



Comprehensive Initiative on
Technology Evaluation



Summary Report: New Packaging Types as Innovative International Food Assistance Instruments

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The Comprehensive Initiative on Technology Evaluation (CITE) at MIT is a program dedicated to developing methods for product evaluation in global development. CITE draws upon diverse expertise across MIT and globally to evaluate products and develop an understanding of what makes products successful in emerging markets.

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Acronym List

Units	
FY	Fiscal Year
MT	Metric Ton
USD	United States Dollars
Organizations	
CITE	Comprehensive Initiative on Technology Evaluation
FFP	Food for Peace
FGIS	Federal Grain Inspect Service
FSA	Farm Service Agency
MIT	Massachusetts Institute of Technology
PIO	Public International Organization
PVO	Private Voluntary Organization
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
Packaging	
BP	Bio-pesticide
FIBC	Flexible Intermediate Bulk Container
MWP	Multi-wall Paper Bag
PE	Polyethylene
WPP	Woven Polypropylene Bag

Executive Summary

Commodity quality losses, from issues such as insect infestation and damage to packaging, impact when and what type of food assistance is shipped. They can affect the U.S. Agency for International Development's (USAID) ability to provide life-saving food assistance to vulnerable populations and reduce hunger and malnutrition (USAID 2017a). In some cases, they can even mean less food is distributed to beneficiaries, despite USAID and its partners working to avoid quality losses by expediting shipments through ports and fumigating on board ships while in transit. USAID spends an estimated \$12 million/year on fumigation to mitigate and control infestation.¹ Yet, fumigants are not always effective, require commodities to lay inert for two to seven days, and, if misapplied, can have human health and local environmental implications (USAID 2013).

New packaging types have the potential to reduce losses and/or avoid or reduce the application of fumigation, and complement the effectiveness of both local and regional procurement as well as prepositioning operations. This study evaluates the cost, quality, and timeliness outcomes of new packaging types. With USAID and the U.S. Department of Agriculture (USDA), the Massachusetts Institute of Technology (MIT) Comprehensive Initiative on Technology Evaluation (CITE) answers the question, *"Under what, if any, 'real world' conditions do new packaging types affect the cost and quality of food assistance procured in the United States and shipped abroad?"*

Methods

Through a pilot procurement valued at approximately \$600,000 USD, MIT, USAID and USDA tested eight packaging types, with three representative commodities shipped to two foreign ports, and stored in two of USAID's prepositioning warehouses for at least three months. Figure 1 shows how many of each commodity type, shipping method and prepositioning warehouse we considered, as a share of all in USAID's Title II food assistance program. This produced generalizable data on the cost, effectiveness and feasibility of using new packaging types in the food assistance supply chain. Through fieldwork, we held interviews and key informant discussions with stakeholders in the food assistance supply chain to cross-validate data from the pilot procurement.

¹ This assumes 1.5 million MT/ year and four fumigations across the supply chain that cost \$2/MT each.

Figure 1: Share of Commodities, Shipping Methods and Destinations Included in Pilot Presented as a Share of the Total USAID Food Assistance Program²



Packaging Recommendations

We find that 25 or 50 kilogram bio-pesticide treated bags have the potential to decrease the cost relative to standard packaging types, and maintain the quality about as well as the standard packaging type. This packaging does not require (as regular) fumigation, which may improve the timeliness of USAID’s food assistance efforts. *We recommend using a bio-pesticide on packaging program-wide.*

We also find that 1000 kilogram bags over the long-term may bring cost benefits, conditional on some machinery and capital investments along the food assistance supply chain. In practice, it may be cost-effective to build capacity in USAID prepositioning warehouses to handle these shipping-sized bags. *We recommend using 1000 kilogram bags in the prepositioning supply chain, and for some countries that regularly receive food assistance.*

We also find that the commodity supplier appears to affect the quality outcomes of food assistance, perhaps more than most bag treatments or fumigation practices; we consistently observed infestation in one supplier’s commodities. *We recommend using existing capacities in the USAID-USDA supply chain management software to better track quality.*

Process Recommendations

We relied on experimental principles that underpin many large, randomized, casual effect studies to design and operationalize a relatively small, non-randomized procurement, whose design and data still allowed us to make generalizable conclusions. Our partnerships allowed us to be close enough to USAID and USDA that we could, for instance, visit USAID and partners during the design phase. But, it allowed us to be far enough from them, so that we could

² Based on FY 2016 data, by weight, the three piloted commodities account for 38 percent of all shipped commodities, and packaged shipping accounts for 25 percent of all shipped commodities. About 20 percent of all shipped commodities are destined for prepositioning warehouses, and we picked two of the most active warehouses of the six. The number of commodity types shipped and prepositioning warehouses vary year-to-year, so these data are notional.

identify and introduce innovative products and practices in public procurement, for instance, used in other sectors. *We recommend using flexible partnerships between the government and universities to facilitate close collaboration in addition to an extra-mural perspective.*

Introduction

USAID's Office of Food for Peace has fed over three billion people since its inception in 1954 (USAID 2017a). Through its Title II program, it delivered over 1.7 million metric tons (MT) of food assistance valued at nearly \$2 billion USD to over 30 million beneficiaries in 50 countries in Fiscal Year (FY) 2016. It can take up to six months for these commodities to move from an American farmer to beneficiaries in countries such as Ethiopia or Afghanistan (USAID 2017b).

Commodity losses impact when and what type of food assistance is shipped. This can affect USAID's ability to provide life-saving food assistance to vulnerable populations and reduce hunger and malnutrition (USAID 2017a). USAID estimates that about 1 percent of its food assistance that is shipped is lost (USAID 2013), and the United Nations World Food Program (WFP) estimates that about half of its losses by value are due to quality challenges, such as poor warehousing conditions, broken bags, insect infestations, and contaminated commodities (e.g., WFP 2016).³ These losses are unsurprising, considering the size and mandate of the program, as well as the long distances and varying climates across which these commodities travel. Among other efforts to avoid quality losses, USAID regularly fumigates the commodities in the food assistance supply chain; it is a common practice to apply fumigant gases in commercial and humanitarian food supply chains to avoid insect infestations. But fumigation can take up to seven days, is costly, is not always effective, and, if improperly applied, can lead to adverse health and environmental outcomes (USAID 2013). There is a need:

- To avoid or reduce the need for fumigation in food assistance supply chains to improve cost, quality and timeliness outcomes of food assistance operations; and
- To minimize the effect of quality losses on food assistance programming.

In 2015, USAID initiated a study with researchers at MIT CITE to evaluate new packaging types in the food assistance supply chain, which could reduce the cost and better maintain the quality of food assistance, and/or reduce the need for fumigation across the supply chain, and reduce the time required to deliver food assistance.

³ USAID reports an estimated 80 percent by weight of its food assistance is distributed via WFP.

This report begins with an introduction to the purpose of the study, followed by its background, design and analysis methods. It presents the feasibility, effectiveness, and cost analysis results using data from a pilot procurement, field visits to ports and warehouses, and interviews with supply chain stakeholders. This report concludes with recommendations to USAID, other donors and implementing partners on the comparative evaluation of new packaging types. It also proposes, using experimental principles, how to pilot innovative products and processes. We find experimentation to be an effective way to generate data for the design of programs—and the supply chains that need to support them. Full context and data for the findings in this report can be found in a full report of the same name.

How to Use this Report

This report contains findings relevant to two, overlapping audiences:

- The American and international food assistance community, and specifically the donor, non-governmental and international, private and research-oriented organizations that design and evaluate the supply chains to better procure, ship, and distribute food assistance. This report contains detailed recommendations on new packaging types, illustrating how they affect cost, timeliness, and quality in food assistance operations.
- The federal procurement community, and specifically the Congressional committees, offices in agencies and research-oriented organizations that have considered how procurement can make federal policy more efficient or equitable, and be a lever of federal policy in of itself. This report contains reflections and recommendations on using experimental principles in procurement.

Motivation

This study is motivated by the need to avoid or reduce the need for fumigation in food assistance supply chains to improve cost, quality and timeliness outcomes of food assistance operations. Fumigation costs USAID an estimated \$12 million USD/year,⁴ and accounts for an estimated 5 percent to 33 percent of the total shipping time, as it requires commodities to lay inert for two to seven days after application.⁵ This can affect USAID's ability to provide timely

⁴ This assumes 1.5 million MT/ year and four fumigations across the supply chain.

⁵ This assumes four, seven-day fumigations over three months or four, two-day fumigations over six months. This also assumes that applying fumigants is always a bottleneck, which is unlikely.

food assistance. Yet, this fumigation is not even always effective, and, if misapplied, can have human health and environmental impacts (USAID 2013).

This study is also motivated by the need to minimize the effect of quality losses on food assistance programming. To achieve a low loss rate, USAID, for instance, fumigates or expedites shipments. While necessary to maintain quality, efforts such as expediting shipments can increase the complexity and cost of providing food assistance for USAID and its partners. And despite these efforts, quality losses still affect USAID's ability to provide some types of food assistance. For instance, USAID reports not keeping wheat flour in some of its prepositioning warehouses because of quality concerns, even though prepositioning it may improve programming outcomes.

In the past decade, USAID evaluated two supply chain modifications that could affect food assistance cost, quality, and timeliness outcomes. The 2008 Farm Bill authorized a pilot procurement that showed that the cost, quality, and timeliness of food assistance procured abroad is at least the same as that which is procured in the United States (Harou et al. 2013; Lentz et al. 2013; Lentz, Passarelli, and Barrett 2013). The 2014 Farm Bill reauthorized and expanded USAID's effort to preposition food assistance in its overseas warehouse network, which evaluations showed improves timeliness at a possible increased cost (USGAO 2014).

In this study, we evaluate the cost, quality, and timeliness outcomes of a third supply chain modification: new packaging types. In collaboration with USAID and USDA, we answer the question, "*Under what, if any, 'real world' conditions do new packaging types affect the cost and quality of food assistance procured in the United States and shipped abroad?*" New packaging types have the potential to reduce quality losses and/or avoid or reduce the need for fumigation, and complement the effectiveness of both local and regional procurement as well as prepositioning operations.

To answer this question, this study explores:

- (1) The *feasibility* of using new packaging types in the USAID food assistance supply chain, i.e. procuring and shipping food assistance commodities using new packaging types;
- (2) The *effectiveness* of new packaging types in minimizing packaging breakage, insect infestation and mold contamination, and avoiding or reducing the need for fumigation across the supply chain, which implicitly affects the timeliness of assistance; and
- (3) The *cost differential* of using new packaging types in USAID's food assistance supply chain, including the trade-off between spending slightly more on packaging materials if the overall cost is lower through reduced fumigation.

This study explores potential timeliness gains from new packaging types, and, because of data limitations, briefly presents the trade-off between spending slightly more on packaging materials to achieve a lower overall cost due to fewer quality losses.

There are, of course, alternatives to using new packaging types. USAID and its partners can use warehouse management trainings, which may improve warehousing conditions and fumigation practices. But this sort of intervention can be difficult to target: three quarters of USAID food assistance supports emergency programs (USCRS 2014), and the supply chains—and people who run them—are dynamic, with warehouses and staff often changing over months or even weeks. We believe that new packaging has the potential to be the more cost-effective and consistent quality intervention relative to warehouse management trainings, as well as to complement the two other recent modifications to the food assistance supply chain.

Background

USAID ships over one million MT of commodities each year, with grains regularly accounting for over three quarters of the commodities by weight, and other commodities such as legumes, vegetable oil, and milled and fortified products accounting for the remainder. Grains are typically shipped on the ocean in bulk in the hold of a ship, though, like legumes and milled and fortified products, they can also be shipped in packages in containers or in the hold of a ship (i.e., break-bulk).

On average, bulk grains are always the cheapest per MT to procure and ship, often costing about \$200/MT to procure and another \$200/MT to ship. Packaged grains are marginally more expensive, costing about an extra \$100/MT to procure, while packaged legumes and milled and fortified products often cost about \$500/MT to procure—and even up to \$1,000/MT. In general, bulk shipping is cheaper by about \$100/MT than packaged shipping.

Most of the current packaging types used in the supply chain cost between \$0.5 and \$0.8/bag. In general, statute requires that the packaging used in the program be manufactured in the United States and labeled in a particular way, leaving USAID and USDA to specify the more technical aspects of the bags (e.g., requiring woven polypropylene bags instead of paper bags for some commodities).

The procurement and shipping process begins when USAID implementing partners such as World Food Programme (WFP) or Catholic Relief Services have been approved to receive funding and request commodities. USAID and USDA review and approve the requests, and issue public tenders to provide the commodities and ocean shipping service. Commodity suppliers and ocean shipping carriers submit bids on the tenders, and a process that considers the lowest landed cost (the total cost to procure and ship commodities) determines who wins the contract.

Commodity suppliers' contracts cover procurement and delivery to a designated load point, which is often an ocean port. Commodities for bulk shipments are typically already in silos adjacent to a dock at the load-port; commodities for packaging shipments are typically transported by rail to the load-port. Grains and legumes can be packaged either at the

commodity supplier's plant or at the load-port, while milled and fortified products are always packaged at the commodity supplier's plant. USAID and USDA directly contract with packaging suppliers for shipments of bulk commodities, but not for shipments of packaged commodities, for which commodity suppliers directly contract with packaging suppliers.

Ocean shipping carriers' contracts cover ocean shipping and sometimes some inland transportation abroad. At the load-port, bulk shipments are loaded into the hold of a ship, while packaged shipments are loaded into containers or as break-bulk. At the foreign port, bulk shipments are packaged on bagging lines adjacent to the dock, and packaged shipments are unloaded, and all are placed on trucks and driven to a receiving warehouse.

For prepositioning operations, a USAID contractor operates the receiving warehouses. Containerized shipments are de-stuffed at and placed in the receiving warehouse, while now-packaged bulk shipments and break-bulk shipments are unloaded from the truck and placed in the receiving warehouse. Once allocated to a specific program, these shipments are eventually transported to other warehouses run by USAID's partners and eventually provided to beneficiaries.

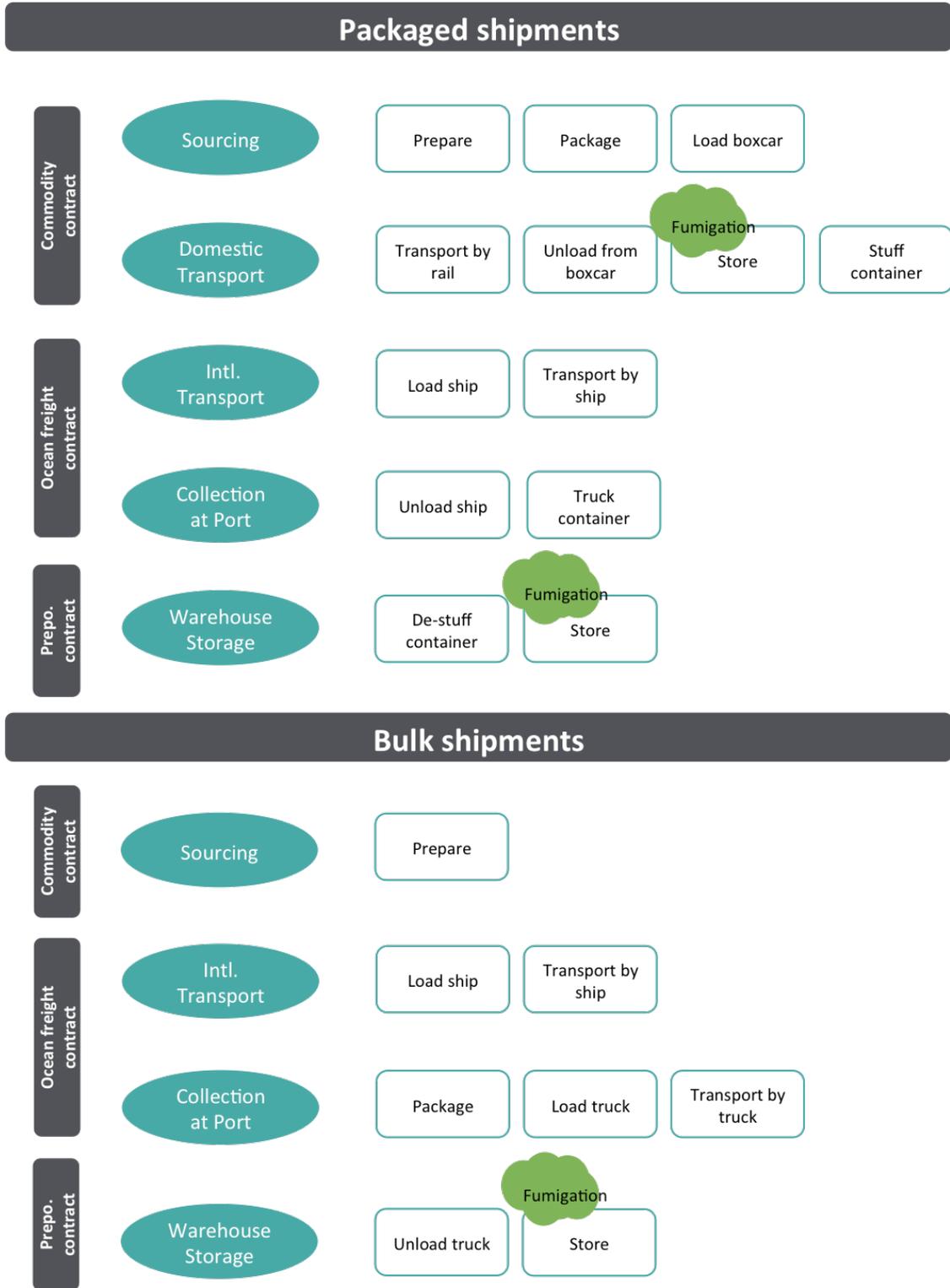
The three contracts and stages of the supply chain that they cover are presented in Figure 2.

Study Design and Data Collection

To evaluate the feasibility, effectiveness and cost differential of new packaging types in USAID's food assistance supply chain, we use a mix of experimental and qualitative methods to gather data.

We define "feasibility" as a qualitative measure related to the ease and practicality of using new packaging types in the supply chain. We operationalize "effectiveness" as quantitative measures of commodity quality, e.g., insect infestation (binary), moisture content (percent). We operationalize "cost" as a quantitative measure of the cost per MT shipped to and stored in a prepositioning warehouse.

Figure 2: The Food Assistance Supply Chain to a USAID Prepositioning Warehouse



First, through a pilot procurement valued at approximately \$600,000, MIT, USAID and USDA tested eight packaging types, with three representative commodities shipped to two foreign ports, and stored in two of USAID’s prepositioning warehouses for at least three months. About one fifth by weight of all commodities were shipped to prepositioning warehouses. We qualitatively analyzed the feasibility data obtained through this experiment, and quantitatively analyzed the effectiveness and cost data (a “top-down” cost analysis).

Second, through fieldwork, we held interviews and key informant discussions with stakeholders in the food assistance supply chain, which generated additional data on feasibility and cost. We qualitatively synthesized this interview- and discussion-based feasibility data with that gathered from the pilot procurement, and quantitatively analyzed the cost data (a “bottom-up” cost analysis) and used it to validate our analysis of cost data from the pilot procurement.

We collected and analyzed data on the prepositioning food assistance supply chain, which we define as starting with the commodity resting in a silo in the United States and ending with the commodity resting in a stack in a USAID prepositioning warehouse abroad.⁶ These data collection and analysis methods are summarized in Table 1.

Table 1: Methods, Data Sources and Analyses

Method		Experimentation		Interviews and Key Informant Discussions	
Data Generated		Tendering Data	Quality Data	Interview Data	Key Informant Data
Analysis Type	Feasibility	Feasibility Analysis	Feasibility Analysis	Feasibility Analysis	Feasibility Analysis
	Effectiveness	-	Effectiveness Analysis	-	-
	Cost	Top-Down Cost Analysis	-	Bottom-Up Cost Analysis	-

Experimentation

Consider the food assistance supply chain. We defined aspects like “destination” and “commodity” as *factors*; types of a factor like “Djibouti” and “Durban” or “sorghum” and “yellow split peas” as *levels*; and interactions between levels like “yellow split peas shipped to Djibouti” or “sorghum shipped to Durban” as *runs*.

⁶ There are two limitations to using this supply chain. First, while the overseas prepositioning supply chain and standard food assistance supply chain are identical until commodity collection, after commodity collection USAID has better visibility and control of the prepositioning supply chain relative to the standard supply chain. Second, commodities resting in a prepositioning warehouse likely experience several fewer handlings and possibly more professional fumigation practices than those resting in a partners’ secondary and tertiary warehouse. These limitations weaken our external validity—our ability to apply our findings to other contexts. But even with no external validity, this study would be valuable because 20 percent by weight of all food assistance is destined for prepositioning warehouses.

We designed the pilot procurement as an experiment, in which we varied four factors: commodity type, packaging type, shipping method, and foreign destination. These factors were chosen from a larger number of possible options (e.g., which packaging supplier is used, where shipments are packaged, whether containerized or break-bulk shipping is used), due to the fact that regulatory and contracting processes determine most of USAID and USDA’s control of the supply chain, leaving these as the main four that we could vary.

We carefully selected levels of each factor. For commodity type, we included sorghum, yellow split peas, and corn soy blend plus. Bulk and packaged sorghum together accounted for 27 percent of food assistance shipped in FY 2016, and are representative of other grains shipped. Likewise, yellow split peas accounted for 8 percent and corn soy blend plus of 1 percent of food assistance shipped in FY 2016, and are representative of other legumes and milled and fortified products shipped, respectively. Though corn soy blend’s standard bag is unique, the commodity itself has a moisture content profile similar to other milled and fortified products.

Picture 1: Packaging types used in the pilot

		
<p>Shipping-sized bags</p>	<p>Distribution-sized bags</p>	<p>PE container liner</p>
<p>Pictured: shipping sized bags in the pilot in a USAID warehouse.</p>	<p>Pictured: WPP bag with a PE liner in the pilot. (Liner not visible.)</p>	<p>Pictured: An installed PE container liner in the pilot in an American warehouse.</p>
<p><i>The pilot used standard FIBCs, FIBCs with a PE liner, and FIBCs with a BP.</i></p>	<p><i>The pilot used standard WPP bags, WPP bags with a PE liner, and WPP bags with a BP.</i></p>	<p><i>The pilot used PE container liners, which be used with both sizes of bags.</i></p>

For packaging types, we used the standard packaging for each of the three commodity types— 50 kilogram woven polypropylene (WPP) bags for sorghum and yellow split peas, and 25 kilogram multi-wall paper (MWP) bags for corn soy blend plus—and identified seven new

packaging types. These are seen in Picture 1. We piloted three packaging varieties as “quality” treatments that we hypothesized would reduce insect infestation and/or moisture/mold damage: bags with bio-pesticides (BP) applied and polyethylene (PE) liners inserted, as well as PE liners for containers. We also piloted one packaging variety as a “size” treatment that we hypothesized would reduce bag breakage and/or handling costs: 1000 kilogram flexible intermediate bulk containers (FIBC). Finally, we piloted combinations of quality and size treatments. Table 2 shows the set of packaging types and associated hypotheses.

Table 2: Packaging Types, Treatments and Hypotheses

Packaging Type	Size (kg)	Treatment		Hypothesized Advantage				
		Quality	Size	Avoid fumigation	Avoid infestation	Avoid mold / moisture	Avoid breakage	Handling cost
WPP or MWP	25/50	-	-	-	Y	-	-	-
WPP with PE liner	25/50	Y	-	Y	Y	Y	-	-
WPP or MWP with BP	25/50	Y	-	Y	Y	-	-	-
FIBC	1000	-	Y	-	Y	-	Y	Y
FIBC with PE liner	1000	Y	Y	Y	Y	Y	Y	Y
FIBC with BP	1000	Y	Y	Y	Y	-	-	Y
WPP with PE container liner	20000	Y	-	Y (partial)	Y	Y	-	-
FIBC with PE container liner	20000	Y	Y	Y (partial)	Y	Y	Y	Y

We attempted to use both bulk and packaged shipping methods, which account for about 75 percent and 25 percent of food assistance shipments by weight, respectively—though ultimately only piloted packaged shipments, because of practical considerations. Finally, we used the Ports of Durban, South Africa and Djibouti as foreign destinations because each offers different absolute humidity, humidity variation, absolute temperatures, temperature variation, shipping times from the United States and degrees of mechanization. When taken together they are indicative of other ports to which food assistance is shipped.

In this experiment, our unit of analysis (and one run) was 20 MT of one commodity type in one packaging type shipped to one foreign destination. Twenty MT fits in a 20-foot container, often the standard shipping increment. A unit of analysis less than 20 MT may not have revealed common intra-container effects such as cross-bag infestation, while one that was multiples of 20 MT may not have been necessary, and would have increased cost and complexity. The pilot procurement is summarized in Figure 3.

Figure 3: Share of Commodities, Shipping Methods and Destinations Included in Pilot Presented as a Share of the Total USAID Food Assistance Program⁷



We used USDA administrative and a USAID contractor’s quality data for the effectiveness analysis. For the time series data; USDA measured each run once in the United States, and, the USAID contractor measured each run after it had arrived at the foreign port and at one-month intervals for three additional months. Both USDA and the USAID contractor measured moisture content (percent), insect count (number), aflatoxin (parts per million or parts per billion), yeasts, molds, and coliforms (colony forming unit per gram), and damaged kernels (percent weight). The USAID contractor also counted broken bags after de-stuffing, and measured local humidity, temperature, and insect presence.⁸

We used USAID and USDA administrative procurement data for the top-down cost analysis, specifically studying USAID and USDA’s awards to commodity suppliers and ocean freight carriers. Material costs are captured in the commodity contract, while handling and fumigation costs are captured in the commodity, ocean freight, and prepositioning warehouse contracts.⁹

We made inferences about feasibility from both the quality and cost data, which we situated with information from the key informant discussions.

⁷ See Footnote 2.

⁸ There may be measurement error in these data: The five samples were gathered by three labs run by the two organizations in a process that involved four different countries’ standards and testing practices. These standards and testing practices are regularly used by USAID, however, in their routine quality control work. There is also some missing data. The USAID contractor did not take or report some samples, including for all of the shipping-sized bags in Djibouti, and USDA did not measure one variable that the USAID contractor did. This error limits the data, and when coupled with runs with no replicates limits our ability to make strong run-by-run inferences about new packaging types. However, using averages across destinations and/or commodities to reduce noise and simple measures such as infestation, we find the data strong enough to draw conclusions from.

⁹ These awards provide an estimate of the total cost associated with distribution of food assistance, but it is possible that the bids that preceded these awards are biased. Firms may have under-bid to win the contract to gain a first mover advantage with the new packaging types. Alternatively, firms may have over-bid to buffer themselves from high, unanticipated costs. We used the bottom-up cost analysis to help reveal if any such biases were present in the data, and did not find any.

The experiment had runs with no replicates—we shipped one container per run. In the absence of a strong trend it can be difficult to interpret the data and errors using simple statistical techniques, i.e., averaging data across levels and/or factors. Key informants confirmed that our runs – in terms of commodity, shipping method, and destination – were fairly typical. In fact, we selected these factors and levels because they were typical, and USAID administrative data helps confirm this as well. The procurement itself followed the standard competitive process, with USDA and USAID issuing the tenders.

Qualitative Methods

We used interviews and key informant discussions to generate feasibility and cost data, and to inform the design and operationalization of the pilot procurement.

We used interview data to populate the bottom-up cost analysis. We identified each interviewee using purposive and convenience sampling, assuming that their firm’s processes were representative of other firms’ processes in the food assistance supply chain. At each firm, we mapped their current process (e.g., filling, palletizing, loading); determined the labor, machinery and rates associated with each activity in their current process; introduced each new packaging type; and asked how these packaging types would affect the labor, machinery and rates associated with each activity. The types and number of organization that participated in discussions are listed in Table 3.

Table 3: Interviews and Key Informant Discussions

		Organization type	Count	Organization type	Count
Where		Interviews		Key informant discussions	
<i>United States</i>		Milled commodity suppliers	2	USAID office divisions	2
		Legume supplier	1	USDA services	2
		Grain supplier	1	Agricultural associations	3
		Port warehouse	2	Packaging suppliers	4
<i>South Africa</i>		Bulk port	1	Fumigation provider	1
		USAID prepositioning warehouse	1	USAID M&E contractor	1
<i>Ethiopia</i>	<i>North</i>	PIO/PVO warehouse	1	-	-
	<i>East</i>	PIO/PVO warehouse	1	-	-
	<i>Central</i>	PIO/PVO warehouse	2	USAID mission	1
<i>Djibouti</i>		Bulk port	1	USAID M&E contractor	1
		Container port	1	USAID mission	1
		USAID prepositioning warehouse	1		
		PIO/PVO warehouse	2		

We used key informant discussions with USAID and USDA, as well as firms and organizations that did and did not participate in the pilot procurement, for the feasibility analysis. These discussions also helped justify assumptions for the bottom-up cost analysis,¹⁰ as well as shape the experimental design. These discussions happened often during the study, and were less structured relative to the interviews. The types and number of organization that participated in discussions are listed in Table 3.

Analysis Methods

Feasibility Analysis

We qualitatively synthesized experimental, interview, and key informant data to determine the feasibility of using new packaging types in the food assistance supply chain, i.e. filling and handling food assistance commodities using new packaging types, procuring the packaging types, and complying with statutes and regulations that affect the packaging types. This is the most integrative, but also most straightforward of the four analyses. We analyzed these data by commodity, packaging type and destination, and the findings follow.

Effectiveness Analysis

We quantitatively analyzed the quality data that the pilot procurement generated to determine if new packaging types reduce packaging breakage, insect infestation and mold contamination, and thus avoid or reduce the need for fumigation across the supply chain. Results are presented by packaging type, destination, and commodity type.

We also examined the factors over which we had no control in the pilot procurement through the tendering or prepositioning process—noise variables—but which may affect quality outcomes: these include which bag supplier, commodity supplier, domestic load port, and ocean freight carrier participated in the pilot. We reviewed data on insect presence, humidity, and temperature in USAID’s prepositioning warehouses to determine if there was the potential

¹⁰ Through these discussions we obtained (1) the contracted cost of fumigation per MT in prepositioning warehouses in Djibouti, Durban and Jacintoport, Texas, as reported by USAID; (2) the estimated average FY 2016 commodity cost to USDA for bulk and packaged sorghum, yellow split peas and corn soy blend plus, as reported by USAID; (3) the cost per unit of new packaging types, as reported by bag suppliers; and (4) the contracted cost of re-bagging the contents of a shipping-sized bag into distribution-sized bags in prepositioning warehouses in Djibouti and Durban, as reported by USAID. To be complete, we note that we rely on secondary data for (1) minimum wage estimates for Djibouti, Durban and Houston; and (2) shipping costs from three destinations in the United States to Houston, and from Houston to Djibouti and Durban.

for infestation or mold growth, and show that a lack of infestation or mold is not due merely to an absence of insects or humidity, respectively.

Top-Down Cost Analysis

Likewise, we quantitatively analyzed the cost data that the pilot procurement experiment generated to determine the cost differential of using new packaging types in the supply chain. We estimate the cost per MT across the supply chain by examining the costs of three contracts: the commodity contract, the ocean freight contact and the USAID prepositioning warehouse contract, which includes the cost of fumigation and, with an amendment, of re-bagging.¹¹ The trade-off between spending slightly more, likely on packaging materials, to achieve a lower overall cost across the supply chain through reduced fumigation and/or more efficient handling is the focus of the analysis.

Similar to the effectiveness analysis, we examined the factors over which we had no control to estimate their effect (if any) on cost per MT shipped.

Bottom-Up Cost Analysis

We also built a cost model to estimate the cost differential of using new packaging types using data from interviews and key informant discussions. Again, the trade-off between spending more on packaging materials but less on fumigation is highlighted in results.

For this analysis, we discretize the supply chain that serves USAID prepositioning warehouses into five stages—procurement, domestic transportation, international transportation, collection, and storage.¹² We assume the commodities follow the most common pathway along this supply chain: packaging at a commodity supplier’s plant, shipping via boxcar, container stuffing at a port warehouse, container de-stuffing at a USAID prepositioning warehouses, if necessary, re-bagging at that USAID prepositioning warehouse, and storing at the warehouse. The activities in this pathway that are affected by packaging types (i.e., where packaging and handling occurs) are shown in Figure 4.

Figure 4: Contracts, Stages and Activities in Cost Analyses

Contract	Commodity			Ocean Freight	Prepositioning	
Stages	Procurement	Domestic Transportation		International Transportation	Collection	Storage
Activities	Packaging	Loading	Unloading	Stuffing	De-stuffing	Re-bagging

¹¹ In our analysis, we assume that any packaging type that in principle does not require fumigation is not fumigated (e.g., WPP with BP, WPP with PE liner).

¹² The first two stages roughly map to the commodity contract, the next to the ocean freight contract, and the last two to the FFP prepositioning warehouse contract.

This cost model accounts for (1) the packaging and commodity costs per MT shipped; (2) the domestic (i.e., boxcar) and international (i.e., twenty-foot container via ocean carrier) transportation costs per MT shipped, with commodity-specific domestic points of origin and Djibouti and Durban as the foreign destinations; and (3) fumigation costs per MT shipped, assuming one fumigation in the United States and two abroad.¹³ Again, we assume that any packaging type that in principle does not require fumigation is not fumigated.

For any of the six activities in the supply chain pathway that are affected by packaging type—packaging, loading a boxcar, unloading a boxcar, stuffing a container, de-stuffing a container, and, if necessary, re-bagging shipping-sized bags—we estimate the labor cost per MT shipped required to achieve each activity. Some packaging types increase or decrease labor requirements for some activities; likewise, some affect throughput rates, which affects the labor effectiveness per MT shipped. Of course, some packaging types also affect machinery requirements for each activity. However, we found that the cost increase per MT shipped of adding one laborer to an activity is one to two orders of magnitude higher than adding a machine (e.g., a heat sealer or even a forklift), and so we omit machinery costs from this analysis.

One advantage of this analysis relative to the top-down cost analysis is that it does not reflect the biases that could lead to over- or under-bidding, though it reflects the biases of our interviewees. Another advantage is that this analysis may better capture the medium-term costs of new packaging types, because we assume that firms in the supply chain invest in machinery and processes that improve throughput rates.

Neither of the cost analyses systematically incorporates the savings garnered by avoiding quality losses. The estimates of food assistance losses above based on WFP and USAID data (i.e., USAID 2013; WFP 2016), as well as the pilot procurement quality data, are uncertain enough that we do not include them as part of the differential cost analysis.¹⁴ Importantly, this does not limit our findings – the cost per metric ton shipped of commodity quality loss is small in the first place, though admittedly just large enough that including it may render some cost-ineffective packaging types as cost-effective. But by excluding it we simply provide a more conservative estimate of the cost of new packaging types. Moreover, while the study was in part motivated by reducing quality losses, it is largely the administrative and environmental costs of avoiding and managing quality loss – which are difficult to quantify – that outweigh the estimated monetary costs of quality losses and that motivate our study. Only in our discussion

¹³ This cost model does not account for the storage cost per MT, because we assume that the storage cost per MT—likely a function of floor space consumed—is effectively the same for all new packaging types. The shipping-sized bags would be, in principle, re-bagged immediately after arriving at the warehouse.

¹⁴ WFP and USAID data are generated through voluntary reporting, and our data through sampling shipments – but of a small set of shipments. The WFP and USAID data likely give loss estimates of the correct order of magnitude; our pilot was so small we did not observe much loss, with the exception of breakage. Given the sensitivity of our cost analysis, we do not include savings through avoided loss.

on breakage do we relate the cost of quality losses with the potential cost-effectiveness of a packaging type, but we make several strong assumptions (related to disposal of commodities after packaging tears) in this analysis so it should be treated carefully.

Findings

Feasibility Results

We found that some commodity, packaging, and foreign destination interactions lead to some impractical, if not infeasible, outcomes.

First, while USDA issued a tender for corn soy blend plus in eight packaging types, like for sorghum and yellow split peas, firms only bid on seven of the packaging types. And the winning firm was able to fulfill the contract for only three of these. No firms bid to supply corn soy blend plus in a WPP bag with a PE liner; and the winning firm found that corn soy blend plus “gums up” the pneumatic transfer system used to fill shipping-sized bags, making filling them infeasible. Simply piloting WPP bags with a PE liner would have required substantial investments from corn soy blend plus firms because they do not have sewing machines on their corn soy blend plus production line.

Second, shipping-sized bags challenged firms and organizations as well as regulatory authorities across the supply chain. In the United States, some shipping-sized bags tipped in railcars, making unloading difficult. This is seen in Picture 2. The smaller bags into which their contents would need to be re-bagged abroad were lost somewhere along the supply chain. Abroad, the re-bagging process was labor intensive and took longer than what USAID prepositioning warehouses had anticipated. Such handling challenges were counterintuitive because all five of the plants and warehouses that we visited during fieldwork regularly used shipping-sized bags, as does much of American industry. Even the USAID prepositioning warehouse in Durban to which they were shipped had worked with shipping-sized bags. In the United States, USDA has noted that there are no policies for re-constituting shipping-sized bags that are torn or have partial water damage. This is problematic because they hold 20 to 40 times as much of a commodity as distribution-sized bags, which would make disposing of their contents after water damage or tearing expensive. Abroad, after six months of discussions with USAID, the Djibouti Customs Authority, for example, issued a special certificate to the USAID prepositioning warehouse that allowed them to re-bag the contents of the shipping-sized bags, because the warehouse was in an import-export zone that prohibits value addition.



Picture 2: Tipped FIBCs in the Pilot Procurement

There were also challenges with the PE container liners. Installing the liners proved difficult, and moving commodities into them—especially with a forklift—without tearing them proved complicated, though most were loaded without damage. This indicates that an installation and loading protocol would need to be developed, and training provided at load ports.

Almost as important as the feasibility outcomes of the packaging types that we tested were those of the packaging types that we did not test. We did not pilot insecticide treated bags because their handling requirements—such as workers wearing gloves—would be cumbersome and, in the worst case, not followed. Obtaining regulatory approval to use these bags from the more than 50 countries to which USAID ships food assistance also seemed impractical. The initial USAID and USDA tenders included extra thick, hermetic PE bags, but we quickly learned they could not be sourced in the United States at reasonable costs and order quantities. These would not have required an extra laborer on the packaging line like WPP bags with PE liners.

We initially aimed to evaluate bulk PE container liners, but USAID and USDA suggested the infrastructure (e.g., machines that can tip twenty-foot containers) would not be in place to use them at most receiving ports or warehouses and even in the United States at load ports or commodity suppliers.

Overall, packaging types that changed a filling or handling processes the least were the easiest to integrate into the process. Bags with BP only required existing packaging suppliers to change their activities, and minor coordination between existing packaging suppliers and commodity suppliers; WPP bag with PE liners required commodity suppliers to coordinate with new packaging suppliers and change their filling processes; shipping-sized bags required changes related to packaging suppliers, and filling and handling processes.

Effectiveness Results

First, we observe that there was *the potential for* insect infestation and/or mold growth in the USAID prepositioning warehouses. In Djibouti there was a heavy insect presence for the first two months of storage (until the commodities in the warehouse, with the exception of our treated bags, were fumigated) and a light presence after, and in Durban there was a mild presence throughout the storage period; temperatures were high in Djibouti, and humidity high

in Durban.¹⁵ We had no visibility of the presence of insects during domestic and international transportation.

Next, we note that the commodity supplier—one of the noise variables—does appear to affect commodity quality downstream. Of the two commodity suppliers that provided sorghum, one of the supplier’s sorghum arrived infested, despite that supplier’s sorghum being shipped on two different ocean freight carriers. The major noise factors with the exception of packaging supplier are listed in Table 4.

Table 4: Pilot procurement noise factors

Commodity	Number of Commodity Suppliers	Number of Load Points	Number of Ocean Freight Carriers
Corn soy blend plus	1	2	2
Yellow split peas	1	1	2
Sorghum	2	3	2

Packaging supplier is also a noise variable, and likely has an effect on commodity quality. But unlike commodity supplier, load point, or ocean freight carrier, we had limited ability to track packaging suppliers. For instance, we were unable to verify that all suppliers of WPP bags with PE liners actually met the oxygen and vapor permeability requirements that USDA set forward in the tender. These noise factors affect our results and limit the strength of any conclusions.

We find that MWP bags tore more often than WPP bags in both destinations, and tore more in Djibouti than Durban, after adjusting for the number of bags per container.¹⁶ Given reported challenges loading the shipping-sized bags into standard containers with PE container liners, there was evidence that they tore more than distribution-sized bags, though any tearing might be reduced with learning—over time, firms may learn to and invest in machinery to handle them better.¹⁷ Our data also indicate that the WPP bags with BP tear more than standard WPP bags, but there is no chemical reason that this should be the case. This tearing data is summarized in Table 5, and a torn bag is seen in Picture 3.

¹⁵ The USAID contractor used qualitative terms to describe infestation—heavy infestation lead to immediate fumigation, while mild infestation did not result in immediate fumigation.

¹⁶ MWP bags are 25 kilograms, while WPP bags are 50 kilograms. There are 800 MWP bags and 400 WPP bags per 20-foot container.

¹⁷ There is likely bias in this tearing data. It is likely simpler to document tearing for a container of 20, 1000 kilogram bags, than to do so for a container with 400 or 800 distribution-sized bags.

Table 5: Torn Bags and Value Loss Model¹⁸

	Approx. Bags Shipped	Bags Torn	Bags / MT	Value / MT	% Torn	Avg. Value Loss / Bag	Avg. Value Loss / MT
WPP	4800	6	20	\$400.00	0.13%	\$0.03	\$0.50
FIBC	320	3	1	\$400.00	0.94%	\$3.75	\$3.75
WPP	3200	6	20	\$800.00	0.19%	\$0.08	\$1.50
FIBC	320	3	1	\$800.00	0.94%	\$7.50	\$7.50
MWP	9600	35	40	\$700.00	0.36%	\$0.06	\$2.55



Picture 3: Punctured WPP bag with PE liner in Djibouti

On arrival in Durban and Djibouti, the new quality treated packaging types filled with sorghum and yellow split peas were infested. Commodities in standard packaging and fumigated before ocean shipping appear to have fared better during ocean shipping than commodities in treated packaging. The sorghum shipments to Durban were so infested that they required fumigation; the yellow split pea shipments to Djibouti did not. From this we can conclude that infestation is possible in new packaging types. This contradicts previous lab results, which indicate that the new packaging types suppress infestation very effectively; we found that handling along the supply chain introduced small tears, which may have depressed the effectiveness of the new packaging types.

However, after arrival and any initial fumigation in both ports, data show that new packaging types perform about as well as the standard packaging types (which were fumigated once in Djibouti) over the following months, even in the presence of infestation and high temperatures or humidity. The data are noisy, but overall there are limited and no consistent instances of insect presence or excessive moisture content and/or molds for both quality treatments—BP applied or PE liners inserted—and the standard, fumigated bags. In other words, there was no

¹⁸ This assumes that contents are discarded when a bag tears, and that corn soy blend is valued at \$700/MT after procurement and shipping in 25 kilogram multiwall paper bags, while sorghum and yellow split peas are valued at \$400 and \$800/MT, respectively, after procurement and shipping in 1000 kilogram FIBCs or 50 kilogram WPP bags.

(re-)infestation of the quality-treated bags after their arrival and any initial fumigation. These data are available in Section 7 of the full report.

Considering fumigation's effect on timeliness, and given that new packaging does not suppress infestation under all conditions, for illustrative purposes we assume that new packaging requires half as many fumigations as standard packaging. We estimate that fumigation would account for 2.3 percent to 20 percent of the total shipping time. Here, we observe that fewer fumigations would reduce the total shipping time as well as the amount of shipping time allocated to fumigation.¹⁹

Top-Down and Bottom Up Cost Results

Top-Down Cost Results

Examining the noise variables, we find that bag supplier, commodity supplier, domestic load port and port warehouse, and ocean freight carrier do not appear to affect the cost per MT as calculated by the top-down analysis. These noise factors are referenced in Table 4. This is likely because the USAID and USDA award process in general favors least-cost bids.

Averaging across commodities and destinations, we find that WPP or MWP bags with BP provide cost savings of about \$17/MT shipped relative to standard bags, which is substantial relative to the average cost of procuring and shipping a MT. They have effectively the same handling requirements and a slightly higher material cost compared to standard WPP or WMP bags, so this cost saving is realized by avoiding fumigation. We also find that despite packaging and handling practices for FIBCs being quite different from those for standard bags, their cost averaged across commodities and destinations is only about \$18/MT shipped higher than that of the standard bags—but to Durban and averaging across commodities costs only \$1.7/MT shipped more than standard bags. This indicates that some firms have packaging and handling processes in place for their commercial customers, as we hypothesized. At the other extreme, the WPP bag with PE liner costs on average \$44/MT shipped more than standard bags, averaging across commodities and destinations. This is likely due to a higher material cost compared to standard WPP bags, and possibly a increased labor requirement and depressed throughput rate, both a result of heat sealing or zip tying the bags.²⁰ The data are available in Section 5 of the full report.

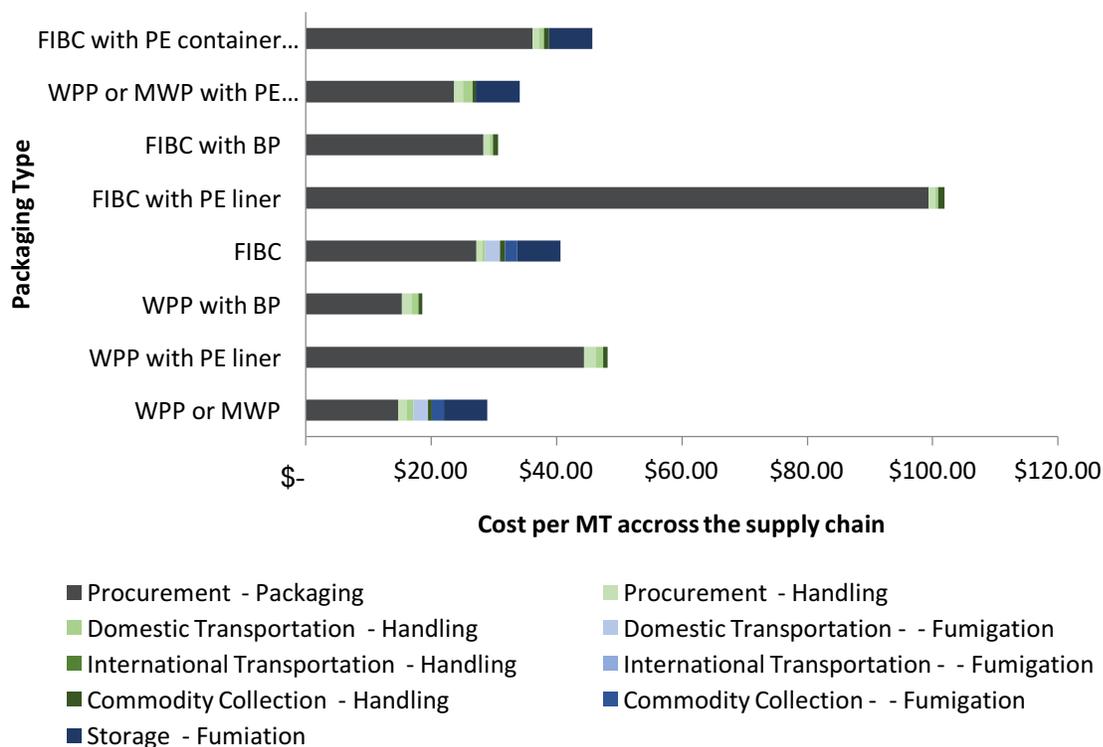
¹⁹ This assumes two, seven-day fumigations over ten weeks (i.e., two fewer weeks) or four, two-day fumigations over 176 days (i.e., four fewer days). This also assumes that applying fumigants is always a bottleneck, which is unlikely.

²⁰ There is some unexplainable variation in these data. We find shipping to Djibouti is more expensive than Durban, which aligns with other USAID administrative data. But, after adjusting for the difference in shipping costs per MT shipped to Djibouti and Durban, we find that similar packaging types cost different amounts per MT shipped. For instance, WPP or MWP bags and WPP or MWP with BP bags should intuitively cost about the same amount per MT shipped, with WPP or MWP bags with BP costing a bit less because they avoid fumigation—but

Bottom Up Cost Results

We estimate that most cost savings per MT shipped come from avoiding fumigation, and most cost increases per MT shipped come from higher material costs; increased handling costs per MT shipped, even for shipping-sized bags, are small relative to fumigation and material costs. This can be seen in Figure 5. We estimate that WPP or MWP with BP would save \$9/MT shipped relative to standard bags averaging across commodities and destinations. We also estimate that shipping-sized bags would cost about \$12 more per MT shipped compared to standard bags, averaging across commodities and destinations; this reflects the fact that most of the firms that we interviewed in the United States had well established filling and/or handling for shipping-sized bags, and some of those that we interviewed abroad did not. Two packaging levels—WPP bag with a PE liner or FIBC with PE liner—appear to substantially increase the cost per MT shipped, with much of the increase attributable to the packaging material costs. A standard WPP bag costs about \$0.5, while a WPP bag with a PE liner costs about \$1.75; a standard FIBC costs about \$12.5, while an FIBC with PE liner costs about \$55. The addition of BP to any bag is comparatively a much smaller incremental cost (i.e., \$0.02-\$0.03/bag). These data are available in Section 4 of the full report.

Figure 5: Affected cost types by packaging types



they differ by about \$20/MT by destination, even after accounting for the difference in shipping costs and that one avoids fumigation. This cost differential by packaging type by destination suggests that these data are noisy.

Comparison

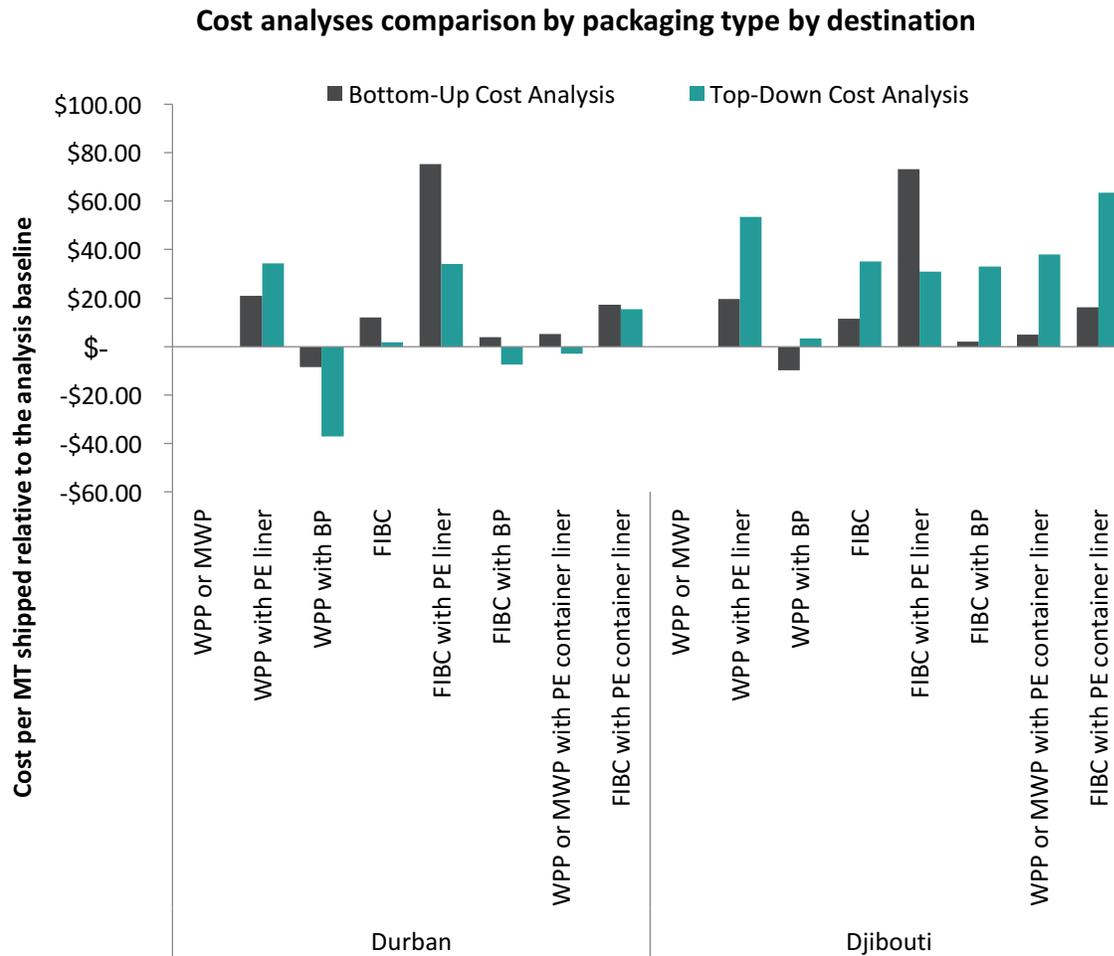
We compare the top-down and bottom-up analyses, focusing on where they differ. The data are presented in Figure 6. For some packaging types, the bottom-up cost analysis suggests that learning or scale effects are not accounted for in the top-down cost analysis. A learning effect implies that as the total number of shipments in a new packaging type increases, firms will fill and handle them more efficiently. A scale effect implies that as the size of shipments in a new packaging type increases, firms will fill and handle them more efficiently.

Both analyses presented in Figure 6 show savings with the WPP or MWP bags with BP averaging across destinations and commodities, though the top-down cost analysis shows more savings on average per MT shipped than the bottom-up cost analysis predicts. This could be because we assumed commodities have to be fumigated more times than they were in practice over that portion of the supply chain.

Considering the quality data alongside the cost data, use of BP will likely be a cost-effective intervention, though will still require some fumigation. Commodities are typically fumigated several times, either in response to infestation or prophylactically across the supply chain. From the quality data we infer that BP may help avoid at least one of those fumigations. If packaging with BP (costing about \$0.6 more per MT for WPP bags) requires just one less fumigation across the supply chain (saving about \$2/MT), it will be a cost-effective intervention.²¹ We note that in our pilot procurement the packaging with BP was not fumigated alongside the standard bags after two months in the Djibouti warehouse, but remained in comparable quality throughout the pilot. Fewer fumigations may also lead to quicker distribution.

²¹ We note that if use of packaging with BP reduces quality losses to 0 percent (saving about \$1/MT shipped, based on USAID (2013) and WFP (2016) estimates, and assuming the same number of fumigations across the supply chain, it will also be a cost-effective intervention for most commodity types. In practice, cost-effectiveness may emerge from a mix of these two savings. This assumes a MT requires 50 kilogram WPP bags, but holds for 1000 kilogram and 50 kilogram bags.

Figure 6: Cost comparison by packaging type by destination²²



In contrast, for shipments to Durban the bottom-up cost analysis consistently over estimates the cost per MT of using shipping-size bags relative to the top-down cost analysis—but the opposite is true for shipments to Djibouti. By trying to account for learning and scale effects in our analysis, we appear to have under-appreciated the processes already in place or that could be put in place in the supply chain that serves Durban, but over-appreciated the processes already in place or that could be put place in the supply chain that serves Djibouti. Overall, our bottom-up cost estimates of shipping-sized bags are consistent with the hypothesis that over the medium-term, and with filling and handling policies in place, actual costs per MT will approximate and even become less than those of distribution-sized bags. The costs per MT averaged across commodities that were observed in Durban supports this hypothesis.

²² For each analysis, the cost per MT shipped in WPP or MWPP is the baseline cost. Costs for each analysis in Figure 6 are presented relative to their respective baseline cost.

The bottom-up cost analysis also over predicts the cost per MT across the supply chain of WPP with PE liner relative to the top-down cost analysis, averaging across commodities. Commodity suppliers and port warehouses actually zip tied instead of heat sealed WPP bags with PE liners, because they did not want to buy a heat sealer to satisfy, possibly, only one contract. This indicates that perhaps zip ties are not inefficient relative to heat sealers, but also reinforces that fumigation and material costs affect the total cost per MT shipped more than handling costs.

Conclusions and Recommendations

Packaging Conclusions and Recommendations

Differentiate packaging types by destination

Standard FIBCs cost \$1.7 and \$35 more per MT shipped to Durban and Djibouti, respectively, than standard WPP bags. We hypothesize that over the medium-term (e.g., 6 to 18 months) shipping-sized bags may cost less per MT shipped than distribution-sized bags, as firms invest in the machinery required to handle them slightly more efficiently. If the cost of re-bagging per MT decreases by one-third in Durban, shipping-sized bags would become cost-effective. While the infestation data were noisy, qualitatively the shipping-sized bags avoided infestation and broke about as often as distribution-sized bags.

We recommend USAID and USDA further explore shipping-sized bags.

We qualify this recommendation by noting that shipping-sized bags may only be cost-effective (a) when shipped with commodities like sorghum and yellow split peas, and (b) when shipped in a supply chain that has the machinery *and* regulatory environment to handle and re-bag them. This is based on feasibility findings related to corn soy blend plus and Djibouti.

In practice, it may be cost-effective to build capacity in USAID prepositioning warehouses to handle shipping-sized bags, and only ship these bags to these warehouses. It may be impractical to assume most PIOs or PVOs would be able to handle them. And given the regulatory challenges that we observed, using shipping-sized bags only in prepositioning warehouses would also limit the number of regulatory authorities that would need to approve re-bagging processes. However, this would reduce operational flexibility: USAID would not be able to divert packaged shipments en route to prepositioning warehouses if the shipments contained shipping-sized bags, because most PIOs or PVOs would not be able to handle them. Over fiscal years 2007-2012, of 947 shipments destined to prepositioning warehouses, 568 were diverted to WFP and eight other partners (USGAO 2014).

More generally, USAID ships food assistance commodities to over 45 countries every year: specific packaging types for each destination would add complexity, but there may be instances in which particular packaging types become cost-effective for certain countries or certain operations. For instance, Ethiopia may be developing capacity to efficiently bag bulk commodities arriving on the train from Djibouti. WFP Djibouti is also building grain silos; and it is possible that shipping-sized bags could be used to bag commodities from these silos. With enough volume, shipping-sized bags could become cost-effective for Ethiopia (which receives in some years almost one third of USAID's in-kind food assistance by weight) though we do not want to understate the degree of mechanization necessary to efficiently re-bag shipping-sized bags.

Relatedly, it is also worth exploring that some break-bulk carriers have the capacity to very efficiently load and un-load shipping-sized bags, such as in Durban.

Apply bio-pesticides to bags program-wide

The application of a bio-pesticide to bags was the least costly quality treatment per MT shipped, with the bottom-up cost analysis indicating the marginal increase in material cost was offset by the decrease in fumigation costs. While the quality data is noisy, packaging with BP appears to perform about as well as standard packaging in the warehouse, though in shipping packaging with BP appears to perform marginally worse than standard packaging based on insect infestation measures. This indicates that application of BP could not replace fumigation.

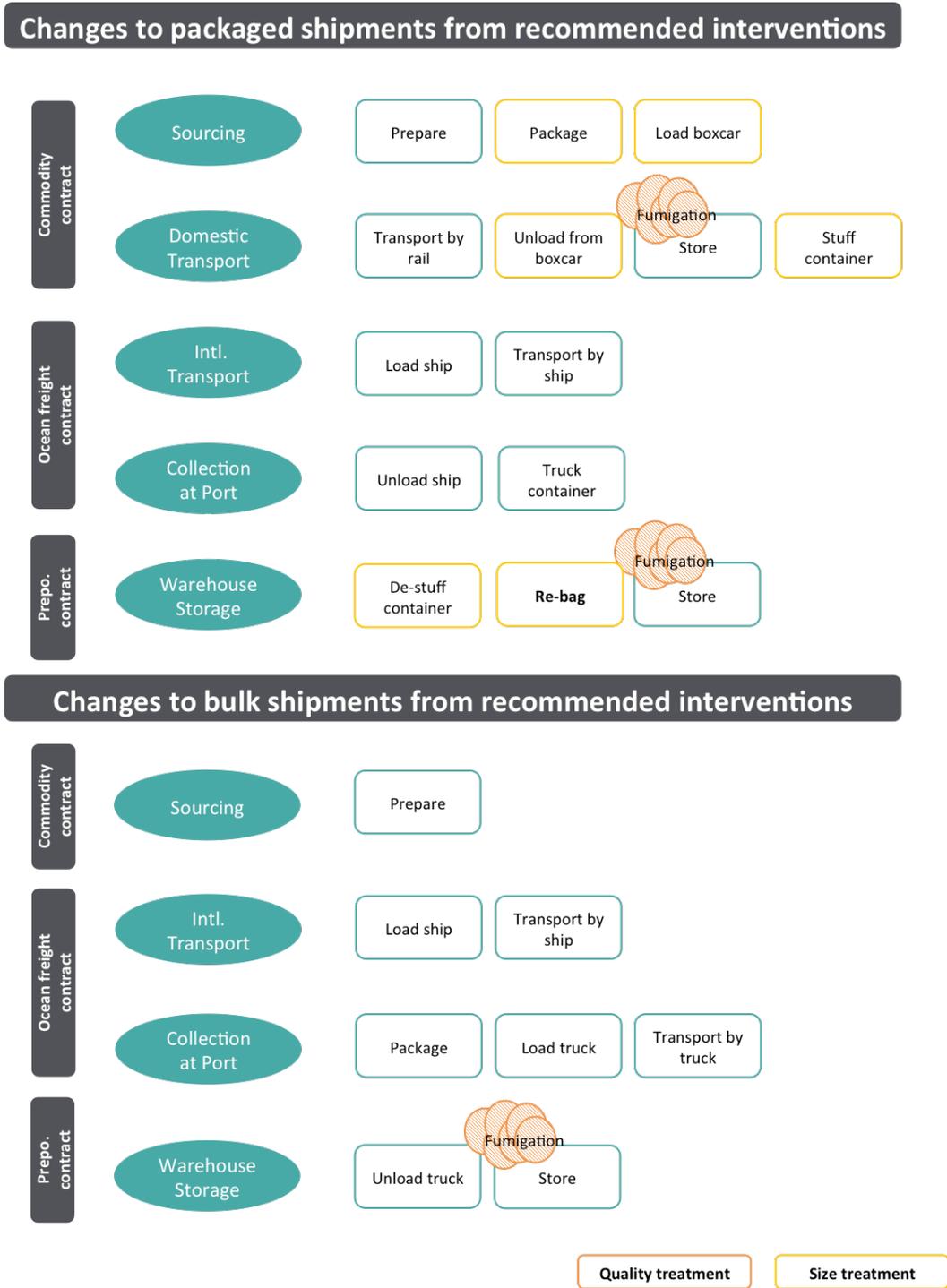
*We recommend that packaging with BP be used in conjunction with some phosphine fumigation.*²³

In practice, this will likely be a cost-effective intervention. If packaging with BP requires one less fumigation across the supply chain costing \$2.05 per MT, it will save \$1.40 per MT shipped after accounting for the slight increase in packaging costs.²⁴ It will likely be a time-effective intervention too. Packaging with BP should not affect filling or handling processes and, in some cases, may even avoid two to seven day fumigations. This recommendation as well as the recommendation on shipping-sized packaging are presented graphically in Figure 7. In Figure 7, quality treatments are bags with BP, which may help reduce the need for fumigation, and size treatments, which will affect handling.

²³ To our knowledge, there are no chemical interactions between methoprene and phosphine fumigants.

²⁴ \$2.05 is the average fumigation cost per MT of three of four USAID prepositioning warehouses. This assumes WPP bag with BP that cost an extra \$0.6 per MT.

Figure 7: Potential changes to supply chain from BP and shipping-sized bag recommendations



Consider WPP bags with PE liners – but for different commodities and objectives

The WPP bag with a PE liner increased the cost per MT shipped, mostly due to increased material costs. Despite the noisy quality data, the WPP bag with a PE liner performed about as

well as the standard WPP bags based on insect infestation as well as moisture/molds measures, which indicates that the airtight environment does not maintain moisture and prevent mold growth as we hypothesized that it would.²⁵ (We have similar findings for the PE container liner.) Given the high material costs, these quality findings eliminate the potential for the WPP with PE liner to be used regularly. Or even the potential to be used under select operational conditions, such as prepositioning in rural warehouses before a rainy season where the programmatic benefits of prepositioning may outweigh the costs of using WPP bags with PE liners.

However, we recommend trialing a cheaper WPP bag with a PE liner (i.e., with more permissive oxygen and water vapor permeability rates) and with corn soy blend plus to reduce tearing.

There is one condition under which WPP bags with PE liners may approach cost-effectiveness: using a PE liner that is cheaper because it has more permissive permeability rates and that breaks at rates similar to standard WPP bags, which, because corn soy blend plus is relatively expensive and cannot be re-constituted, may help offset material costs.²⁶ The pilot procurement indicated that 0.13 percent of all WPP or MWP with BP bags were torn by the completion of de-stuffing, while 0.36 percent of all MWP or MWP with BP bags were. Accounting for the value of commodity lost, a 25 kilogram WPP bag with PE liner could be about \$0.13/bag more expensive than standard 50 kilogram WPP bags, and still be cost-effective relative to MWP bags.²⁷ We note that the European Union uses a bag like this for its version of corn soy blend plus. This variety of WPP bag with PE liner could be just sewn or heat sealed closed, further reducing costs relative to the variety that we piloted.

Examine upstream quality

The quality data indicate that the domestic portion of the supply chain was likely a source of infestation in the pilot procurement, rather than the international portion of the supply chain.

We recommend that USAID and USDA use existing capabilities in WBSCM to track domestic and international quality issues.

If there are certain conditions that tend to lead to negative quality outcomes, USAID and USDA could consider placing tighter controls on the domestic supply chain. Alternatively, if there are certain conditions that lead to positive quality outcomes, USAID and USDA could design contracts and guidance accordingly. This recommendation to gather more data is in line with

²⁵ We must note that one major noise variable was packaging supplier, so this assumes that all the WPP bags with PE liners that were used in the pilot met the specifications put forward by USDA.

²⁶ One recommendation to avoid breakage for all WPP bags, but especially those filled at foreign ports, is to include a colored thread across the top to indicate to the sewer where the bag should be sewn.

²⁷ This assumes that the new variety of WPP with PE liner breaks at the same rate as a WPP bag, a 50 kilogram WPP bag is \$0.5, and a 25 kilogram MWP bag is, conservatively, about \$0.6. A 25 kilogram WPP bag would likely cost much less than \$0.5, which would allow for the WPP bag with PE liner to be closer to \$0.2 more than the standard WPP bag and still be cost-effective.

discussions at the May 2017 Michigan State University—U.S. Government Food Assistance Packaging Convening.

Use insect traps – back to the basics

We began this study under the assumption that warehouse management interventions are difficult to target and implement, and are not necessarily cost-effective relative to new packaging types. However, one outcome of this study is actually a warehouse management intervention that began as a byproduct of the study: the insect traps that we used to measure the presence of flying and crawling insects also became a mechanism that gave USAID good visibility into its prepositioning warehouses' conditions.

We are encouraged that USAID is continuing to use the traps in its prepositioning warehouses.

Process Conclusions and Recommendations

Start with small and deliberate pilots

Procuring and shipping the commodities in the pilot cost about \$600,000, while data collection cost about \$150,000. However, because the commodities were programmed after the pilot ended, there was little differential cost to USAID and USDA on that \$600,000. With this differential cost, it is tempting to consider a pilot procurement several times larger—not made larger by including more commodities or destinations, which would add more complexity with little extra insight, but by including two or three replicates per run, which could strengthen data. However, risk increases with pilot procurement size: while all of our commodities were of programmable quality at the end of the study, which kept the differential cost low, that was not a given. If just one of the bag types rendered commodities un-programmable in our pilot procurement, it could have cost USAID about \$75,000;²⁸ that cost would scale linearly with the size of the procurement. The design of the experiment—systematically selecting representative commodities and foreign destinations—allowed us to gather data and draw conclusions that are applicable to many commodities and destinations from a small procurement, and, especially, make strong feasibility recommendations.

We recommend initially using a design of experiments approach with a small procurement to pilot new food assistance supply chain modifications, and draw generalized conclusions, especially related to feasibility.

Work toward bigger evaluations

The pilot procurement generated strong feasibility data and modest cost and effectiveness data, to the extent that we supplemented the top-down cost analysis with the bottom-up cost analysis. One or several procurements at least an order of magnitude bigger than our pilot procurement would generate more and likely stronger cost and effectiveness data, and

²⁸ This assumes each of the eight packaging type cost about the same to procure and ship.

different feasibility data.²⁹ We hypothesize that costs would decrease and effectiveness increase with larger and more procurements, and that previously infeasible packaging types would become feasible. For instance, our pilot procurement was so small that the WPP bag with PE liner cost about \$2.50/bag—but they cost \$2.00/bag with orders of 10,000 bags, and \$1.75/bag with orders of 100,000 bags. Moreover, no corn soy blend plus firm bid to provide the only 40 MT in WPP bags with PE liners; doing so would have required that they install a sewing machine on their production line. It is worth noting that we find that larger and more procurements may not overcome some hurdles: tenders have their limits. To more successfully pilot a packaging type that requires major changes to a packaging or handling process, such as WPP bag with PE liner for corn soy blend plus, it may be necessary to work even very closely with the commodity or shipping community that the packaging type substantially affects.

We recommend using results from small pilot procurements to inform larger and more procurements, but recognize the limits of even larger and more substantial procurements.

Learn from the design and operationalization

We initially proposed a pilot procurement with three commodities, ten packaging types, two shipping methods, and three destinations, which entailed 180 feasible and infeasible runs. Working with USAID and USDA, we eliminated some packaging types and destinations, as well as over half of the runs to generate 62 runs that were, in principle, feasible. After USAID and USDA issued the tender, we eliminated another packaging type and 20 additional runs. Finally, during the procurement and shipping processes, we eliminated another eight runs. At the close of the pilot, the procurement entailed three commodities, eight packaging types, one shipping method, and two destinations. These revisions are described in Table 6.

Table 6: FFP and Pilot Procurement: Factors, Levels and Runs over Phases

FFP and Pilot Procurement: Factors, Levels and Runs					
Factors	Commodity	Packaging	Shipping	Foreign Destinations	Runs
<i>Infeasible and feasible levels</i>					
FFP Annual Procurement	15>	1	2	>50	1,500
Proposed Pilot Procurement	3	10	2	3	180
<i>Revisions: feasible levels and runs at end of each phase</i>					
Design Phase	3	9	1	2	62
Tendering Phase	3	8	1	2	42
Procurement and Shipping Phase	3	8	1	2	36

We found most of the general learnings happened during the design process (e.g., that destination is impractical). The design phase is primarily when we eliminated factors, while

²⁹ In practice, larger and more procurements would require a similar tendering process but different monitoring process that may require random sampling, because commodities would have to be shipped to PVOs and PIOs as well as USAID prepositioning warehouses.

many of the more nuanced learnings for us *as well as* USAID and USDA happened during tendering, procurement, and shipping (e.g., that bag cannot be used with that commodity or at that destination). Those phases are primarily when we eliminated runs. The general learnings did not require that the pilot be operationalized, but the nuanced learnings did. This is discussed in Section 9 in the full report.

We selected factors, levels and runs that would generate meaningful variation in response variables used in our effectiveness and cost analyses, but we did not select them anticipating such variation in the number of levels and runs over the course of the pilot. Nor did we anticipate how meaningful this latter source of variation would become; it actually formed the basis of our feasibility analysis.

We recommend treating a pilot procurement as a two-stage process and anticipating general learnings early and nuanced learnings later in the pilot procurement process. Moreover, we recommend designing procurements anticipating revisions along the different phases.

Introduce variation thoughtfully, if not randomly, to evaluate programs

Evaluating the causal effects of programs is an increasingly common practice in development and humanitarian interventions (e.g., Imbens and Wooldridge 2009). However, in practice introducing random variation is difficult in most supply chain contexts (e.g., with village-level retailers abroad), and nearly impossible in supply chains like those that serve food assistance programs (e.g., with American commodity suppliers who regularly bid on USDA tenders). Thus, we relied on the same experimental principles that underpin many causal effect studies, but (1) without randomly applying the “treatment.”

To evaluate programs, we recommend using design of experiments at different scales—multiple and large procurements, singular and small pilots—to thoughtfully introduce variation when introducing random variation is not possible.

Design flexible partnerships with universities

This work was completed by CITE at MIT in partnership with USAID and USDA. These partnerships allowed us to be close enough to USAID and USDA that we could easily exchange data or travel with USAID staff to interviews during fieldwork. But it also gave us flexibility to work with the private sector and other universities. We drove over 2,000 miles across the Midwest to see packaging and handling processes at multiple commodity suppliers and port warehouses, and worked with other universities that study the technical issues related to food quality to ensure the right technical data was collected and analyzed in a meaningful way.

Our extra-mural position served another purpose. New to the field, we brought an aspirational perspective to food assistance packaging. In addition, we could even bear some of the risk of the pilot procurement; while no packaging types rendered commodities un-programmable, if they had it would have been on the basis of our recommendation to pilot the packaging type. Taken together, this partnership gave us the space to serve as “honest brokers” for public and private stakeholders.

We recommend forging close partnerships between USAID, USDA, universities and the private sector to facilitate the type of collaboration necessary to carry out effective research in this space.

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USDA Kansas City

USAID contractors in Washington DC, Djibouti, South Africa and Kenya

American agricultural associations and check offs

Packaging firms in the Southwestern United States

Commodity suppliers located between North Dakota and Texas

Port warehouses in the Gulf of Mexico

Ocean freight carriers across the Eastern Seaboard

Ports in Djibouti and South Africa

PVOs and PIOs in the Horn of Africa

Universities in Manhattan, KS and Boston, MA

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