Agriculture Sector Cost-Benefit Analysis Guidance

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INTRODUCTION

MCC is required by statute to conduct cost benefit analysis (CBA) and to calculate the economic rate of return (ERR) on projects supported through compacts.[1] ERRs are a critical part of the project approval process and are required to exceed a threshold level of ten percent over the life of the CBA. Economists in MCC's Economic Analysis (EA) Division conduct CBAs in a variety of sectors, including for programs based on policy and institutional reform. To clarify sector-specific methodology and to achieve an appropriate level of consistency across models, the EA Division is developing sector-specific CBA guidance. The CBA guidance for the *water and sanitation* (Osborne, 2019), *land* (Bowen and Ngeleza, 2019), *energy* (Epley et al., 2021), and transport (Carter, 2020) sectors have each been completed, and guidance for the education and health sectors are forthcoming. This guidance focuses on agricultural projects and is intended to serve three purposes: 1) to help economists charged with developing CBAs understand available methodological tools, and the relationships between various project types and features and ERRs; 2) to provide greater clarity to external practitioners and economists in partner countries and other agencies on the methodologies used at MCC to construct CBAs and estimate ERRs; and 3) highlight key project monitoring considerations. This is a living document that will be updated periodically.

As of December 2022, MCC had funded $1.7 billion in agricultural interventions spanning infrastructure, producer organizational development, policy and regulatory reform, market development, resource management, research, and finance. Weighted by the dollar value of programming expenditures, most agriculture investments have centered on irrigation infrastructure. Benefit-cost ratios associated with and independent evaluations of MCC's agriculture projects have produced a mixed record. On one end, costly irrigation investments have yielded modest results, while on the other, some policy reforms appear headed for high payoffs.[2] Before considering the details of MCC's agricultural interventions, the next section reviews the ways in which agricultural productivity typically evolves and contributes to broader economic growth.

AGRICULTURE, ECONOMIC GROWTH, AND POVERTY

MCC aims to reduce poverty through economic growth. Agricultural growth in particular can play an outsized role in poverty reduction, and (on a per growth episode basis) is estimated to reduce poverty two to three times more effectively than is the case for non-agriculture sectors (Christiaensen and Martin, 2018). In developing economies, agriculture figures critically in structural transformation, the process by which an economy transitions away from rural, subsistence agriculture into more modern activities, including commercial agriculture as well as (primarily urban) services and manufacturing. Countries with large shares of labor in agriculture, large rural shares of population, and low agricultural productivity struggle to create conditions for rapid, sustainable growth. The mechanisms that transform such economies occupy a lively literature, and agriculture's role, its contribution to human survival and health through the production of food, stands out.[3]

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1 The ERR is a key result of a CBA and is the interest rate which sets the discounted sum of net benefits equal to zero. Intuitively, the ERR estimate takes on higher values when benefits are high relative to costs, and events which happen sooner in time have a greater impact on the estimate than events which happen later.

2 More on evaluations of MCC agriculture projects is available *here*.

3 Other well-known drivers of economic growth include quality of institutions, technology, and higher levels of human capital (Dell, 2010; Acemoglu et al., 2002; Hanushek and Woessmann, 2008). Research has delved beyond these proximate drivers into

In stylized two-sector, closed economy models of structural transformation, most workers begin in subsistence farming and exhibit preferences such that food consumption precedes that of all other goods until caloric and nutrition needs are met (Gollin et al., 2002, 2007). In one transformation scenario, agricultural productivity growth raises crop yields, first satisfying agricultural workers' food needs and, later, generating a marketable surplus. Income from the sale of these surpluses stimulates demand for goods and services produced off-farm. Meanwhile, owing to these same surpluses, food supplies increase and prices fall. Over time, per-worker productivity improvements reduce demand for on-farm labor, including children who are freed to attend school. Also, and critically, lower food prices both raise real incomes off-farm and lower labor costs for firms. No longer dependent on land for food, workers migrate to cities, where opportunities for growth further proliferate across a more diverse array of activities. This pattern of transformation, observed over history across Europe, the Americas, and throughout East Asia, presents a straightforward model of agriculture's role in driving early-stage economic growth.[4],[5] As Section 3 below makes clear, explicit consideration of structural transformation highlights several novel ways in which MCC economists might model benefits from agriculture projects.

Structural transformation and its attendant economic growth can take generations to unfold, but in principle, productivity growth in agriculture can also help achieve short-term gains in income, particularly among poor farmers and anyone able to obtain employment within better-developed value chains. More input use, improved technologies, better transportation and storage infrastructures, and more market information can all contribute to higher farm-household incomes and a raft of other indicators of well-being, e.g., higher consumption, asset growth, improved nutrition and poverty reduction (Gollin et al., 2021; Takahashi et al., 2019). Among these inputs are seed varieties bred for higher yield, drought- or flood-resistance, or enhanced nutrient content, as well as yield-boosting fertilizers and pesticides. Better technologies supported by markets and training, including irrigation, mechanization, and soil mapping, not only confer direct benefits in terms of reduced input and labor costs, but also amplify the benefits of seed and fertilizer inputs. Transportation infrastructure, in addition to connecting rural producers to larger markets, can also ease access to critical inputs such as fertilizer. Better roads allow perishable goods to travel longer distances with less spoilage and loss. With better storage options, producers can ease the seasonal glut of harvest and its attendant downward pressure on prices (Omotilewa et al., 2018). Storage also boosts producer sale price prospects by allowing sellers to consider higher offers in the future.

But research points to several causes behind farmers' inability or unwillingness to adopt more modern practices and technologies (Suri and Udry, 2022). Farmers could simply lack information and skills. Export restrictions can discourage cultivation in cash crops. Credit constraints are often present. Without cash on hand, farmers must rely on finance to obtain inputs for production, but well-known market failures prevent loans from being available. (See Section 8 for a discussion on Blended Finance.) Missing markets

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so-called "deep determinants" of growth, including geographic conditions linked to agricultural production, disease prevalence, and access to waterways, as well as the diversity and density of early population centers (Henderson et al., 2018; Galor, 2005).

4 Early human civilizations first emerged from settlements that gradually adopted cultivation of crops that could be stored, i.e., grains like wheat, rice, and corn (Diamond, 1997; Bairoch, 1998). Storage facilitated a greater stability in consumption over time, and granaries became storehouses of wealth. Over time, hierarchical authorities emerged to manage food and the land resources it demanded, giving rise to increasingly sophisticated forms of government (Mayshar et al., 2022).

5 Open-economy models suggest that countries with comparative advantages in agriculture will specialize in agricultural production, potentially forestalling structural transformation of the sort described here (Matsuyama. 1992). That said, trade openness also plays a key role in economic growth, particularly insomuch as it offers markets for export-oriented production and potentially absorbs productivity-enhancing technologies into domestic production.

in insurance further expose growers to risky production and market conditions, and ultimately financial or health jeopardy. Aversion to risk is particularly high among poor farmers who must weigh uncertain gains against the possibility of starvation or destitution, which can discourage adoption of unfamiliar technologies (Omotilewa et al., 2018). Other crop features, including storability, taste, and processability, also factor into farmers' adoption decisions.[6] Adoption decisions and outcomes are also affected by how new technologies fit within the livelihood and income strategies of farmers that differ by socioeconomic status, gender, and cultural context, facing different vulnerabilities, power relationships, and institutional environments.[7] Understanding these multiple, simultaneous challenges and how MCC interventions can help address them are ongoing themes of this guidance.

Separately, the question of beneficiaries arises. Traditionally, projects in agriculture aim to raise the productivity and, by extension, the incomes of smallholder, subsistence-oriented farmers.[8] A major challenge with this approach is the tension between the scientific and skill-intensive characteristics of modern production agriculture and the capacity of smallholders to absorb technical knowledge and orient their production to markets, particularly in settings where rates of literacy and numeracy are low. This "human capital" constraint underlies much of the challenge in effectively applying inputs, accessing finance, and delivering services to many farmers in low-productivity settings. For these reasons, smallholders have often proven to be difficult targets for productivity improvement.[9]

As an alternative, projects can focus on improvements to agriculture as a sector and in turn, identify broader poverty-reducing benefits. Rather than targeting interventions to smallholders, projects may simply target the rural poor, recognizing that the majority are best served by opportunities for either commercial agriculture or off-farm employment. Rural investments in agriculture-adjacent activities (e.g., input supply, food processing, transport and logistics, and cold chains) present an opportunity for the rural poor to escape subsistence farming and either move into commercial agriculture or engage in waged labor that at once absorbs and sustains upstream production and diversifies the labor force into manufacturing and service sectors. Where market failures prevent such investments from being made, MCC could help.

In this case, benefits could accrue not just to more productive farmers and newly employed workers off-farm, but also to consumers whose access to affordable, nutritious food rises. Lower food prices raise real incomes, a critical benefit to poor households that spend up to half their budgets on food. And as highlighted above, with higher real incomes, demand grows for non-food goods and services, including housing, healthcare, education, as well as consumer products, triggering the diversification and growth of the economy, both rural and urban, across an array of sub-sectors. In parallel, as on-farm productivity rises (e.g., through mechanization), demand for on-farm labor falls, freeing women, children, and youth to

6 In Sierra Leone, for example, adoption of higher yielding varieties of NERICA rice remains very low, in part due to the seed's shorter maturation period which compels farmers to harvest before the rainy season ends. Without dryers or even covered surfaces, farmers resort to drying rice under the sun. But seasonal rains threaten the exposed grains with moisture, causing them to germinate and rendering them unsuitable for commercial markets.

7 See Adato and Meinzen-Dick (2007) for more.

8 This focus on smaller farms was motivated in part by the evidence of an inverse relationship between farm size and productivity. More recently, the validity of this evidence has come into question.

9 One potential small farm-based approach would be to link farmers to large buyers in the form of outgrower schemes. MCC has considered piloting such programs in recent compacts. See Barrett et al. (2022) for more.

pursue off-farm jobs, more education, and other productive activities. While a large literature documents these multiple streams of benefits, many of these outcomes do not materialize quickly, cannot be easily tied to a particular intervention, and are often difficult to observe and measure. All this may complicate efforts to identify and quantify benefits for CBA purposes, but notwithstanding these challenges, recognizing these benefits not only can help guide the design of investments, but also inform discussions surrounding CBA work and offer additional context to decision makers weighing investment decisions.

Finally, there are potentially sizable economic gains associated with addressing the generally weak position of women in commercial agriculture. Gender norms, including those related to domestic responsibilities, the freedom to occupy public space, control over household assets and labor, and norms which define cash crops as inherently "male," drive substantial gender gaps in agricultural productivity and often lead women to concentrate in lower-value cultivation and limit their access to markets and storage facilities.

OVERVIEW OF AGRICULTURE INTERVENTIONS

The challenges and risks facing producers in the agriculture sector and the range of actors across its diverse value chains motivate an overview of the broad landscape of agricultural interventions.[10] Beginning with on-farm production, research and donor agencies have addressed a variety of critical inputs:

- **Seeds:** In most low-productivity settings, low quality seeds are a common technical constraint. Efforts to develop genetically modified crops, or breed, distribute, and regulate seeds of higher yielding, more climate-resilient, and more nutritious varieties, optimized for a location's soils and climate, can have a variety of impacts. In particular, such efforts can raise yields, reduce down-side risks, and ultimately improve the health and livelihoods of rural households. (Examples *here* and *here*.)
- **Water:** Improving access to water, whether through irrigation or improved water resource management, can dramatically elevate the productive potential of farmers, raising and stabilizing their yields, permitting multiple crops per season, diversifying the mix of crops, and generally protecting farmers from droughts. With irrigation-related technology arises the need for power sources for operation, and on- and off-grid solutions for power become relevant (Mashnik et al., 2017). Also, as we discuss below, successful irrigation investments frequently involve new forms of governance and legal arrangements.
- **Fertilizer, pesticides, and other chemicals:** The absence, mismatch, and low quality of agro-chemical inputs in many low-productivity settings depress yields, and as with seeds, efforts to develop and distribute modern chemical inputs can generate outsized returns. (Examples *here* and *here*.)
- **Land:** Secure and stable access to land, whether through customary or statutory law, represents a key element to long-run agricultural productivity growth. Where access to land is unclear or inequitable, investments to formalize tenure within a sound legal framework can stimulate more, and higher-value, investments in long-run agricultural land use. (Examples *here*.) For more on the benefits and costs of land use formalization programs, see Bowen and Ngeleza (2019).

10 For an additional and similar characterization of agricultural interventions, readers can refer to the *MCC Agricultural Economy Program Design Toolkit* (Trachtenberg et al., 2022).

- **Management:** In low-productivity settings, human capital constraints play a significant role in suppressing output. Strategies to educate farmers, whether through formal schooling, training, or extension services, can contribute to not only better farm management practices but also broader natural resource stewardship and sustainability goals.

Interventions to support on-farm production, while critical, represent just the first step along the agriculture and food value chain. Post-harvest investments can target several key activities, each of which create additional value while simultaneously determining the quantity and quality of food that reaches the final consumer (Bellemare et al., 2022):

- **Transportation:** Moving harvested crops from the farm to their next destination, be it a nearby market, a storage elevator, or a processing facility, requires a network of roads (and sometimes rails) that can convey goods quickly and affordably. Similarly, poor quality transportation networks also raise the cost of inputs. In developing country settings, rural roads that serve farmers, to the extent they even exist, are often in disrepair and poorly maintained, limiting the geographic extent of a grower's market, raising the costs of transport, and increasing the rates of crop spoilage and losses en route. Investments that address the construction, repair, and maintenance of road networks can reduce these costs for growers and transporters.[11] See Carter (2020) for MCC CBA guidance for transport investments.
- **Storage:** Insomuch as transportation presents the possibility of spatial arbitrage, storage confers the same function temporally. By storing commodities, growers and traders dampen the seasonal pattern of prices driven by harvest time gluts and pre-harvest scarcity. Storage also permits sellers to better time their sales and exert relatively more power vis-à-vis buyers who otherwise might offer a lower price knowing that a crop will otherwise rot. Relatedly, storage preserves the edibility and value of food over longer stretches of time, reducing losses owing to spoilage. Storage consists of a variety of technologies, including elevators with dryers, silos, cold facilities that preserve perishables, and even small bags that preserve foods from pest infestations.[12] (Examples *here* and *here*.)
- **Processing and packaging:** Processing and packaging raw food commodities into final products is a key step in adding and preserving value. Drying, de-husking, de-stoning, milling, quality sorting, and other processes render food more edible and amenable to transport and storage. Other processes entail the application of heat and other chemical inputs, like converting raw milk into the range of familiar dairy products, *e.g.*, butter, yogurt, cheese, or ice cream. Processing equipment often relies heavily on electricity, the absence of which, correspondingly, limits the potential and profitability of value-adding activities.[13] (Examples *here* and *here*.)

Apart from tangible inputs along the food value chain, a variety of institutional and policy-related factors can meaningfully shape the market and performance of the entire sector:

11 Of course, rural roads could also decrease costs associated with seeking off-farm employment (which could constrain farm output), and it is not obvious that rural roads will lead to locally higher agricultural output. See Asher and Novosad (2020) and Carter (2020).

12 It should be noted, however, that the justification for public support of crop storage facilities is not obvious.

13 Once again, generally speaking, evidence of some market failure as the cause of underinvestment in processing is needed to justify public assistance.

- **Market information:** A sizeable literature has studied the role of information on production, demand, and prices in determining the opportunities and decisions facing actors in the agriculture sector. Generally, more access to information facilitates more efficient transactions and reduces potential for market power concentration, rent-seeking, and overall market failures. Efforts to publicize and disseminate price information could help producers choose a more optimal choice of crops, acreage, input use, harvest time, time of sale, and critically, a buyer. Technologies, such as mobile phones, that facilitate access to such information are one strategy to overcome barriers to information access (Deichmann et al., 2016; Aker and Mbiti, 2010). Other examples of technological solutions to information barriers appear *here* and *here*.
- **Policies and institutions:** The suite of policies and institutions that govern agricultural production and markets often plays a decisive role in the success of the sector (Torhonen et al., 2019). Policies that dictate and distort access to inputs, whether in the form of import restrictions or input subsidies, price controls, large parastatals that operate according to non-market priorities (e.g., political or social pressures), distortive trade interventions including export bans, and the effective de-prioritization of research, development, and extension services all can effectively constrain growers from achieving their highest potential. Broader policies governing land use, resource management, and taxes also weigh heavily on the agriculture sector's outcomes. Separately, but equally important, are the competence, capacity, and transparency of institutions tasked with agriculture-related outcomes. Efforts towards achieving policy and institutional reform (PIR) include decreasing heavy-handed, prescriptive input subsidies, reducing the distortive role of state-owned entities, and building capacity among administrators in government. Illustrative examples of PIR projects are *here* and *here*.
- **Access to finance:** A persistent barrier to investments in productivity-enhancing tools and technologies is the limited availability of credit. On the supply side, efforts to mobilize capital through blended and leveraged finance instruments channeled through private lenders aim to deepen the available supply of funds and simultaneously reduce risks with the goal of growing lenders' confidence in the agriculture sector. Examples of supply-side finance-related projects appear *here* and *here*. On the demand side, a growing recognition exists that many small and medium enterprises lack the elements of modern business recordkeeping and planning that make their operations "bankable." Projects that address these shortcomings can narrow the gap between borrowers and lenders (Dokle and Farrell, 2021).

The interventions highlighted above address different problems, reach different beneficiaries, and result in differing impacts. MCC has worked in a subset of these areas and in the process gained valuable experience, to which we now turn.

MCC WORK IN AGRICULTURE

This section offers an overview of the programmatic areas in which MCC has previously focused its agriculture investments. For ease of exposition and based on the typical features of the associated CBA models, we consider three sets of MCC agriculture projects: (1) irrigation infrastructure; (2) increased on-farm productivity and downstream value addition, and (3) improved resource management.[14] Future iterations of this document will include a fourth category for PIR investments.

Irrigation: MCC's work in irrigation to date has primarily entailed the construction or rehabilitation of mostly large-scale centralized systems consisting of dams, dikes, canals, and pumps, complemented with farmer training, water user association (WUA) capacity building, land formalization, and other programming. The lack of investment in such systems often owes to coordination failures, due to the challenge of organizing hundreds of farmers spread across thousands of hectares to procure physical works on and manage a common water and infrastructural resource. Such failures can justify a public intervention to coordinate efforts. Although public management may appear to be a solution, challenges with capacity and resource constraints can give rise to additional problems, namely asset mismanagement and degradation. Additional barriers to investment relate to access to credit, given the high start-up costs of installations. To take a broadly typical example, MCC's Moldova Compact featured the $129 million *Transition to High Value Agriculture* Project dedicated to the rehabilitation of irrigation infrastructure and WUA member training.[15]

Productivity and value addition: Inadequate national systems of education and agricultural extension services arguably explain much of the knowledge and skills gaps that impede farmers' productivity growth. Meanwhile, low access to credit, driven by weak business practices, high transactions costs and risks, and information gaps between borrowers and lenders, significantly curtails access to productivity-enhancing technologies and equipment. In principle, interventions to encourage farmers to take up more advanced technologies via training or the availability of credit could be justified by reference to these market failures.[16] MCC programs have invested considerably in addressing these gaps. For example, the Georgia Compact's $52 million *Enterprise Development Project* set out to deliver long-term risk capital and technical assistance to agribusiness enterprises. long-term risk capital and technical assistance to agribusiness enterprises.

Resource management: Natural resource management interventions address the externalities associated with the individual or private use of water, land, and air, and the management challenges of collectively owned natural assets. Public interventions to sustainably manage and allocate such resources can ensure their long-run preservation, availability, and value. For example, in the Niger Compact's $104 million *Climate Resilient Communities* Project, MCC funded PIR-style investments in the management of communal lands used for livestock intended to reduce "tragedy of the commons" outcomes as well as the restoration of degraded farmland that reduced water runoff on sloped plots (among other interventions). Benefits therefore accrue not only to the plot's owners but also, critically, their neighbors' plots.

It should be emphasized that many of MCC's agriculture projects were not designed to address a binding constraint to growth as determined at the Constraints Analysis stage of compact development. This is mostly because more than half of MCC agriculture projects were implemented before MCC began to conduct Constraints Analyses (or used the results of those analyses to guide project development). In

14 For an alternative categorization of MCC agriculture projects, see the MCC Monitoring and Evaluation division's sector results and learning for agriculture *here*.

15 Other MCC compacts with irrigation projects include Armenia, Burkina Faso, Ghana, Mali, Morocco, Niger, and Senegal. See Appendix I for details about MCC agriculture projects.

16 On the other hand, there is not obviously any market failure preventing the private provision of farmer training.

particular, all agricultural value addition projects and the majority of irrigation projects were not based on the results of a Constraints Analysis. Exceptions to this tendency have mostly involved projects addressing constraints related to irrigation or access to water for productive purposes. In (more recent) cases of agricultural projects or other programming still under development, associated binding constraints include agricultural policy and implementation (Mozambique II), the high cost of road freight transport services and barriers to linking farms to markets in rural areas (Malawi II), public administration (Lesotho II), and food insecurity (Sierra Leone). Indicators in Constraints Analyses of the potential benefits of irrigation include yield differentials between rainfed and irrigated plots, and the relationship between rainfall and GDP over time (which supports the idea that water for agricultural purposes can affect national economic outcomes).

In addition to a substantial focus on beneficiary behavior change (see Section 2), there are also normally policy and institutional reform (PIR) components to MCC agriculture interventions. In a pair of recent cases PIR has played or is planned to play a larger and more important role. Typical PIR components in irrigation projects include the formation or support of WUAs to manage and sustain physical irrigation assets and land title formalization. A larger PIR effort has been made in Niger, where MCC worked to increase the role of private sector firms in the importation of fertilizer, and where the consequences have been national in scale. This reform appears to have greatly increased the quantity of fertilizer available each year, and initial indications are that the associated benefits are large (including relative to benefits from other Compact investments). The Mozambique II Compact (which is still being developed at the time of writing this guidance) will focus on agriculture-related PIR investments. Specifically, to increase the agriculture sector's contribution to GDP via increased foreign direct investment, corporate income tax rates in the agriculture sector will be decreased. Finally, PIR in the case of the Malawi II compact is at the time of writing expected to take the forms of improved access to seeds, fertilizer, and export markets.

AGRICULTURAL PROJECT LOGICS AND THEIR TAXONOMY

The logic of MCC agriculture projects usually hinges on behavior change among targeted beneficiaries. For irrigation investments to pay off, for example, farmers must switch to more lucrative crops, work to achieve higher yields, and properly operate and maintain new equipment.[17] Each of these represent pronounced behavioral change in a subsistence agriculture context. Access to irrigation infrastructure perhaps encourages change on this scale, but it is likely insufficient on its own and is therefore typically complemented by "soft" program components to encourage the desired behavior change. Behavior change is just as important in the case of agriculture programs without an irrigation component, where (for example) farmer training and/or access to credit might be meant to affect a switch to a more lucrative set of crops or the use of more expensive inputs, as well as natural resource management programs.[18] In all such cases, it is imperative that behavior changes are explicitly modeled in CBAs. Economists should integrate evidence-based parameters associated with the intended behavior changes into CBAs to support design work and for program evaluation purposes. Also, where behavior change cannot simply be assumed to take place on its own, programming to encourage it should be considered.

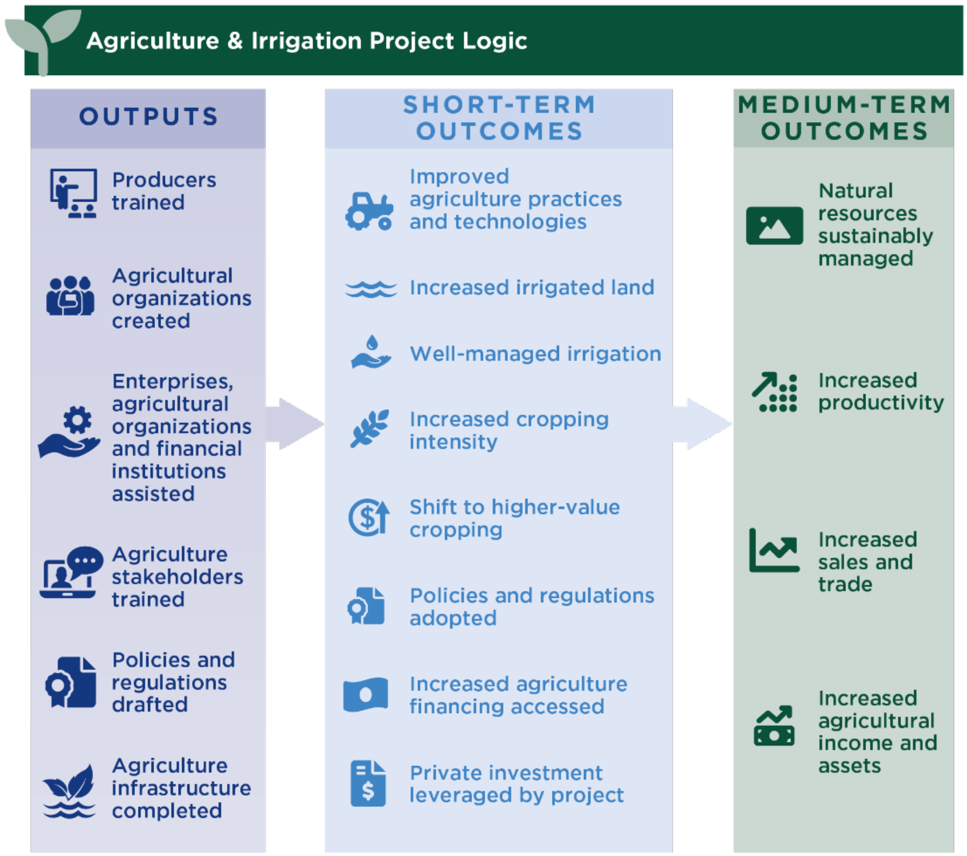
A salient feature of the context in which agriculture projects normally take place is the high degree of risk that economic actors face. It is therefore worth highlighting the potential benefits associated with the reduction of risk. Risk averse farmers often shy away from commercializing their production for fear that a failed crop might jeopardize their food security or land tenure. Research points to reduced crop area, reduced input applications, and a retreat to lower value, lower risk crops among producers who face outsized risks in production. To that end, risk-reducing inputs, e.g., drought resistant seed varieties and irrigation, can generate benefits by reducing downside risk to yield and mitigating the risks to income, thus creating opportunities for more commercial endeavors. Moreover, risks to income owe not just to unpredictable yields but also volatile prices. Coping with price risk certainly implicates production decisions, particularly with respect to crop selection, but also speaks to post-harvest activities, namely storage. Without storage, producers must sell their harvest all at once, creating gluts in the market and depressing prices. With storage, the boom-and-bust price cycle diminishes as stocks can be accumulated and dispersed in response to demand conditions over longer periods of time, effectively smoothing growers' incomes. (On the other hand, if demand for storage was in fact high enough for it to be an economically worthwhile investment, it is not clear why it would not simply be privately provided. In the absence of a market failure, we might therefore presume, any benefits from storage would be outweighed by its costs.) Finally, where adequate legal frameworks exist, contracts between growers and buyers can confer greater certainty on a transaction, creating incentives for commitment and delivery and stabilizing prices in the market.

The relationships between project inputs and objectives are made explicit with project logics. More specifically, project logics outline the causal relationships between MCC investments and the outcomes underlying benefit streams, and they clarify the assumptions under which these relationships hold. Figure 1 displays how outputs are linked to outcomes for generic MCC agriculture and irrigation projects.

17 This logic underlies MCC's irrigation investments in Burkina Faso, Moldova, Morocco, Niger, and Senegal.

18 See the El Salvador, Georgia, Honduras, Namibia, and Nicaragua compacts.

Figure 1: Generic Agriculture and Irrigation Project Logic



Project logics for agriculture projects normally assume that farmers will take up more lucrative technologies, that firms can increase their profits by participating in value addition activities, or that infrastructure will be maintained or new relationships between farmers and firms will be sustained. These logics are naturally context-dependent, in the sense that programming elements should be tailored to relevant conditions and needs. Also, to avoid logical leaps, project logics should consider multiple steps between project outputs being provided and the ultimate project objective. For example, if there is no tradition of cash crop cultivation in some project location where the logic invokes such cultivation, the design should explicitly address the introduction of cash crops to farmers and encourage their cultivation. In this case (and as shown in Figure 1), cash crop take-up by farmers would be included as a short-term outcome in the logic rather than something that was simply assumed to take place.

A key feature of agriculture projects that MCC has historically supported is that their objective is to increase agricultural household or agribusiness incomes. (See Section 3 for a discussion of outcomes of interest which go beyond incomes.) Table 1 displays the benefit streams typically associated with each of the three types of projects we consider and is followed by a discussion of some key assumptions underlying the logic for the project types.

Table 1: Agriculture Project Taxonomy

Project Type	Benefit Streams
Irrigation projects: provision of irrigation infrastructure along with complementary inputs	Increased irrigated land, increased cropping intensity, shift to higher-value cropping, improved agriculture practices and technologies, well-managed irrigation, increased productivity, increased sales and trade, and increased agricultural income and assets
Value addition projects: attempts to encourage more lucrative cultivation and agricultural output value addition via some combination of training (including business development services) and access to credit	Improved agriculture practices and technology, shift to higher-value cropping, increased agriculture financing accessed, private investment leveraged by project, increased productivity, increased sales and trade, and increased agricultural income and assets
Natural resource management projects: agricultural sustainability or natural resource management investments	Improved agriculture practices and technologies, policies and regulations adopted, private investment leveraged by project, natural resources sustainably managed, increased productivity, increased sales and trade, and increased agricultural income and assets

IRRIGATION AND AGRICULTURAL HOUSEHOLD PRODUCTIVITY

Irrigation provides farmers a way to control the quantity and distribution over time of water for crop cultivation purposes. This is of critical importance in settings where rainfall is low and irregular, and climate change stands to further aggravate these issues. Generally, however, it is reasonable to suppose that irrigation alone would not suffice to increase yields, encourage more lucrative crop choices, and lead to cultivation in an additional season, which each tend to play important roles in irrigation project logics. MCC therefore typically invests in complementary program elements including farmer training, land formalization, and the distribution of starter kits of seeds and other inputs.[19] The idea is to invest in whatever combination of program elements will succeed in making beneficiary farmers willing and able to achieve more lucrative production, given sufficient understanding of the context (including prevailing gender norms, which could imply additional or different programming for women).

It is worth emphasizing that the assumptions underlying the logic of irrigation projects are potentially strong, and outcomes might not be achieved if these assumptions do not hold. First, the provision of outputs is not a simple set of tasks. Coordinating the implementation of several program elements in rural areas of MCC partner countries on time and in the correct sequence is frequently extremely challenging. Construction or rehabilitation of physical infrastructure tends to be the most complex and expensive

19 Again, a given irrigation project's complementary program elements should reflect the country team's understanding of the relevant context and what is necessary to achieve project objectives. To the extent that programming includes elements which are unlikely to contribute substantially to benefits, economists should make this clear to country team colleagues.

program element by far (especially when resettlement is required), and delays in these works are common. This has implications for other program elements such as farmer training and WUA capacity building, which are ideally not undertaken until physical works are completed, when farmers can farm using improved irrigation and WUA can begin solving typical problems. Delays in construction or rehabilitation therefore have important cascade effects.

On the farm household side, the with-project scenario—with its higher crop intensification or emphasis on cash crop rather than staple cultivation—typically represents a drastic departure from the rainfed agriculture that beneficiary farmers tend to have long and formative experience with. Beneficiary farmers might have had one agronomic objective for their entire lives (and whose roots could go back generations)—namely, to minimize the likelihood of crop failure, likely by cultivating weather-robust but lower value staple crops—and whether the advent of improved irrigation and supplementary investments will suffice to change farmer economic objectives should be critically examined.

FARM AND AGRIBUSINESS VALUE ADDITION

MCC agricultural value addition projects have typically involved training (including business development services for agribusinesses) and increased access to credit or grants. More recently, for the Malawi II compact, MCC also considered a so-called outgrower scheme to establish relationships between large numbers of smallholder farmers and buyers of agricultural output. The intention in all these cases was to encourage farmers to engage in more lucrative cultivation, and for agribusinesses to increase value addition activities. Again, the assumptions underlying these projects are non-trivial. Smallholder farmers typically display strong preferences for staple crop cultivation and seem to forego considerably higher earnings (in expectation) from cash crop cultivation so they can ensure their own household's food supply. Switching to more lucrative crops is presumably an especially tough transition to manage in settings where year-to-year variation in output is high (due to adverse weather events or pests, for example), such that the risk of a lackluster cash crop harvest looms relatively large. Convincing farmers to behave more like expected income maximizers should therefore be regarded as a difficult undertaking, with all that entails in terms of initial problem analysis and subsequent project design work. Similarly, the reasons for a lack of value chain development might be many and compelling, and could go well beyond problems with financial resources and business plans. Caution is especially warranted in situations where a market failure has not been clearly identified, since in these cases it could simply be that firms' decisions not to invest in agricultural value chains were rational because the investments were not economically viable. In the case of outgrower schemes, the key assumption is that buyers have the kind of long-term business interests that would justify years-long dedication to the establishment of trust from smallholder farmers.[20]

We can also consider projects that contain elements of both irrigation and value addition projects, and more. For instance, MCC may consider development of projects centered on Special Economic Zones (SEZs) for agribusiness (including large-scale cultivation by anchor farmers), which would plausibly require an assortment of complementary elements including irrigation, improved roads, improved sources of power, and the policy and regulatory regimes specific to the zone. Such projects are obviously complex, and presumably associated project logics, risks and assumptions will reflect this. The overall question is perhaps what would suffice to induce agribusiness participation on the scale envisioned: Which factors

20 See *here* for more on outgrower programs.

have prevented agribusiness investment thus far, and which program elements therefore need to be in place for agribusinesses to participate? In settings with a sufficiently small agribusiness presence, credibly answering these questions is likely more difficult, since there will be less understanding of typical challenges to profitable operation. Duranton and Venables (2018) describe the many conditions which SEZs should meet in order to be successful and generate jobs: location should be chosen with markets for output, inputs, and labor in mind; the Zone should be large enough to generate agglomeration benefits; there should be evidence of comparative advantage; Zone-specific policies of several types should be implemented in an integrated fashion; and there should be long-term commitment from the highest levels of government.[21] Also, if multiple program elements—each of which might be complicated—need to be implemented in a particular sequence, implementation risks are likely higher.

NATURAL RESOURCE MANAGEMENT AND AGRICULTURAL PRODUCTIVITY

Land is crucial for farming and livestock production and is subject to well-known market failures that result in decreased productivity and degradation. More specifically, to the extent that land is communally used or investments on one plot improve land productivity on surrounding plots, private land users will underinvest and land productivity will be low. Public interventions to improve land productivity are therefore called for, and MCC has experience implementing these kinds of interventions in the cases of livestock rangeland and degraded farmland.[22] These interventions normally consist of physical works and complementary governance (for communal land investments) or training (for plot-level investments) elements to increase sustainability. Key assumptions for these investments are that natural resource improvements will be sustained and that farmers and herders will take advantage of this in a way that increases their household incomes.

21 In principle, there is also the risk of investing in things which would ultimately prove to be superfluous.

22 MCC has also implemented community-level watershed management plans, which are similar to land management projects in that public interventions are justified by within-community externalities from plot-level investments.

GENERAL APPROACH TO THE ECONOMIC ANALYSIS OF AGRICULTURE PROJECTS

MCC CBAs compare benefits and costs in counterfactual and with-project scenarios to establish the estimated return on an investment. We focus here on various alternative approaches to estimating the benefits of agriculture projects.[23] For these projects, the way benefits are modeled typically amounts to estimating the various ways in which real incomes will increase because of MCC investments. Given typical project logics and objectives for agriculture projects—which usually feature higher incomes as a higher-level objective—modeling benefits in terms of incomes tightly links the CBA to the logic. It also speaks clearly to MCC's mission of reducing poverty through economic growth. Regardless of whether the objective is to increase farmer incomes, or agribusiness profits and the earnings of their employees, the calculation of benefits therefore usually involves detailed modeling of something like profit functions.

Such functions, by explicitly accounting for the value of inputs and outputs, clarify the channels by which MCC interventions achieve their objectives. For example, farmers can choose the crops they cultivate, the level of inputs to use, and technologies and management practices to employ. Modeling different combinations of farmer choices can aid in understanding the profit-implications of different outcomes, including various with-project scenarios under consideration. It should also be emphasized that financial analyses (using potentially policy-distorted prices) as well as economic analyses (using economic prices) should be performed (for farmers or agribusinesses, depending on the project). This is so that with-project behavior (including take-up or participation) can be analyzed, and the returns for the economy as a whole can be evaluated, respectively.

An alternative to income-based measures of economic returns are welfare approaches that capture changes in consumer surplus due to project-induced changes in the price and consumption of goods and services. Estimates of these surpluses often come from willingness to pay (WTP) studies, using either revealed or stated preferences, that capture the upper limit of consumers' willingness to purchase a given good or service. Obtaining the difference between each consumer's upper limit and the actual price paid and summing over all consumers yields a "surplus" that reflects the overall value of the benefit. To take an example from irrigation, a WTP survey might focus on demand for pumped ground water, discharges from a nearby dam, or fees to join a self-sustaining water users' group. Farmers who use diesel-powered water pumps or carry water long distances implicitly reveal their preference for water through the price of diesel and the time-value of their labor. Obviously, these types of behaviors need to be in evidence for this approach to be feasible, and the accuracy of results will depend on the extent to which the WTP amongst beneficiaries corresponds to that of WTP survey respondents. Such an approach contrasts with a stated preference survey that solicits farmers' views on water quantities demanded and hypothetical prices.[24] While this latter approach does not require data on the demand-related behavioral choices just mentioned, it could be that survey respondents have trouble imagining what they would be willing to pay in the case of sufficiently transformative interventions. CBAs of MCC agriculture projects have not previously been based on these kinds of welfare analyses, but economists should be aware of the possibility they represent.

23 Section 5 deals with the estimation of costs.

24 MCC adheres to NOAA's 2001 guidelines (NOAA, 2001) on how to conduct contingent valuation surveys.

Also, the Section 1 discussion of agriculture's role in structural transformation would suggest benefit streams in addition to those associated with farmer or agribusiness net incomes. More specifically, depending on the intervention, we could consider a variety of non-farm income- or agribusiness-related outcomes, including lower food prices, higher off-farm job growth and non-farm economic activities, labor savings, and nutrition-related benefits. These alternative approaches will tend to be more applicable for agriculture projects that differ in important ways from the sorts of projects MCC has historically implemented. This list constitutes a suite of outcomes indicative of broader structural transformation, and we discuss each item in further detail now.

The price of food can be expected to fall given widespread adoption of improved technologies or inputs or decreases in trade barriers, which would be good for all net consumers of food. Higher yields can raise farm incomes, but the effect is often fleeting. This is because yield-enhancing or cost-saving technologies can quickly spread and cause a locally grown commodity's market supply curve to shift out and its price to predictably fall. Under inelastic demand conditions (which usually apply in the case for staple foods with few substitutes), the price effect more than offsets the gains to yield, resulting in lower revenues per area for farmers. Only the most efficient producers can survive, leaving less competitive actors to return to subsistence or exit on-farm production altogether. Naively, given the impact on producers' incomes, the effects of yield-enhancing interventions appear perversely harmful. However, the benefits to consumers are potentially enormous. Lower food prices allow households, particularly among the poorest, to satisfy their food requirements and create budget space for housing, health care, and education, as well as other consumer goods purchases, in turn stimulating demand across a range of productive sectors. Employment in urban areas can grow to meet this new demand, often absorbing labor released from the countryside. In short, higher yields can raise consumers' well-being and drive the mechanisms behind structural transformation. To be clear, no evaluation has demonstrated that MCC has caused yield increases on the scale discussed here, but it is important to highlight the potential benefits of doing so.

A subset of cost-reducing inputs, labor-saving technologies can trigger new household dynamics that also generate benefits as they contribute to structural transformation. Mechanization (via tractors or combines, for example) is the primary labor-saving factor, but chemical inputs and certain seed varieties can also reduce labor hours in the field. Within the household, reduced demand for labor frees time for more off-farm (or farm-adjacent) employment opportunities. This includes cottage industries revolving around food processing and preservation. To the extent these new options result in higher incomes, benefits would be generated. Relieved from field work, school age members of the household, particularly girls, can receive more years of formal education and build their human capital. The implications of higher human capital for women's long-run wages and fertility are straightforward and well-documented (see Quisumbing et al., 2014). Finally, of course, households also benefit from relying less on hired help to carry out labor-intensive tasks.

In principle, interventions in input markets can raise demand for complementary agricultural goods and services, which could generate off-farm benefits. For example, reducing barriers to fertilizer access (*e.g.*, lowering import tariffs) not only raises the quantity demanded for fertilizer, but additional inputs that potentially compound fertilizer's benefits, such as boreholes for irrigation, higher yielding seed varieties, or tractor rentals and sales. Accompanying these additional inputs are technical consultation services (*i.e.*, agricultural extension), that impart agronomic know-how, management skills, and market information onto local producers. Commercial providers of these bundles of goods and services grow in response to this greater demand, stimulating job growth and investment in the input sector. These are referred to as indirect benefits, and their estimation should be done in accordance with MCC EA's general CBA guidance. Notably, for these indirect benefits to be additional to the direct benefits described above, there needs to be a distortion affecting the relevant input market (*e.g.*, the presence of unemployment such that increased employment represents net income gains, or distortions which result in the undersupply of complementary inputs).[25] On the output market side, as production grows and the food supply shifts, downstream value addition becomes more feasible. With irrigation or other interventions driving more production and the availability of greater storage capacities, scale economies become feasible for food processors, stimulating investments in labor-intensive manufacturing sectors. These are referred to as induced benefits, and as the general CBA guidance notes, they are typically difficult to measure and in practical terms indistinguishable between projects.[26]

Finally, for projects in which farmers or others might benefit from increased production of food crops, we might consider benefits related to improved nutrition. The standard assumption would be that the value of the nutrition a food contains would be reflected—like all other characteristics of the food—in the food's price. Thus, in the case of a project where some set of farmers increase production of a relatively nutritious crop, the value of that nutrition would be accounted for by simply accounting for the aggregate value of output produced using observed prices (as described in more detail in Section 4). In principle, however, market prices might not reflect nutrition-related benefits (say, if the latter were unknown to and therefore not valued by some set of consumers). In this scenario, market prices would understate the social benefits of the agricultural output in question. To account for nutrition-related benefits without double-counting, however, economists would need good evidence that prices do not in fact account for nutrition as well as a credible estimate of the incremental value of the nutrition.[27]

25 See Boardman et al. (2018) for more.

26 See Section 4 for more on estimating induced benefits.

27 At the time of writing, further guidance on how to quantify nutrition-related benefits is being drafted in an effort led by MCC's Land and Agricultural Economy (LAE) and Human and Community Development (HCD) practice groups.

DETAILED ESTIMATION OF PROJECT BENEFITS

FARMER NET INCOMES

MCC agriculture projects are typically intended to increase the net value of agricultural production at the level of the beneficiaries' farms. Modeling this outcome therefore requires consideration of the value of agricultural output as well as the costs of inputs used to produce that output. These things need to be modeled for both counterfactual and with-project scenarios, and typically separately for a variety of crops and multiple seasons. All of this makes for a conceptually straightforward but highly data-intensive modeling experience: data on output prices, crop choices, yields, farm budgets and more are needed—for multiple crops and seasons—to construct indicators of the value of agricultural output and the economic value of inputs. These two aggregate indicators are similar to agricultural revenues and costs, respectively, and by subtracting the latter from the former we have something like agricultural profits (i.e., the net value of agricultural output). This single indicator goes a long way towards characterizing economic outcomes in each of the counterfactual and with-project scenarios, and farm-specific benefits are typically equal to the difference in this indicator's values (in aggregate terms) across these two scenarios. We turn now to how the net value of agricultural production can be modeled in the counterfactual scenario, and we note that what follows is relevant for any irrigation, value addition, and natural resource management projects which aim to increase net farm incomes.

Modeling the Net Value of Agricultural Output in the Counterfactual Scenario

Again, there are many empirical questions that need to be answered before the net value of agricultural output can be estimated, each of which we consider below:

- How many seasons do farmers typically cultivate crops in?
- Which crops do farmers grow and what shares of their plots are devoted to the cultivation of each of these crops?
- What are output prices?
- What yields do farmers achieve on average, and what share of value is lost to spoilage?
- Which inputs do farmers use, in what quantities, and at what costs?
- What is the total area subject to cultivation in question, how many beneficiary farmers are there, and what are average beneficiary farmer plot sizes?

Knowing the answers to these questions generally suffices to allow for the calculation of the net value of agricultural output, which is of course necessary to construct the CBA. But in addition, understanding the issues that these questions raise will have important implications for project design. However farming in the with-project scenario is envisioned, understanding how farming is currently practiced will clarify the ways and extents to which farmers are expected to change their behaviors. Economists should therefore plan on working particularly closely with Land and Agricultural Economy (LAE) colleagues to understand the issues outlined below.

Planting Seasons: The question of how many seasons farmers typically cultivate crops in is of primary importance for all agriculture (and especially irrigation) projects, which usually have as a key benefit stream that farmers will be able to cultivate in (at least) one additional season with the project. This additional season is typically the dry one, when more lucrative horticulture cultivation is more common, and the associated impacts on farm incomes can be dramatic. Benefits associated with intensification therefore normally constitute a large share of irrigation project benefits, for projects which aim to rehabilitate existing irrigation systems as well as projects which provide improved irrigation for some set of farmers for the first time. Given the economic importance of this question of in how many seasons per year farmers typically cultivate crops, economists should plan on seeking reliable data on this or overseeing the collection of such data (if it was not already obtained at an earlier stage of the due diligence process). It should also be noted that even if most farmers do not cultivate crops outside of the rainy season, a small minority might do so (for example, with the use of wells), and it could be important to understand the extent to which off-season cultivation is already practiced. Project beneficiaries who would cultivate in multiple seasons without the project would presumably experience smaller income increases than other beneficiaries, and it could be useful to understand the extent to which off-season cultivation was already familiar to and profitable for local farmers.

Crop Choice: The crops that farmers choose to grow are powerful determinants of their incomes and strong indicators of their tolerance for risk. In many MCC agriculture project settings, farmers cultivate low-value but weather-robust staple crops almost exclusively, even as more lucrative crops would result in considerably higher incomes in expectation. This might suffice to convince us that would-be beneficiary farmers do not have as their objective the maximization of expected income, and in fact what farmers seek is something like the minimization of the risk of a failed crop and subsequent hunger. To illustrate with an example from Niger, under conservative assumptions, almost all farmers with access to irrigated plots on the Konni irrigated perimeter forego (in expectation) hundreds or even thousands of dollars in agricultural profits each rainy season by cultivating staples rather than some combination of onions and tomatoes.[28] With this kind of behavior in mind, the question of how to convince such farmers to depart from a nearly exclusive focus on staple crop cultivation should receive serious consideration during the project design phase.[29] Finally, given the economic importance of crop choice, economists should have reliable data on both the crops that beneficiary farmers grow and the share of their plots devoted to each crop. Ideally, these data would be sampled directly from the beneficiary population in the case of survey-based data collection, and they can potentially be observed directly for the beneficiary population using remote sensing methods. Such data might be readily available in the case of projects involving the rehabilitation of existing irrigated perimeters, and economists should consult with governing institutions accordingly. When new data collection is not feasible, data on region-wide crop choices might be used.

Prices: Agricultural output prices are another key input for CBAs of projects that intend to increase farm incomes, since they are used to determine the value of agricultural output. In particular, per-unit output prices are multiplied by quantities produced to obtain an estimate of the gross value of agricultural output. Note that output that is consumed within the farmer's own household is valued in the same way as output that is sold. Economists should be aware that, to the extent to which output that is consumed

28 Note that this could reflect an unacceptably high likelihood of low yields or earnings from cash crop cultivation. Economists with access to time series data on yields by crop should examine this possibility.

29 Other important determinants of crop choice could be export bans or unreliable supplies of inputs such as fertilizer.

is less valuable (e.g., for reasons of taste or quality) than output that is sold, treating both types of output as if they have the same value will overstate the gross value of agricultural output.[30] Also, data permitting, economists should consider whether agricultural output that was set aside for own consumption but subsequently wasted should be valued positively or not.[31]

For freely traded agricultural commodities in international markets, the CBA should value output at world prices minus the cost of transporting the output to the border, and corrected for a foreign exchange premium.[32] Very often, however, agricultural commodities grown in developing economies do not respond to international price signals, owing to prohibitive transport costs, trade barriers, and distortive domestic price support policies, both for producers and consumers. For these reasons, national or sub-national prices may better reflect the value of production, and as such, understanding the relevant geographic range of the market in question becomes key. For the financial analysis, however, price data is ideally drawn from sales that take place at the farm gate, to reflect values that are most relevant for farmers. Price data collected in markets (including markets geographically close to beneficiary farmers), for example, might feature prices that are considerably higher than whatever amounts farmers received, thanks to non-trivial marketing margins for middlemen and transportation costs.

Economists should also ensure that data on observed prices corresponds to the degree of processing that the output has been subjected to (since processed output will be priced higher than unprocessed output). Price data is ideally obtained for multiple years so that averages can be taken, and the values entered in the CBA do not reflect inter-annual price variation to an excessive degree. If multiple sources for price data (of a given level of quality) are available and they are jointly controversial, economists should err on the side of being conservative by choosing minimum values for inclusion in the model. Given the economic importance of agriculture in many MCC partner countries, the possibility of there being multiple sources of price data is not as unlikely as it may sound, including in countries where public data collection efforts are inadequate. For example, agricultural research institutes might have price data, and the Food and Agriculture Organization (FAO) is also frequently a useful reference, at least for staple crops.[33] Of course, if beneficiary farmers have been surveyed using reliable methodologies with respect to recent output prices received, it should be clear which of multiple sources are plausibly most accurate. Also, output prices generally exhibit variation across seasons as well as years, and the accuracy of the CBA will therefore depend on the availability of season-specific data. Economists should also be aware that output prices received could vary with the quantity sold (in settings where buyers offer bulk premiums).

How might agricultural output prices be expected to change over time? Depending on the context, economists might examine whether food prices can be expected to exhibit secular changes. For example, rising national or world demand for food or climate change could each be expected to increase food prices over the medium and long terms. On the other hand, there are examples of MCC irrigation projects where

30 Obviously, it is difficult to observe the true value of this set-aside output.

31 To the extent that farmers set aside output for eventual consumption but it subsequently spoils, it would seem to have been positively valued at the harvest time. Also, to the extent that output prices reflect expected spoilage or losses before wholesale or retail markets are reached, it would seem there is further basis for valuing unsold output at the observed farmgate price. The amount of spoilage that typically takes place post-farmgate but pre-final market destination is probably an important determinant of how good of a proxy the observed farmgate price is for unsold output.

32 See *here* and Jenkins et al. (2019) for more.

33 See *https://www.fao.org/faostat/en/#data/PP*.

price collapses occurred, potentially driven by an increase in supply in the face of lack of access to more distant markets. These served as the motivation behind investments in roads near the sites of subsequent agriculture projects. Economists should therefore inquire of their LAE colleagues whether beneficiary farmers who would cultivate more lucrative horticulture crops using improved irrigation have access to markets large enough that they would be price takers. In the absence of good evidence to suggest that output prices will change over time, however, economists might make the default assumption that past prices can simply be projected forward.[34]

Yields: Many MCC agriculture projects are heavily focused on yields, or the quantity (measured by weight) of agricultural output produced per hectare. Yields are ideally measured at the level of beneficiary farmers' plots, but in the absence of the requisite data, regional yield data might suffice (particularly if it covers each of the crops that beneficiaries would be expected to cultivate in the counterfactual scenario, and there is little reason to think that outcomes in project locations differ from the region as a whole). Again, if public organizations or ministries have not collected relevant yield data, agricultural research institutes and the FAO should be thought of as possible sources.[35] Economists should be aware that yield data from crop cut surveys is most accurate, but household surveys and satellite-based collection can also provide data of acceptable quality.[36,37]

Given the typical magnitude of inter-annual variation in yields, counterfactual yield values would ideally be drawn from multiple years' worth of observations. As in the case of output prices, yields can be substantially affected by year-specific events like rainfall shocks, and economists should evaluate a single year's worth of yield data with this in mind. Modeling yields over time also raises some of the same questions related to secular changes as modeling output prices does, and for some of the same reasons (e.g., climate change, increased demand for agricultural output). If drought or flooding is expected to become more common, failing to account for this in the counterfactual would contribute to the underestimation of benefits. Once again, however, in the absence of good evidence that yields will change over time, the default assumption should be that yields will not change, and an average of recent years' yields should be projected forward. Also, to the extent that any crops are cultivated across seasons in the counterfactual scenario, average yields can be expected to vary across seasons (e.g., because pests might be more of a factor during the rainy season), and season-specific estimates of yields are therefore important to have.

34 While it is highly unrealistic to assume that output prices will exhibit no variation over time, in many settings it could very well be reasonable to assume that the net value of agricultural output—the aggregate indicator for which output prices are just one of several types of inputs—will not drastically change in the counterfactual scenario. Moreover, it is ultimately more important to model this aggregate indicator well than it is any of the inputs to this indicator. In other words, CBA quality is robust to errors in the modeling of particular inputs like prices and yields, as long as the net value of agricultural output accurately reflects informed expectations as to how farmers' overall production styles and living standards might change (or not) in the counterfactual scenario.

35 See *https://www.fao.org/faostat/en/*.

36 If data collection efforts are undertaken, lost output should be measured along with output consumed and sold. (Note that crop cut surveys by themselves will not provide information on post-harvest losses.) If economists are instead relying on existing data sources for yield estimates, they should also seek evidence on how much output is typically lost. Depending on what drives output losses and whether it should not in fact be assigned value in the CBA, it could be important to avoid overstating the value of agricultural output by not including that which is lost. Sheahan and Barrett (2017) find that 4-8 percent of harvested yield is typically lost.

37 For more on agricultural household survey best practices, see *here.*

Inputs: Consistent with general MCC CBA guidance, economists must also account for the monetarized opportunity costs of all inputs used in the production of agricultural output in the counterfactual scenario. This includes the costs of capital, materials such as fertilizer, pesticides, insecticides, water, seeds, and materials associated with the harvest such as nets or bags. Again, for the CBA, costs should reflect social costs rather than merely the price that farmers pay for a unit of some input; the price farmers face for the latter could be distorted (e.g., in the case of subsidized fertilizer), or farmers could ignore the external costs to others of their use of some scarce resource (e.g., water from a non-renewable source), whereas what the CBA would ideally reflect is the cost to everyone everywhere of a unit of some input. In practice, for imported inputs, the proper price to include in the CBA is the world price plus the cost of transport from the border to the project location (and corrected for a foreign exchange premium). For the farmer financial analysis, however, the (potentially policy-distorted) prices that farmers happen to face should be used. The modeling of quantities used—which generally varies by crop as well as season--will depend heavily on empirical evidence, ideally drawn from a representative sample of beneficiary farmers. In the absence of that, economists should seek this large volume of detailed information from local experts such as agricultural extension specialists, local or regional agricultural research institutions, or LAE colleagues and their consultants.

Economists also need to account for the quantity and value of any labor used to cultivate crops. This includes hired as well as family labor, each of which might be used for a wide variety of tasks such as clearing fields, planting, applying fertilizer, harvesting output, and potentially subsequent processing activities. All labor should be valued according to its most likely or feasible alternative use, which could be the local wage for unskilled labor (if employment rates are high) or zero (if labor would otherwise be unemployed). For the same reason, economists should seek to understand the extent of seasonal migration and the unskilled wages that migrant members of farm households might earn (particularly during seasons when cultivation is rare).[38] Again, much of this requires highly context-specific information, and if economists do not organize and help manage surveys to observe it directly, they should plan on relying on local experts. Finally, regardless of the data sources underlying the modeling of input costs, with all their many estimates related to quantities used and unit costs, economists should also seek to verify that their end results--crop- and season-specific estimates of input costs—sound plausible to experts. Such experts could have a well-founded sense of what it costs farmers to cultivate a given crop during a given season, and any bottom-up modeling of input costs can usefully be presented to experts for their consideration and feedback.

The model elements described thus far allow for the estimation of the net value of agricultural output on a per hectare or per farm basis. To estimate the aggregate value of agricultural output net of costs in the counterfactual scenario, however, we need to multiply the former quantity by the total footprint size of the irrigation project or the total number of beneficiary farmers, respectively. Operational colleagues usually have plans or targets along these lines, and this final step in the counterfactual modeling process is therefore straightforward. But before we move on to discuss the modeling of the with-project scenario, and apart from whatever might have been learned from the root cause analysis and existing research, it is worth highlighting the insights that a solid model of the counterfactual might offer.

38 As we will discuss further below, understanding seasonal migration amongst members of beneficiary farm households could also be important for understanding labor availability during off-seasons in a with-project scenario. The question of whether farmers will fully take advantage of newly available irrigation to cultivate during off-seasons is extremely important for irrigation project CBAs, and seasonal migration could represent a key production constraint.

A first question we should ask is what our model of the counterfactual seems to be telling us about farmers' living standards. Are farmers earning a comfortable living, or are they near subsistence? In the case of many MCC partner countries, farmer incomes are extremely low, and the model of the counterfactual should illustrate why by shedding light on farmers' behavioral choices: Are farmers willing to take risks with respect to crop choices or input usage, or do they seem unwilling to invest in these ways? How widespread is experience cultivating more lucrative crops, and to what extent do farmers seem focused on the cultivation of relatively hardy staple crops? More generally, is agriculture characterized by a lack of dynamism? Perhaps most importantly for program design purposes, do farmers seem to behave as if they are trying to maximize their (net) incomes, or is their primary objective perhaps more related to household food security and minimizing the likelihood of experiencing crop failure? Once we have enough data to estimate counterfactual farm net incomes, we also likely know enough to estimate what the highest net income a farmer could earn is (given output prices, yields, and so on for the crops that any farmer cultivates). Economists should perform this calculation and then take note of the degree to which actual farmer behavior diverges from this income-maximizing set of production choices over crop choice, input usage, and so on.

Answering these questions is crucial because it gives us a sense of where farmers are starting from and along which dimensions we would hope they adjust following MCC's intervention. In turn, we gain insight into where due diligence should be conducted so that project design can be improved, the assumptions underlying the project logic, and the scale of a project's ambitions. Economists should ask whether these ambitions are realistic. How much can we expect farmers' behaviors to change given those farmers' apparent objectives, even if we are successful in achieving our output targets (e.g., by providing irrigation, training, or credit)? On the one hand, MCC interventions sometimes seem to have the potential to be life-changing, but on the other, farmers tend to be conservative with respect to the adoption of inputs and new techniques, and in some MCC partner country settings farmers may not behave as if their objective is simply to maximize expected income. One question we might therefore ask is how far farmers might be willing to go in the direction of increasing their net incomes, which we turn to now.

Project Impacts and Modeling Net Farmer Income in the With-Project Scenario

Irrigation Project Impacts and the With-Project Scenario

Irrigation projects normally involve several components beyond physical infrastructure, which has two implications for the modeling of project impacts. First, by addressing so many facets of agricultural production, these projects can plausibly increase living standards for beneficiaries to a substantial degree. But the multi-pronged nature of these projects also makes the quantification of that degree difficult, since there is not necessarily rigorous evidence of the effectiveness of comparable interventions to draw on. Put another way, while there is good evidence of the impacts of each of farmer training (Waddington et al., 2014), fertilizer adoption (Beaman et al., 2013; Duflo et al., 2008), and to a lesser extent irrigation (Giordano et al., 2020; Hussain and Hajra, 2004), there is less available on the overall impact of projects that feature all of these elements (and more).[39] Moreover, there is less evidence available on the extent to which irrigation and supplementary program elements will cause farmers to cultivate a more lucrative

39 In principle, evidence of each program element could be used to construct an overall project impact, but it is not obvious how this joint impact might differ from the sum of each element's individual impact (for example).

set of crops. Irrigation project impacts on farmers' net incomes are therefore unlikely to be drawn from a single set of published academic studies.

Where then can economists turn for credible evidence of MCC-style irrigation project impacts? Given a project and agricultural production context, economists in conjunction with operational colleagues should determine the dimensions along which farmer production choices are most likely to be affected. Many MCC irrigation projects are expected to have their largest impacts on farmers' net incomes through an additional season's worth of cultivation and more lucrative crop choices, and to a lesser extent through yield increases and improved input usage. Given all this, MCC's own irrigation project impacts (as reflected in associated evaluation reports) and the outcomes of broadly similar projects in the partner country normally constitute relatively useful evidence. Evaluations of MCC irrigation projects can be found for the Armenia, Burkina Faso, Ghana, Mali, Moldova, Morocco, and Senegal compacts.[40] To the extent that other donors or partner country governments have implemented irrigation projects that resemble what MCC is developing, any associated monitoring data can be highly useful. Such evidence possesses the virtue of being based on the actual behavior of farmers from the same country, who are (hopefully) broadly comparable to the beneficiary farmers who constitute the subject of the CBA. We now discuss how each of project timing and scope, intensification, farmer crop choices, yields, input usage, WUA effectiveness and the maintenance of physical infrastructure, and finally the net value of agricultural production in the with-project scenario might be modeled.

An initial question related to the estimation of irrigation project benefits is when construction and supplementary programming might be completed. As mentioned above, irrigation programming and associated challenges frequently cause initial timelines to slip. In the absence of good evidence to the contrary, therefore, economists should assume that major construction works will not be completed before year five of the compact. The final "footprint" of the completed irrigation infrastructure should also be regarded as a key source of uncertainty, at least initially. This question of how many hectares might ultimately be made subject to improved irrigation can usefully be considered in the uncertainty analysis (see Section 4.4).

It can be naïve to simply assume that farmers will fully take advantage of newly irrigated plots. This has important implications for economic returns since MCC might be investing in more than beneficiary farmers will use, so that not all costs incurred will be offset by cultivation-related benefits. In Moldova, for example, only about 14% of plots made subject to irrigation by the project were ever irrigated by beneficiary farmers within two years of the infrastructure having been completed. The Senegal compact featured a large investment in an irrigated perimeter whose economic justification rested on the assumption that farmers would cultivate more lucrative horticulture crops during at least one additional season. According to the project evaluation, however, beneficiary farmers basically stuck to rice cultivation for one season per year only. MCC's experience in Burkina Faso was much better though, and plots where horticulture crops were intended to be cultivated in the dry season were in fact widely used to that end.[41]

Among the reasons for farmers cultivating less than anticipated along intensive margins, is that they may be constrained with respect to farm labor, managerial capacity, or the irrigation decisions of fellow farm-

40 All evaluation reports can be found at https://mcc.icpsr.umich.edu/.

41 It should be noted, however, that project costs and the slower-than-expected take-up of higher value cultivation by farmers caused Burkina's evaluation-based irrigation project ERR to be negative.

ers (as in the case of the Senegal compact), or that they can achieve satiation with respect to farm income objectives by cultivating less than their whole plot.[42] This risk of low take-up was a concern in the case of a small-scale irrigation program in Niger, and the design was therefore adjusted to link up landowners on whose plots wells would be installed with other farmers who would cultivate horticulture crops on shares of newly-irrigated plots during the dry season. As a result, the CBA featured the reasonable assumption that a high share of the land that MCC paid to make subject to irrigation would ultimately be used to increase net farm incomes. Also, even at times when cultivation is widespread, some plots tend to go un-cultivated (presumably for idiosyncratic reasons). In high-intensification Burkina, for example, roughly 96 (99) percent of the irrigated perimeter was found to be cultivated during the dry (rainy) season according to the project evaluation.

While MCC experiences make clear that irrigation investments will not be fully taken advantage of, the extent to which irrigation investments have gone under-utilized varies so widely across compacts that it is not obvious what these examples collectively imply for any particular irrigation project. In other words, it can be hard to know whether take-up will look more like MCC's experience in Burkina, or its experience in Moldova. Economists should therefore take it for granted that intensification will be incomplete along at least some dimensions, and they should lead discussions with country team colleagues to better understand the related issues. In particular, less than 100% of an irrigated perimeter is likely to be cultivated in the typical season, and the extent to which additional seasons' worth of cultivation take place should be treated as a key open question that due diligence and subsequent project design efforts should focus on. Economists should also seek out evidence from similar projects in the partner country to help them understand how take-up should be modeled in the with-project scenario.

The extent to which benefits from irrigation persist over time depends on the sustainability of any physical infrastructure that MCC invests in. Irrigation project designs usually reflect this by incorporating a focus on WUA formation or capacity building. Once again, MCC experience along these lines is substantially mixed, at least as far as WUA fee collection rates go.[43] This is in line with published evidence on the impacts of interventions to increase WUA capacity and effectiveness: Senanayake et al. (2015) found that only about a third of the interventions to increase WUA fee collections had a positive impact, and a similar share of WUAs was found to be financially viable.[44] In any case, it should be noted that WUA fees are normally only partially cost-reflective: while they are ideally high enough to finance routine operations and maintenance, larger and more expensive repair or replacement work are normally the responsibility of some public organization rather than a WUA. Economists should therefore seek to understand when these larger works are likely to be called for, and what the relevant public organization's history of fulfilling these sorts of responsibilities is. In particular, in the absence of a promising intervention to improve large-scale maintenance practices, economists should assume that current practices persist (with all that entails for the persistence of project benefits).[45] With all of this in mind, economists should consider whether and the extent to which benefits might persist past the 20-year mark that is standard for MCC CBAs.

42 In Senegal, small farmers could not cost-effectively operate irrigation pumps without the simultaneous participation of large farmers.

43 Again, Burkina Faso's irrigation project represents a success story along these lines while Moldova's represents a cautionary tale.

44 See Section I.B.2 of Mathematica (2021) for more on the impacts of WUA interventions.

45 In keeping with this, multiple evaluation-based CBA models lower estimated benefits given observations of post-project maintenance practices.

MCC irrigation project experiences of beneficiary farmer crop choices are also highly varied. While an additional season's worth of primarily horticulture crop cultivation played a key role in the logic underlying irrigation projects in Senegal and Burkina Faso, it was only in the latter where farmers took up the cultivation of more lucrative crops.[46] Three reasons why things might have worked as planned in Burkina Faso are that beneficiary farmers were provided so-called starter kits containing horticulture crop seeds and other inputs as well as associated training, the irrigated plots provided to beneficiary farmers were mostly additional in that farmers had other plots on which to cultivate staple crops, and the costs of irrigating were less dependent on the choices of particular farmers.[47,] Once again, and given the dearth of published evidence on farmers' crop choices following MCC-style irrigation projects, country teams can substantially improve their sense of what to expect with respect to farmer crop choices in the with-project scenario by seeking evidence from similar projects in country. For example, in the case of a rehabilitation of an existing irrigated perimeter in Niger, there was administrative data on farmer crop choices for irrigated plots on which to base beneficiary farmer crop choice assumptions. In the case of a newly constructed irrigated perimeter in a different region of Niger, there was an irrigation project implemented by another donor which also featured a focus on more lucrative crop cultivation whose monitoring data on farmers' cultivation choices informed the with-project scenario of the CBA. While this kind of evidence is anecdotal, it will tend to constitute a stronger basis for key CBA modeling choices than would whatever set of crop choices are said to be optimal by agronomists or extension agents. Ideally, such evidence could also shed light on the time it might take for farmers to switch to higher-value cultivation, since published evidence on this appears to be scarce.[48]

Even if farmers do initially cultivate more lucrative crops, the extent to which they continue to do so when and if output prices change such that the crops for which they were initially given seeds are no longer especially lucrative is an open question. In other words, while the likes of starter kits and associated training might result in relatively high farm incomes over the short or medium terms, it would be non-trivial to assume that farmers will quickly pivot to more lucrative crops in response to output price changes. Altogether, therefore, economists should err on the side of being conservative when it comes to modeling beneficiary farmers' crop choices in the with-project scenario.[49]

Economists must also model potential irrigation program impacts on yields. FAO data should serve as a useful reference, and again yields associated with similar programming can be highly informative. Relying on these sources would be equivalent to assuming that with-project yields will approximate what seems to be typical, which is likely reasonable. Conservatism with respect to yields assumptions might be thought of as a virtue, given yields results from evaluations of MCC irrigation programs. While rice yields in Senegal were shown to have been positively affected by irrigation, these evaluations have tended to show that achieved yields were lower than the CBA model had assumed. Suggestions by consultants or agrono-

46 Even in the Burkina Faso case, however, actual onion cultivation was found to be 60% lower than initially modeled in the CBA.

47 Off-season irrigation operation costs were relatively high in Senegal, such that farmers with the largest plots were largely discouraged from taking up, which had the practical effect of preventing off-season system usage for other farmers.

48 Economists should be aware that the take-up of higher-value cultivation need not occur with a lag. In Niger, for example, contractors hired to train farmers reported that the take-up of different crops was highest immediately post-intervention, and tended to decrease thereafter.

49 Evaluations consistently show that farmer crop choice changes are overestimated in original CBA models developed around the time of compact signing.

mists, as well as evidence based on laboratory-style experiments, should therefore be taken with a grain of salt.

Irrigation program impacts on input usage are also likely to be of second-order importance in empirical terms. Evaluations have mostly failed to demonstrate that MCC's irrigation projects have meaningfully affected input usage and related expenditures (in either direction).[50] Barring exceptional circumstances or strong evidence, economists should therefore model program impacts on input usage as being modest.

The overall effect of all the specific irrigation project impacts described above will be reflected in their collective impact on farm household net incomes (evaluated using economic prices). Indeed, as part of the modeling process, economists should calculate this implied total impact on net incomes, so that its magnitude can be scrutinized. Published evidence suggests that irrigation can have substantial impacts on farm household incomes. Tucker and Yirgu (2019) concluded that Ethiopian households that adopted irrigation experienced annual income increases of 20 percent, while Dillon (2008) found that access to motorized pumps for irrigation in Mali increased household consumption by 20 to 30 percent. Economically significant impacts of irrigation are not guaranteed, however; Sanfo et al. (2017) found that supplemental irrigation in southwestern Burkina Faso only affected income modestly, due in part to labor and capital constraints. Again, however, given the broad scope of MCC's irrigation projects, evidence on net income impacts from MCC evaluations might be particularly relevant for economists constructing CBAs (depending on project design details, of course). Here, and in common with the evidence just mentioned, higher incomes cannot be taken for granted: While beneficiary farm household net incomes rose by around $840 in Burkina Faso, there was no evidence of impacts on Armenian beneficiary farmer incomes following an irrigation project there. Economists should therefore be skeptical if their with-project scenario implies net farm incomes per hectare that are, say, several thousands of dollars higher than their counterfactual scenario analogs.

Agricultural Value Addition Project Impacts and the With-Project Scenario

As described above, agricultural value addition projects can be expected to increase beneficiary farmers' incomes through their impacts on crop choices, yields, input usage, or improved post-harvest outcomes. Once again, economists should work closely with operational colleagues to understand which of these channels are expected to be most substantially affected. Occasionally this will be clear. For example, in the first Mozambique compact, MCC supported the surveillance and removal of threats to farmer incomes in the form of diseased coconut trees. Farmers were therefore expected to benefit from reduced disease incidence as well as support of alternative forms of crop cultivation. In the case of a grants facility, however, the means through which farmer incomes might increase will likely be less clear ex ante, given that there will be multiple investments, which are not usually identified at the time the initial CBA is carried out. To the extent there's a basis for doing so, however, economists should seek in this latter case to model a representative portfolio of potential projects in the run-up to key MCC investment decisions.

Perhaps this lack of ex ante clarity helps explain why existing CBAs do not always explicitly model the channels through which farmer income might increase for these projects. Instead of clearly modeled im-

50 Burkina Faso's irrigation project was exceptional in this regard, since the associated evaluation found that beneficiary farm households hired more labor than a control set of farm households.

pacts on (say) crop choices or post-harvest outcomes, some CBAs simply feature higher (net) incomes in the with-project scenario. In any case, the principles outlined above on how to conduct CBAs of irrigation projects also apply for value addition projects: economists should seek out the most credible and relevant evidence for key impact parameters, which would likely include available monitoring results from similar projects and contexts as well as MCC's own evaluations. Available published evidence is of course also instructive. As Waddington et al. (2014) makes clear, the rigorous evidence on the effectiveness of farmer training (via farmer field schools) is arguably less relevant for value addition projects, given how focused it has been on integrated pest management.[51] Also, depending on the project context, Deutschmann et al. (2021), Ashraf et al. (2009), Bossuroy et al. (2021), Chambers (2013), and Appiah et al. (2020) might provide useful evidence of overall impacts of value addition projects for farmers. Suri and Udry (2022) sum up these evaluations of multi-faceted interventions by noting that, "we lack a clear understanding of what elements of these programs are essential and in which environments."

The principle of relying on available, relevant evidence also holds in the case of value addition projects which aim to improve the quality of agricultural output and therefore prices received. First and foremost, such quality-based pricing should be in evidence in a comparable setting. This might take the form of clear and strong interest on the part of large-scale buyers in output that is of a particular quality standard. In the absence of this, the possibility of monopsonistic or oligopolistic behavior on the part of buyers should be carefully examined. Such behavior would presumably imply low or no quality-based benefits for smallholder farmers.

Independent MCC evaluations suggest the results of agricultural value chain projects for farmers have been mixed. A rigorous evaluation of outcomes associated with three value chains in El Salvador concluded that farmer incomes only increased in one of them, while incomes associated with the aforementioned Mozambique intervention were found to have increased but only because farmers sought non-farm earning opportunities rather than the on-farm options the program supported.[52] [53] Farmer incomes were found to have increased as a result of the Nicaragua Compact's Rural Business Development Activity, however. Clearly, ERR hurdle-exceeding benefits or even merely increased incomes cannot simply be assumed to follow from value addition interventions.

Natural Resource Management Project Impacts and the With-Project Scenario

As described above, natural resource management projects are characterized by some attempt to improve a common-use resource such as land, so that farmers or herders can increase production using that resource. Again, the multi-pronged nature of MCC investments can make estimation of key impacts for these projects difficult. The strategy of seeking monitoring and results data for similar programs and contexts should therefore once again be prioritized when relevant published evidence is lacking.

51 In any case, the authors conclude that farmer training programs have been shown to increase yields by 13 percent and agricultural net incomes by 19 percent.

52 In time, however, it could be that the Mozambique program will have resulted in income gains relative to the counterfactual. This is because the program aimed to improve fruit tree outcomes, which can only happen with a lag.

53 The evaluation of an agriculture value chain project in Georgia found evidence of positive impacts on access to credit and investment, but not on incomes. Sample sizes were such that these conclusions should be taken with a grain of salt, however.

A good example of an MCC natural resource management project for which published evidence might have been unavailable was the Watershed Management Resources Project from the first MCC Compact with Cabo Verde. The basic logic of this project was that the combination of MCC-supported improvements to the capture, storage and distribution of water, combined with access to credit, would induce farmers to borrow to purchase equipment for drip irrigation. Ex ante estimation of impacts of joint programs like these is generally challenging, but now we have the benefit of hindsight in the form of the independent evaluation associated with this project. Unfortunately, only about a fifth of sampled farmers borrowed to purchase drip irrigation, with only about a quarter of them ultimately adopting the technology. Obviously, the would-be beneficiary farmers did not optimize in the way the project logic envisioned.

Another kind of intervention for which underlying empirical evidence is incomplete is that of communal land improvement for the sake of more productive livestock herding. MCC has supported such investments in Namibia and Niger, and as IPA (2020) makes clear, evidence on the impacts of similar programs is mixed or incomplete. The CBA associated with the Namibia Compact's Land Access and Management and Livestock Support Activities models increased herder incomes from having more, and more valuable, animals as well as reduced losses from drought. Once again, however, that same source provides evidence based on MCC's own experience (in Namibia), which led to improvements in measures of rangeland governance and positive perceptions among herders but no changes in rangeland productivity or herder household incomes. Modeled benefits for the livestock rangeland program in Niger, which seeks to rehabilitate degraded rangeland and construct water points in locations previously considered too remote for exploitation, include increases in the value and number of tropical livestock units. The key magnitudes associated with these benefits are derived from observed relationships between the quantity of forage per animal on the one hand, and animal value and the number of animals (respectively) on the other. The sources for the associated parameters in the CBA come from the FAO and Nigerien livestock experts. At the time of writing, evidence of this program's impact is not yet available.

There are also natural resource management interventions for which relevant, credible empirical evidence of impacts is readily available. An example of this is MCC's Integrated Climate-Resilient Investment Plans (ICRIPs) in Niger, which are grants to communes mainly meant to fund small earthworks and training to arrest water runoff from marginal (slanted) lands. In other words, the provision of small pits and terraces (or the proper pruning of particular tree species such that they thrive and their above-ground roots expand) decreases water runoff and improves the cultivability of affected land. As Aker and Jack (2021) and Reij et al. (2009) show, these rainwater harvesting interventions are responsible for non-trivial increases in the yields of staple crops, and they appear to be subsequently taken up by farmers.

AGRIBUSINESS PROFITS

MCC's value addition agricultural projects sometimes feature agribusiness beneficiaries, and the associated CBAs typically focus on profits as the key indicator of project success. Analogously to the construction of farmers' net incomes, estimating agribusiness profits requires consideration of costs as well as revenues. Also, once again, the profits of agribusinesses largely characterize the counterfactual and with-project scenarios. We now discuss how agribusiness profits can be estimated.

Modeling Agribusiness Profits in the Counterfactual Scenario

The counterfactual scenario for an agribusiness project will tend to focus on the total net income of some group of beneficiary farmers or firms. The specific type of income earned will depend on the intervention and context and can include anything from subsistence agriculture to business profits or the net earnings of primary producer organizations (PPOs).[54] Estimating agribusiness profits and PPO net earnings should involve adherence to the same principles which guide the estimation of the value of agricultural production for subsistence farmers (as discussed in section 4.1.1). In particular, high quality surveys of beneficiary firms or organizations are ideal, and in the absence of these some reliable alternative source should be sought. In the case of grants facilities with agribusiness beneficiaries, baseline data on net earnings can sometimes be obtained as part of the screening process associated with the awarding of grants (as was the case for an intervention under the Niger Compact). Also, when evaluating data and sources, economists should seriously consider the data collection process. How carefully are available estimates of net incomes built from the bottom up, starting with the specific components of revenues and costs on which any reliable estimate of profits should be based? Also, in the case of net earnings amongst PPOs, economists should keep in mind that surplus might be reflected in relatively high prices received by primary producers rather than profits as conventionally calculated. In other words, PPOs might be compensating members by offering relatively large amounts per unit of output, rather than (say) distributing profits. PPO profits would of course understate producer surplus in this case, and the latter should be thought of as the sum of PPO profits and whatever is distributed back to primary producers in the form of generous per-unit compensation.

In another similarity with the counterfactual estimation of the net value of agricultural production, economists should also reflect on what estimates of agribusiness or PPO net earnings suggest with respect to organizational capabilities and appetites for risk or novel approaches. Are agribusinesses engaged in a wide variety of activities, or do they mostly seem to be involved in only a few (such that competition amongst them might be strong, and their willingness to try something novel might be in question)? Do PPOs engage in extensive value addition, or do they mostly focus on one or two basic transactions? Knowing the answers to questions like these could be helpful for understanding whether an intervention can realistically achieve its objective, by clarifying whether the assumptions underlying the program logic are realistic.

Project Impacts and Modeling Agribusiness Profits in the With-Project Scenario

Consistent with the logic of agricultural value addition projects described above, existing MCC CBAs of these projects have modeled agribusinesses or PPOs as benefiting from engagement in more lucrative lines of business. Examples of this include the processing of agricultural output (whose costs as well as benefits are modeled), substantially more valuable forms of agriculture such as fruit tree cultivation, or off-farm business expansion. Historically, project impacts have typically been modeled as net incomes consistent with some degree of take-up of suggested interventions. Economists should of course seek out evidence along both of these lines: the many specifics of revenues and costs (assuming full take-up) should be informed by data, and the degree of take-up assumed in the model should be realistic. Obviously, infor-

54 Here, PPOs (or cooperatives) should be thought of as groups of producers who work together to take advantage of economies of scale. For example, transporting output or renting heavy equipment is less expensive on a per capita basis when many producers cooperate and spread fixed costs relatively widely.

mation on results from similar interventions would be highly valuable, not least because the independent evaluations of MCC's own agribusiness projects have been inconclusive.

INDUCED BENEFITS

In principle, increases in farmer or agribusiness net incomes can in turn positively affect economic outcomes for additional sets of actors. In the case of an irrigation project, increased output could make investment in storage facilities or value addition attractive. Similarly, the advent of successful agribusiness investment could beget additional investment in economically adjacent businesses. To estimate these induced benefits (in the case of the Lesotho II Compact), MCC economists have used the Local Economy-Wide Impact Evaluation (LEWIE) model (Filipski et al., 2013). This model is an example of a computable general equilibrium model, and as such, the main results are sensitive to the assumptions on the economic relationships between direct beneficiaries and other economic agents. In particular, the LEWIE model assumes that those relationships (which are typically estimated ex ante using survey data) are accurately estimated and will not be affected by the program, which could be unrealistic in the face of sufficiently transformative investments. Obtaining estimates of these many relationships in the first place also requires substantial data, time, and expertise. Finally, these models can be sufficiently complex that analysts struggle to understand which model inputs are driving main results. As an alternative to the LEWIE model, economists could model the impacts of agriculture projects on job generation in relevant value chains using survey data as described *here*. Jobs generated can then be mapped to economic benefits given a proper understanding of local labor market conditions.[55] MCC CBA guidance calls for sound logic and evidence underlying the decision to include induced benefits in CBA models, given the difficulty of estimating them credibly, and independent evaluations of MCC agriculture projects do not find evidence of induced benefits.

UNCERTAINTY

The preceding discussion highlights the many uncertainties which characterize the typical CBA of an agriculture project. These include implementation risks, risks related to program impact parameters, and a wide variety of exogenous factors including prices and weather and climate conditions. In accordance with general MCC CBA guidance, economists tasked with constructing CBAs for agriculture projects should use their context- and project-specific knowledge to highlight the ERR consequences of key risks and thereby illustrate the potential impacts of related design changes. The specific form that this analysis of uncertainty should take will depend on the nature of the risk and what is known about its probability distribution, and could include anything from explicit consideration of various scenarios to Monte Carlo analyses. See MCC's general CBA guidance for more.

55 See more on applying these methods *here* and *here*.

DETAILED ESTIMATION OF PROJECT COSTS

Consistent with MCC's general CBA guidance, agriculture project CBAs need to account for all costs that must be incurred in the generation of benefits. This includes costs borne by MCC, a partner country government, and private sector actors. For example, if there is reason to believe that some asset or capability will be financially sustained post-Compact, the associated cost should be accounted for in the CBA alongside whatever benefits are modeled. In particular, expenditures associated with routine and periodic maintenance should be accounted for (to the extent that these maintenance activities are expected to take place). Also, in addition to the costs of physical works and supplementary activities, CBAs should include costs associated with the administration and monitoring of Compact investments.

For relatively complex programs such as irrigation projects, the number of line items contributing to overall costs can be large. Physical works tend to be the largest single contributor to irrigation project costs, but it is common for there to be additional costs associated with farmer training, WUA capacity building, land formalization, and resettlement and the mitigation of environmental damage. Each of these will typically be managed by a separate contractor, and there are likely non-trivial fixed costs associated with the mere mobilization of these contractors; costs for these individual line items can be multiple millions. As we will see below, economic viability is more likely when irrigation project footprints are large (all else equal); it is better to be able to spread these fixed costs around larger areas, such that average costs per hectare are driven down. Finally, some line items are likely to have larger impacts on benefits than others, and economists should discuss this with country team colleagues.

ECONOMIC VIABILITY OF AGRICULTURE PROJECTS

Having described the modeling of the benefits and costs of agriculture projects, we now consider how benefits typically compare to costs. We focus mainly on irrigation projects before turning briefly to value addition and natural resource management projects.

The economic viability of irrigation projects can be roughly modeled quite easily by simply thinking in terms of costs and benefits per hectare of agricultural land made subject to improved irrigation. Here, benefits per hectare should be thought of as roughly equivalent to the net value of agricultural output per hectare in a single year, or the net income that a farmer could generate from a hectare of irrigated land. Again, in many settings, there will be a fairly low ceiling for this variable: the combination of what is feasible given output market prices and yields and what is reasonable to assume given typical farmer crop choice preferences will limit project benefits.

Set against benefits per hectare are costs per hectare. In principle, costs per hectare represent a choice variable, at least to some extent—MCC can design a variety of types of irrigation infrastructure. Given the aforementioned benefits ceiling, the economic viability of irrigation projects will tend to hinge upon costs, and so economists are encouraged to emphasize that inexpensiveness is a virtue (all other things equal).

Table 5 displays the ERRs associated with different combinations of benefits and costs per hectare.[56] The values of benefits and costs per hectare chosen for consideration are based on MCC experience with irrigation projects in Senegal, Moldova, Burkina Faso, and Niger. While this is not a random sample of MCC irrigation projects, the relevant data (including from independent, ex post evaluations in most cases) for each was readily available. These examples of irrigation projects make clear how we should think about the benefit and cost-related data displayed in the matrix. In particular, in initial CBAs (i.e., CBAs completed by compact entry into force), benefits per hectare were never modeled as exceeding $3,000, so benefits per hectare that large should be thought of as ambitious or optimistic.[57] Generally speaking, economists should make clear that this is the low ceiling against which costs will be set in the CBA.

The variation in costs per hectare across the irrigation projects in the four example compacts is of course much larger than the variation in benefits per hectare, and ranges from initially modeled and ultimately realized values under $10,000 (in Moldova and Senegal), to realized or forecasted values of more than $45,000 in Burkina Faso, $46,000 in one case in Niger, and $131,000 in a second case in Niger. All of the costs per hectare values displayed in Table 5 should therefore be thought of as plausible, even if higher costs might be more likely (perhaps because lower costs up-front for MCC might mean higher operating costs for farmers, which could discourage take-up to the point where the lower costs do not actually im-

56 We model costs here as being realized over a seven-year period, including two years of pre-Compact development plus the five Compact years, with increasing shares of costs being incurred over time. Benefits are first realized post-Compact and simply persist for 20 years.

57 The one example from these four Compacts where an evaluation-based estimate of benefits per hectare is available (Burkina Faso) suggests that the initially estimate of around $2,500 was likely in the right ballpark. More specifically, the independent evaluators estimated agricultural profits per hectare of around $1,800, but their estimate only considered the value of output which was sold (rather than simply produced). The $1,800 estimate is therefore likely an underestimate, but on the assumption that relatively lucrative horticulture crops contributed the lion's share to the total value of agricultural production, we might suppose that the initially modeled value of $2,500 is plausible.

prove economic viability). Also, in most cases costs per hectare ultimately rose over the Compact lifecycle, and so initial estimates should be assumed to be optimistic.

As the table shows, all other things equal, low costs per hectare represent a great opportunity as far as economic viability is concerned—even modest benefits per hectare would justify a sufficiently low-cost irrigation intervention. By the same token, as costs per hectare escalate, achieving MCC's ERR hurdle rate of 10% becomes unrealistic. With costs per hectare as high as $25,000, exceeding the hurdle rate is unlikely. In fact, it is probably fair to say that in the absence of a design strategy which prioritizes affordability, the default assumption should be that costs per hectare will likely rule out economic viability. Economists should therefore emphasize the importance of keeping costs down, starting as soon as possible.

Table 2: ERRs for Various Combinations of Benefits and Costs per Hectare

	$5,000 cost/ha	$10,000 cost/ha	$25,000 cost/ha	$40,000 cost/ha	$55,000 cost/ha	$70,000 cost/ha
$1,000 benefit/ha	15.05%	6.55%	-1.82%	-5.31%	-7.47%	-9.00%
$2,000 benefit/ha	26.38%	15.05%	4.27%	0.00%	-2.56%	-4.36%
$3,000 benefit/ha	34.57%	21.29%	8.56%	3.64%	0.74%	-1.27%
$4,000 benefit/ha	41.09%	26.38%	12.05%	6.55%	3.35%	1.15%

We briefly consider here the economic viability of value addition and natural resource management projects by considering available closeout ERRs and independent evaluations (where available). Changes in ERRs between compact entry into force and closeout for Value Addition projects do not exhibit any clear pattern: Among four examples (from the El Salvador, Georgia, Mozambique, and Namibia compacts), one ERR dropped substantially, one exhibited no change, and the remaining two increased. Again, however, in the case of the latter two, the associated evaluations were less conclusive. For Natural Resource Management projects, there is just one example of a project with an initial and closeout ERR (also from Namibia), and its ERR increased. Evaluations of Natural Resource Management projects in Cabo Verde and Namibia failed to show evidence of program impacts on key indicators like beneficiary incomes, however. In sum, MCC's experience with value addition and natural resource management projects is not characterized by clear success, and economists should tailor their engagement during project development accordingly.

ALTERNATIVES AND OPPORTUNITIES

In many settings in which MCC might implement an agriculture project, the magnitude of potential benefits will be limited by compelling factors. Economic viability therefore requires a focus on relatively inexpensive interventions. This is illustrated in the negative by irrigation projects with sufficiently large costs, whose ERRs were ultimately low or negative. By the same token, rainwater harvesting interventions which plausibly increase yields by 30-50% but which only cost a few hundred dollars per hectare are economically viable. Also, while both program types possess the virtue of focusing on the extremely poor, all other things equal, the latter can count a much greater number of them as beneficiaries.

Another relatively promising example of an agriculture project is the reform to the way fertilizer was imported and sold in Niger. In practical terms, this reform has resulted in considerably more fertilizer being imported for sale each year compared to pre-reform quantities, all at a lower unit price. Even conservative estimates of the monetarized benefits of this reform are substantial, and the quantifiable costs of the reform are trivial in comparison.[58] Interventions like this plausibly affect outcomes like the price of food, and therefore have the potential to benefit large numbers of people and even contribute to the structural transformation of the economy.

58 Not all of the costs of reforms like these can be observed, however. For example, in the case of Niger's fertilizer reform, it is unclear what the value of the political capital that senior Nigerien government officials expended to achieve the reform was.

ADDRESSING AGENCY PRIORITIES

Opportunities to integrate additional MCC priorities into agriculture-related programs can potentially amplify the benefits of specific investments and diversify the beneficiaries. MCC's agency priorities include (1) inclusion and gender (2) climate change, and (3) blended finance. EA's equities partially overlap with these priorities, raising the possibility of intra-agency complementarities, but efforts to pursue certain priorities can present meaningful trade-offs against the agency's larger mission of poverty reduction through economic growth.

INCLUSION AND GENDER

As stated on MCC's *website*, "Structural exclusion of disadvantaged groups is a problem in all countries. MCC recognizes that growth alone will not meet its poverty reduction mandate if its programs are not inclusive and sustainable." Excluded groups can include the poor, women, or other marginalized groups, and the extent to which MCC's investments explicitly target them can drive key outcomes of interest, including intergenerational poverty and social equity. While a strong research literature underscores the impact of growth on poverty (Dollar and Kraay, 2002; Dollar et al., 2013), targeting sub-groups within MCC investments offers potentially more rapid poverty reduction and fosters greater economic resilience among vulnerable populations. Women in agriculture experience constrained access to inputs such as seeds, fertilizer, water, and land, as well as to information, technology, and knowledge to expand productivity. Addressing these constraints can yield substantial economic gains (Quisumbung et al., 2014).

In sub-Saharan Africa, the sector that employs the largest, poorest, and most rural segments of the population is agriculture. On average, women account for *nearly half* of agricultural workers and yet are less likely to cultivate cash crops than men, less likely to take up commercial contracts, less productive, and in general less likely to market their own crops, instead either working as unpaid laborers on husbands' plots or producing for home consumption. This is driven by an array of interlocking factors. Women often receive disproportionately fewer productivity-boosting resources, including inputs, credit, and extension services. They have more limited access to the labor of other household members than male counterparts, and limited control over household assets like land. In some settings there are also strong normative barriers to women's entry into cash cropping and their public travel to markets, and women's domestic burdens frequently impose tight limits on their time. Unsurprisingly, women's agricultural enterprises are also less profitable and less likely to grow in comparison to men's. By virtue of its labor force characteristics and geography, agriculture offers a potentially valuable entry point to serving MCC's target beneficiaries, and as such, investments in this sector offer good opportunities to center MCC's inclusion and gender priorities in program design. Additional attention to credit provision, off-farm activities, and complementarities with larger infrastructure investments (e.g., power and roads) offer opportunities to boost the impacts of projects with accompanying agricultural interventions.[59] This kind of focus should be emphasized because gender gaps do not necessarily decline with economic growth (Croppenstedt et al., 2013), and special attention to these issues is therefore warranted when projects are being designed. The consideration of

59 In the Sierra Leone compact, investments in power transmission and distribution comprise the bulk of program activity, but a key complementary Productive Use of Energy (PUE) activity aims to support food sector firms involved in power-intensive post-harvest storage and processing with the goal of reducing costly spoilage and losses, increasing off-farm value addition, and improving the country's overall food security. While still undergoing due diligence at the time of writing, the PUE activity explores opportunities in blended finance, business development services, and technical training to help small and medium enterprises more fully exploit their improved access to the electrical grid.

related benefit streams might generally focus on increasing women's participation in more lucrative activities, increasing women's asset ownership, and increasing female entrepreneurial ability. It should also be noted that agriculture projects sometimes offer the opportunity to model program impacts separately by the gender or other demographic characteristics of beneficiaries. For example, to the extent that female farmers farm differently than male farmers, and gender-disaggregated data is available, program impacts can be modeled separately across genders.

CLIMATE CHANGE

Agriculture interacts with climate in multiple ways, and as such, presents opportunities for both climate change mitigation and adaptation strategies. Depending on precise definitions, agriculture, including land conversion, fertilizer and other inputs, livestock production, and post-harvest activities, accounts for between *one-fifth* and *one-third* of total greenhouse gas emissions. High rates of post-harvest food loss and spoilage also contribute, not only for the "wasted" emissions they embed, but also the carbon and other particulates they emit through decomposition. Efforts to reduce emissions from agriculture operate across multiple dimensions, including: (1) Improving production along the intensive margin, i.e., raising yields, which can ease pressure to convert uncultivated land to farming; (2) applying more efficient management and climate-friendly technology to reduce the need for greenhouse gas emitting inputs, and (3) improvements in storage and processing to extend the life and value of food, reducing a point-source of emissions, and more critically, lowering demand for upstream on-farm production.

However, while MCC investments can help support these objectives, consideration for MCC's climate-related priorities should fit *within* MCC's larger mission of poverty reduction through economic growth. Otherwise, taken to its logical extreme, the best way to reduce emissions is to simply end all economic activity. Separately, and more subtly, some investments can drive second-order climate benefits in equilibrium that offset, often disproportionately, the first-order costs.[60] A careful analysis of any investment's potentially multiple and offsetting climate effects, rooted in economic logic and reliable data, is key to guiding program design and approval.

Separately, the impacts of a changing climate on agriculture and challenges around adaptation carry significant implications for MCC investments. As shifting and more volatile temperature and rainfall patterns add stress and risk to crop and animal farming conditions, investments in climate-resilience become increasingly important for rural incomes, food security, and social stability. A key opportunity for managing climate-related risk relates to water's increasing scarcity, e.g., irrigation technologies and water supply management, given its critical contribution to crop and livestock production. Conversely, investments in flood and storm-resistant road and transport infrastructure can enhance year-round access to markets, both for inputs and final outputs, ensuring that food supplies reach consumers with less interruption and cost. Apart from infrastructure, investments can support the research, development, and deployment of climate-smart inputs, including drought-resistant crop varieties, drip-irrigation technologies, and precision technologies that either enhance resilience or reduce dependence on less dependable natural resources.

60 For example, an MCC investment for which every additional hectare of land brought into cultivation yields three times the national average could, in equilibrium, displace three hectares of low-yielding land elsewhere. Returning those three hectares to nature potentially sequesters more carbon than the newly converted high-yield land emits.

BLENDED FINANCE

Farmers typically struggle to secure funds from private lenders to finance the purchase of land, machinery, and inputs. Downstream from farmers, post-harvest processors and storage and logistics providers similarly face obstacles to working and investment capital finance. Reasons for this disconnect between the finance and agriculture sectors abound and include borrowers' inadequate collateral and lack of credit history, high rates of non-performing loans, poor record keeping and business planning, and loan tenures that fail to match agricultural timelines. The inherent riskiness of agriculture underlies many of these factors. But in addition, governments' unpredictable agriculture support and trade policies often inject uncertainty into markets, further raising the risk profile of the farm sector in the eyes of banks and other financial institutions, while high rates of public borrowing from the domestic financial system reduce the available supply of funds to the private sector.

While some of these problems fall outside MCC's scope of intervention—MCC rarely intervenes in macro-level debt management issues, for example—smaller solutions can address the risk, whether real or simply perceived, of lending to the agriculture sector. Blended finance tools such as leveraged loans, loan guarantees, technical assistance, and public-private partnerships (PPPs) can offer remedies for immediate constraints to credit access. Leveraged finance entails matching grants with loans to attract private investment in specific activities. Loan guarantees help banks "de-risk" their portfolio's exposure by covering a portion of losses in the event of non-repayment. For example, to incentivize the creation of an agriculture lending portfolio, MCC could offer to guarantee some share of any realized losses. PPPs offer the private sector the opportunity to combine resources with MCC and other government entities to share finance and management responsibilities for certain public goods. While each setting is unique and the financial instrument deployed can be precisely tailored, the overarching goal is to bridge specific gaps in credit facing private sector and government given an economic justification for doing so.

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