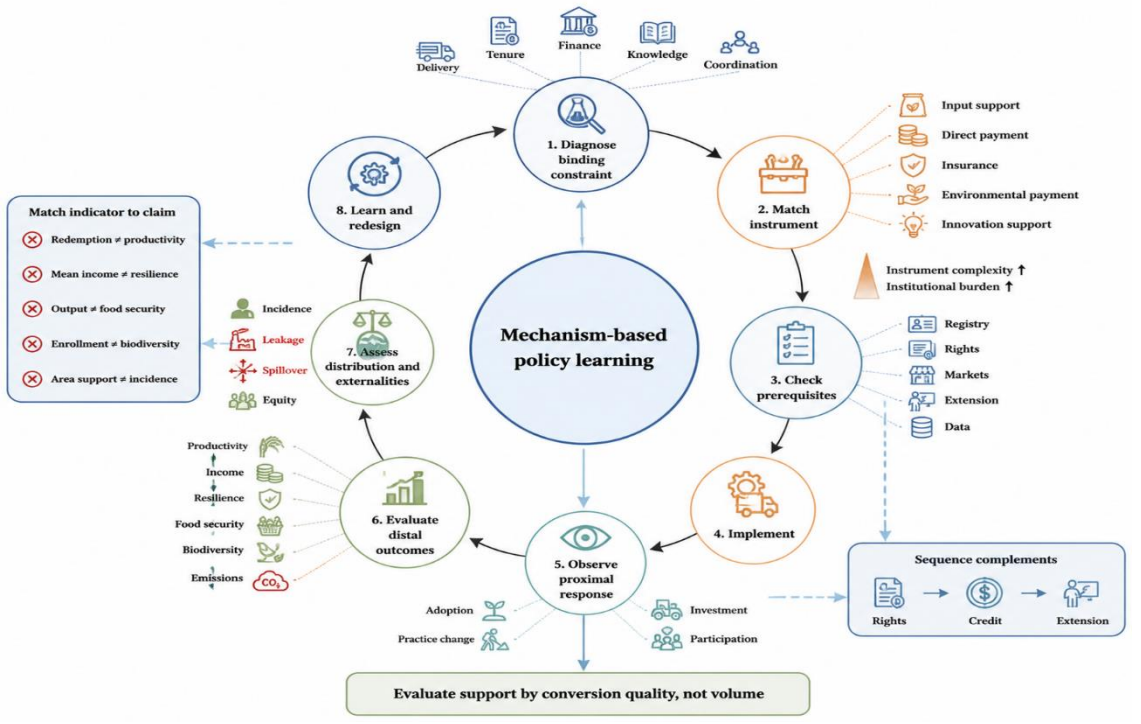


Figure 5. Adaptive mechanism-based framework for diagnosing, evaluating, and redesigning agricultural support.

Effective evaluation begins with diagnosis of the binding constraint, matches instruments to the relevant mechanism, verifies institutional prerequisites, and then tracks proximal responses, distal outcomes, distributional incidence, and externalities within a feedback loop of learning and redesign. The framework emphasizes that indicators must match policy claims and that support should be judged by conversion quality rather than fiscal volume alone.Conclusion

The evidence reviewed here supports a more specific interpretation of institutional quality in agricultural policy. Institutions are not a background country characteristic that can be appended to a subsidy model; they are the transmission infrastructure through which public support is targeted, delivered, combined with complementary services, interpreted by farmers and converted into economic and environmental outcomes. Decomposing that infrastructure into administrative capability, land institutions, markets and finance, knowledge and digital systems, and collective coordination explains why the same nominal instrument can produce different outcomes across places and groups.

This mechanistic view also imposes discipline on causal claims. Input use is not transformation; payment delivery is not implementation success; formal land rights are not equivalent to investment; digital access is not effective use; and administrative capacity is not synonymous with environmental alignment. Recent evidence provides counterexamples to each shortcut. The practical research task is therefore to identify the failure stage and test the binding constraint rather than to infer institutional weakness from an unfavorable outcome.

For future review and empirical work, the most productive unit of analysis is the policy–transmission chain: design → targeting and delivery → institutional complements → farmer response → multidimensional outcomes → feedback. This chain accommodates both productivity and sustainability and can be examined with measurable diagnostics. It also clarifies the scope of evidence: some studies identify delivery effects, others adoption effects, others environmental consequences. A credible synthesis should preserve those boundaries. Agricultural support is most informative when evaluated not by its fiscal volume, but by how reliably the institutional system converts each unit of support into the intended outcome without shifting unacceptable costs to other farmers, places, or environmental domains.

Author contributions

Muhammad Ishaq: Conceptualization, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Zunaira:** Formal analysis, Writing – review & editing. **Sehrish:** Visualization, Formal analysis. **Iqra Tariq:** Writing – review & editing.

Declarations

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Not applicable.

Consent for publication

Not applicable.

Availability of data and material

No new data were generated in this study.

Competing interests

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