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National Drug Stockout Risks in Africa: Analysis of the Global Fund Disbursement Process for Procurement from 2002 to 2013

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National Drug Stockout Risks in Africa: Analysis of the Global Fund Disbursement Process for Procurement from 2002 to 2013

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Abstract

Despite substantial financial aid from international donors for procurement of health products, stockouts of life-saving drugs related to prevalent infectious diseases are still widespread in Africa. Addressing the lack of research on why these stockouts occur, we study the relationship between The Global Fund to Fight AIDS, Tuberculosis and Malaria and its grant recipients. Specifically, we leverage extensive historical fund disbursement and drug procurement data to build a discrete-event simulation model predicting the joint impact of procurement and grant disbursement processes on national drug availability for the Global Fund's recipient countries in Africa. This model is validated against cumulative stockout levels inferred from historical grant implementation lengths, and used to evaluate potential high-level modifications of disbursement or procurement processes. Results show the existence of substantial intrinsic stockout risks in many countries, due to the unpredictability of fund disbursements and the frequency of grant performance monitoring performed by the Global Fund. Interventions increasing fund disbursement levels to protect against disbursement timing uncertainty are predicted to be more effective than others that include regional buffer stocks and bridge financing.

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1. Introduction

Twenty-five years ago, almost one-third of the world's population did not have access to essential medicines (Foster et al. 2006). Major trends in global health since then include the emergence of new actors such as The Global Fund to Fight AIDS, Tuberculosis and Malaria (*Global Fund*), the Global Alliance on Vaccines and Immunizations (*GAVI*), the Bill & Melinda Gates Foundation as well as budget increases of bilateral donors such as the US and UK governments (Atun et al. 2012). This has resulted in a significant increase of international funding for health programs in low-income countries (currently US $27 billion a year, see IHME 2013, Yadav 2010). Unfortunately, communicable diseases treatable in the developed world remain widespread: HIV/AIDS remains the leading cause of adult death in Africa with estimated 23 million people living with HIV at the end of 2011 and 2.5 million new infections a year (United Nations 2013); malaria and tuberculosis combined led to over 2 million deaths in 2011, again mostly in Africa (WHO 2013a and 2013b).

Established in 2002, The Global Fund is currently the world's largest external financier of HIV, tuberculosis and malaria programs. Funded by countries such as the United States (29% of total paid to date), France (13%), the United Kingdom (9%) and Germany (7%); private foundations such as the Bill and Melinda Gates Foundation (5%); and corporations such as Chevron (0.2%), by October 2012 it had committed US $22.9 billion to prevention, treatment and care in 151 low and medium-income countries. This includes US $9.2bn (around 40%) for procuring medicines and health products, and US$9bn (around 38%) for strengthening health systems (Global Fund 2012a). A key feature of The Global Fund that has been material to its ability to raise funds from donors is performance-based financing. In this financing model, proper use of past funds and the achievement of predefined results by grant recipients (e.g., number of patients treated, number of doctors trained, number of facilities opened) become prerequisites for future disbursements by the Global Fund (Center for Global Development 2013).

Despite the positive impact of Global Fund-supported programs (Brugha et al. 2004), stockouts of health products at health facility (peripheral) and national level (e.g. central warehouse) are widespread in countries receiving Global Fund financing, particularly in Africa (Yu et al. 2008, PLoS Medicine Editors 2009, Oliynyk 2011): in a 2009 survey, 9 out of 14 surveyed African countries reported stockout of at least one type of medicines related to Global Fund grants within the last year, 4 reported stockouts of two or more types, and all reported at least one near-stockout situation (Global Fund 2009). Stockouts cause treatment interruptions, loss of confidence in health systems and providers, increased risks of drug resistance and adverse effects on disease epidemiology. Consequently, stockouts lead to increased morbidity and mortality for a large number of patients receiving treatment for AIDS, tuberculosis and malaria and pose a major challenge to public health (WHO 2004, Levine et al. 2008, Hawkes 2011). In general, stockouts of medicines in Africa have been attributed to procurement delays (ALMA 2011), fund

disbursement delays (Lane and Glassman 2008, Celasun and Walliser 2007), and among others insufficient visibility of stock levels in peripheral health facilities (Shretta and Yadav 2012). While the existing literature does include rich contextual observations of stockouts however, rigorous quantitative research on their causes is lacking. This paper is an empirical study of the relationship between national stockout risks for health products purchased with Global Fund grants in Africa and the legacy process used by the Global Fund between 2002 and 2013 for performance monitoring and procurement fund disbursements. Specifically, we leverage publicly available historical fund disbursement and drug procurement data for Global Fund grants in Africa to build a discrete-event inventory simulation model predicting the joint impact of procurement and grant disbursement processes on national drug availability in recipient countries. This model is validated against cumulative stockout levels inferred from historical grant implementation lengths, and used to evaluate potential high-level modifications of disbursement or procurement processes. Exemplifying the application of standard management science methods to address global health challenges (Garnett et al. 2011, Kraiselburd and Yadav 2013), this work may thus inform the policies of the Global Fund, but also other international financing institutions using performance-based financing.

After a review of existing related work in §2, we formulate, estimate and validate our strategic inventory model in §3. Section §4 presents the experiments performed with that model and their results, which are then discussed in §5. Concluding remarks along with an agenda for further research on global health procurement are presented in §6. In the remainder of this introduction, we provide additional background on the Global Fund's funding process (in §1.1) and discuss various potential or actual interventions related to that process (in §1.2).

1.1 The Global Fund's grant funding process

Following a Global Fund announcement of a funding round (roughly once a year), nominated organizations (governments, NGOs or private sector institutions) called *principal recipients* (PR) submit proposals for Global Fund financing for disease-specific programs. Global Fund approval of a total program budget sets out a disbursement schedule of successive reporting periods for the awarded grants, each typically three or six months (90 or 180 days). The reporting frequency used for each program is determined by the Global Fund's perception of the risks associated with its implementation. Implementation risks could stem for example from overspending or lack of respect of budget lines, lack of suitable accounting software and procedure, excessive use of cash payments, absence of supporting documentation for expenditures, inadequate storage and distribution of pharmaceuticals, lack of transparent procedures to select or monitor subcontractors, data quality problems, etc.. After each period, PRs submit a progress report and fund disbursement request for the next period that must be consistent with the needs defined in the initial proposal. The first disbursement includes an additional "cash buffer"

of three months, and similar buffers may be subsequently approved by the Global Fund (Global Fund 2012b).

The Global Fund contracts *local fund agents* (academic institutions, private management consulting firms) to act on their behalf and to audit and assess programs. Based on the recommendations of these local agents, the Global Fund may issue program evaluation scores including:

- A - meeting or exceeding performance expectations;
- B1 – adequate performance;
- B2 - inadequate performance but with demonstrated potential; and
- C - unacceptably poor performance; may be discontinued.

Based in principle on these scores, the Global Fund will determine its response to disbursement requests in each period. The procedure is repeated every period, with the most recent evaluation score being from the preceding period. Disbursement delays are common, and may for example result from missing documentation, PRs not completing performance-related preconditions identified by fund agents, or resource constraints affecting either the Global Fund or PRs. Because grants occasionally get discontinued due to poor performance and public financing is distrusted in low-income countries, disbursement completion is nearly always required before associated procurement orders can be placed from vendors. Therefore disbursement delays can prompt emergency searches for alternative funding sources and/or affect the continuity of the local drug supply (Brugha et al. 2004).

Historically, the first two years of a grant were called Phase I, which recipients could often extend by a few months through specific ad-hoc requests. To ensure more predictable long-term funding beyond that first phase, recipients could then submit funding continuation applications for another three years called Phase II. Formal evaluations by the Global Fund during Phase I have been far less systematic than during Phase II.

1.2 Process modifications considered by the Global Fund

To reduce stockouts of medicines at the national level, several interventions related to the Global Fund financing and procurement processes have been introduced or considered. They include Voluntary Pooled Procurement, which makes procurement services available to grant recipients (GFPSS 2012); Pledge Guarantee for Health, a bridge financing scheme developed by the United Nations Foundation to provide funds for the period between grant approval and disbursement (United Nations Development Fund 2011); and international or regional buffer stocks designed to reduce procurement lead times (Global Fund 2011). In late 2012, the Global Fund announced an intention to completely redesign its legacy funding process (Global Fund 2013). While the core principles, methods for investment project selection and financing allocation are already in place, detailed operational features related to

procurement and disbursement are still being refined at the time of writing, and we hope that the present paper may inform the operational aspects of this initiative.

2. Related Literature

Existing quantitative studies of Global Fund grant operations have examined the factors influencing grant evaluation scores (Radalet and Siddiqi 2007) and cumulative disbursements (Cohen, Singh and O'Brien 2008, Lu et al. 2006). Fan et al. (2013) have recently argued that current incentives mechanisms are not adequate as performance ratings are not replicable by external observers and not sufficiently connected with actual funding decisions. Our work extends this stream of research by characterizing the factors affecting Global Fund disbursement and procurement lead-times, and by quantifying the link between these lead-times and the risks of national stockouts of health products faced by Global Fund grant recipients in Africa.

There is also a recent body of work on operational issues related to donor funding for global health that is relevant to large-scale subsidy programs. In particular, Tougher et al. (2012) provide an empirical study of the Affordable Medicines Facility for malaria commodities program (AMFm) showing that subsidies combined with supporting interventions can rapidly improve availability, price and market share of quality-assured artemisinin-based combination therapies. Theoretical models of subsidies include Taylor and Xiao (2014), which consider the effectiveness of sales vs. purchase subsidies in improving the availability of malaria drugs, and show that the donor should only subsidize purchases and not sales; Levi et al. (2014) analyze an optimization model to show that uniform subsidies to competing manufacturers do maximize consumption under some assumptions. In contrast, our work focuses on grants to be used for full payment of procurement by grant recipients (as opposed to subsidies), which is the traditional and predominant funding channel for the Global Fund.

Another theoretical analysis related to our work is Natarajan and Swaminathan (2012), which characterizes the optimal procurement policy for a health product in the presence of funding uncertainty over a finite time horizon. While their mathematical model is therefore closely related to our work, our intended contribution is an empirical one that focuses on the Global Fund and performance-based funding. This contextual focus is motivated by the dominant role currently played by the Global Fund in the global financing of procurement for health products relative to other agencies such as UNICEF that primarily support in-country implementations of health programs and use more traditional fund transfer mechanisms. This has important modeling implications, because under the performance-based funding mechanism used by the Global Fund, grant recipients submitting fund disbursement requests are required to document the satisfactory use of funds previously disbursed during past grant review periods, consistent with the initial grant agreement (see §1.1). Global Fund grant recipients therefore have strong incentives to commit funds quickly after their disbursements. This can be verified empirically from our

dataset, where 79% of the 3027 procurement orders funded by Global Fund grants between 2008 and 2012 were placed in the two weeks around a fund disbursement, even though the Global Fund grants we consider involve disbursement inter-arrival times of three to six months (delays of up to two weeks between disbursement approval notification and actual fund transfer are observed). Given the various steps involved in public procurement processes and related data entry issues, it is also possible that many of the remaining 21% of orders were in fact committed in the days following a fund disbursement. This justifies our model assumption that procurement orders are placed immediately after fund disbursements, and the procurement policy of Global Fund recipients (order timing and quantity decisions) is in effect entirely determined by the disbursement schedule. In contrast, Natarajan and Swaminathan (2012) derive the optimal inventory policy for a more traditional and less constrained theoretical procurement model involving inventory holding costs and interest income for unused funds, and where there is no endogenous relationship between the use of funds by recipients and the timing of future disbursements. Hence, the focus of our work is on the empirical link between stockout risks and the grant-recipient interaction process, rather than determining an optimal procurement policy. Notably, both papers establish in their respective motivating contexts that uncertainty in disbursement timing has a substantial negative impact on service levels.

Finally, our work includes a case study on the operations of a major global health organization, and an empirical analysis of related data resulting in validated distributional forecasts of procurement lead times for several important categories of health products in Africa. Other references providing contextual information and data about global health supply chains include Yadav (2007), who qualitatively discusses long and unpredictable procurement lead times for essential commodities in Zambia and their relation to drug stock-outs; and Gallien et al. (2014), which contains a detailed case study of the public distribution of pharmaceuticals in Zambia and presents related datasets and a validated simulation model.

3. Simulation Model

Our simulation model is designed to characterize the relationship between actual disbursement lead-times linked to the Global Fund performance monitoring process, actual procurement lead-times for health products, and the risks of national stockouts in African countries receiving Global Fund grants. In addition, we want to evaluate the relative effectiveness of various possible strategic interventions for reducing these stockout risks (see §1.2). We emphasize that our objective is therefore not to develop realistic predictions of inventory levels of actual products in specific facilities of recipient countries at any point in time. Such an objective would likely imply a considerably more complex model than is formulated here, and require more detailed data than was available to us for this study (see §3.4 for a related discussion).

To achieve our goals, we first perform econometric analyses of historical *disbursement inter-arrival times* (DITs) and *procurement lead times* (PLTs) associated with Global Fund procurement grants from 2002 to 2013. We then leverage these analyses to construct distributional forecasts of DITs and PLTs, and perform out-of-sample validations of these forecasts. We then consider a simple discrete-event model relying on these distributional forecasts of DITs and PLTs to simulate the inventory level of a single commodity in a central location when subjected to such disbursement and procurement lead-times. Finally, we perform an out-of-sample validation of this model's predictions against the cumulative stockout levels inferred from historical grant implementation lengths obtained from public sources, and use this model to generate insights about potential high-level modifications of disbursement or procurement processes. Figure 1 provides a schematic methodology overview.

[Figure 1]

In the remainder of this section we present a precise definition of our model in §3.1, describe in §3.2 the methods followed for estimating model input data, discuss the results of a model validation experiment in §3.3, and finally provide a qualitative discussion of the main model assumptions in §3.4.

3.1 Model definition

Our discrete-event model simulates the inventory level of a single health product in a central location for each country, before that inventory is shipped to patient-facing health facilities. In many countries, this central location would correspond to the national warehouse where public procurement orders are delivered. As we do not model potential changes in health product prices, inventory levels and disbursement amounts are both measured in duration of demand coverage. The model is instantiated for principal recipients in 53 African countries, the five types of health products procured with Global Fund grants (anti-malarial, anti-tuberculosis, anti-retroviral, malaria prevention and HIV prevention), and 90 and 180-day grant reporting periods. Baseline simulation dynamics rely on the following steps (Figure 2 provides a sample simulation replication output for illustration):

- The initial inventory available at the time origin equals 6 months of demand, which corresponds to the initial disbursement cash buffer and recommended inventory level stated in several existing guidelines for preventing stockouts (Ministry of Health, Uganda 2012, Global Fund 2006). The initial grant rating is set to the most frequent rating in the historical disbursement database for the principal recipient considered (see §3.2);
- Subsequent demand depletes available inventory at a constant and deterministic rate. Demand occurring when there is no inventory is recorded as lost;
- From either simulation time origin or the time of a grant disbursement, the time duration before the next grant disbursement is simulated as a random realization of the distributional forecast of DIT corresponding to that country's region, the grant period considered, and the grant rating

corresponding to the previous period (see §3.2). As the simulation moves to the next reporting period, a new grant rating is simulated by an independent random draw consistent with the grant rating transition frequencies estimated from the historical disbursement data for that principal recipient. The default disbursement amount corresponds to the procurement funds necessary to cover demand for one grant period (90 or 180 days) plus 10% of additional funding, i.e. a *cash buffer level* of 10% of the demand per period;

- Each grant disbursement is immediately and entirely committed to a procurement order for the product. The quantity purchased then is added to the inventory after a lead time obtained as an independent random realization of the distributional forecast for PLT corresponding to that country's region, whether it is landlocked, and the product type (see §3.2).

[Figure 2]

In each simulation replication the fraction of demand lost over the first three years (duration of Phase II) and the time required to fulfil three years of demand from inventory are recorded. For sensitivity analysis the initial inventory coverage is varied between 0 and 9 months in increments of 3 months and the cash buffer level is varied between -20% and 100% in increments of 10% - variations around the baseline of 6 months of inventory on hand and 10% discretionary cash buffer suggested by the Global Fund (Global Fund 2012b). In the Phase I scenario DITs are generated according to estimations from Phase I data only.

Using this model we can consider three possible major interventions related to Global Fund financing and procurement processes (see §1.2), simulated as follows:

- *Instantaneous Replenishment* (IR): PLTs are set to zero to represent immediate delivery of all procurement orders e.g., from an international or regional buffer stock (warehouse managed by a third-party for the purpose of storing inventory closer to the PR and thus reducing procurement lead times, Global Fund 2011);
- *Bridge Financing* (BF): a third party loan for an amount equal to the next anticipated disbursement triggers advance procurement order placement whenever the DIT exceeds the grant period length, consistent with the definition of Pledge Guarantee for Health (United Nations Development Fund 2011). Grant disbursements following such loans are paid back to the lender, and financing costs are ignored;
- *Synchronized Financing* (SF): grant disbursement amounts are increased to cover one and a half reporting period, i.e. cash buffer level is set to 50%. Overall grant budget is unchanged so that disbursements stop when budget is exhausted, i.e. funding is gradually moved forward in time or front-loaded (Natarajan and Swaminathan 2012) but the total amount disbursed over the grant lifecycle remains the same.

3.2 Input data estimation

Procurement lead time (PLT) is defined as the number of days from order placement to product delivery. For estimation purposes, historical PLTs are obtained from the publicly available Price and Quality Reporting database maintained by the Global Fund, where each principal recipient of a procurement grant is required to report all purchases of health products from the following five categories: anti-retroviral drugs, anti-malarial drugs, anti-tuberculosis drugs and prevention of malaria and HIV (Global Fund 2012c). Using this dataset, we estimate a number of econometric models to identify the main factors affecting PLTs (e.g., product category, geographic region, whether the country is landlocked…), define data categories to remove the predictable variability associated with the value of these factors, then construct a distributional forecast of PLT for each principal recipient in each data category. Finally, we validate the predictive accuracy of these forecasts using repeated out-of-sample evaluation of their predictive accuracy using 1000 randomly selected partitions of the dataset into separate estimation and evaluation sub-samples. For each partition, we use the Kolmogorov-Smirnov test to compare the distributional forecast estimated in-sample and the empirical out-of-sample distribution of PLTs (Arlot and Celisse 2010). As a maximum of 67‰ repetitions (mean 46‰) were rejected at the 5% significance level across all data categories for that test, we conclude that our model of PLTs seems suitably accurate for our purposes (Section A1 of the supplementary material provides more details on this analysis, including the complete econometric study of PLTs).

To estimate *disbursement inter-arrival times* (DITs), we consider a dataset of 2068 disbursements from the Global Fund to principal recipients in 53 countries in Africa from January 2005 to June 2012, which we obtained from the Global Fund web site (Global Fund 2012d). The variables in this dataset include grant number and disease program funded, disbursement date, reporting period start and end date, and when applicable rating for the previous reporting period data. Disbursements within the first two years of each grant lifecycle are identified as Phase I, all others as Phase II. Disbursement inter-arrival times are calculated as the number of days between disbursements in consecutive periods of the same grant. For each principal recipient we construct a distributional forecast of DIT conditional on the grant rating in the previous period, then perform an out-of-sample validation of this forecast using a methodology similar to the one previously described for estimating PLTs (details provided in section A1 of the supplementary material).

Finally, frequencies of grant rating transitions in Phase II are estimated for each principal recipient from the disbursement dataset just described as the fraction of past periods with rating i when the next period rating was j with $(i, j) \in \{A, B1, B2, C\}$ (see §1.1).

3.3 Model validation

The goal of our model validation exercise is to evaluate the predictive accuracy of our main simulation model output, namely level of national stockouts over a grant lifecycle. This presents a methodological challenge however, because despite the widely reported prevalence of national stockouts for essential medicines in Africa (see references cited in §1), we are not aware of any readily available dataset systematically documenting the historical national stockout episodes of any African country, let alone for all of Africa. Because of the public health impact of stockouts, this data is associated with management performance and political accountability, which makes it sensitive and/or confidential. To overcome this challenge, we chose instead to base our validation on actual versus simulated implementation lengths of Global Fund grants. This is meaningful because the grants supported by the Global Fund have a fixed total budget determined upfront in each phase and designed to precisely cover health program needs without interruptions over the grant implementation period planned at the outset (e.g., 3 years for Phase II). As a result, whenever an actual grant implementation period is longer than the implementation period planned initially for that grant, that difference corresponds to a shortfall in the procurement funds available to cover demand for the health products purchased over the actual grant lifecycle, and therefore indicates a commensurate risk of national stockouts (see §3.4 for related interpretation guidelines). For analysis purposes, we focus on data related to grants in Phase II, because in contrast with Phase I their planned implementation periods are all the same (three years) as they are not eligible for potential extensions (see §1.1). We formally define the *actual grant implementation period* as the time between the first and last disbursement recorded for Phase II in the available historical grant records (see below), plus the duration of one grant review period (90 or 180 days) corrected by a multiplier accounting for the assumed cash buffer level. Given the data available to us, that definition corresponds to our best estimate of the actual time period over which the funds from Phase II of that grant were used.

Using the previous definition, we compute the estimated actual implementation lengths for all 429 grants to 62 principal recipients with at least three grants starting before 1 January 2007 recorded in the grant disbursement dataset available from the Global Fund website (Global Fund 2012d), and compare these with the actual implementation lengths simulated by our model out-of-sample. More specifically, we select around 80% of each principal recipient's grants (total 347 grants) for estimation of PLT, DIT and rating transition probabilities, and use the remaining 82 grants for out-of-sample validation. We evaluate ranked probability scores of the out-of-sample observations against the distributional predictions of the in-sample data simulation (Taylor 2012). Fractions of observations falling below the θ-quantiles of the density forecasts (hit fractions) and their 90% acceptance regions are calculated for θ between 0.25 and 0.95 in increments of 0.1.

Our baseline simulation parameters (6 months of initial inventory and 10% cash buffer level, see §3.1) minimize ranked probability score across 347 in-sample grants. Table 3 shows average simulated in-sample implementation lengths obtained with these baseline parameters, against average actual in-sample and out-of-sample implementation lengths. Out-of-sample simulated implementation lengths of 90-day grants (resp. 180-day grants) are on average 2.9% shorter (resp. 2.4% longer) than actual values in Phase I (resp. Phase II), and for 180-day reporting grants these average relative prediction errors are +6.7% in Phase I and +4.0% in Phase II.

[Table 3]

Figure 3 shows the hit fraction of out-of-sample observations below selected quantiles of the predicted implementation length distribution, along with the corresponding 90% acceptance region. The hypothesis that the out-of-sample observations are drawn from the simulated distributional predictions cannot be rejected at the 10% significance level.

[Figure 3]

From the validation results shown in Table 3 and Figure 3, we conclude that the simple simulation model and associated data estimation procedures defined in §3.1 and §3.2 seemingly provide suitably accurate predictions given our study objectives, both on average and in distribution, despite the salient assumptions underlying this model. We emphasize again here that the present paper does not aim theoretical contributions but rather empirical contributions relative to the specific context of the Global Fund, so that the validation study just presented arguably constitutes an appropriate instrument for evaluating the realism of our model and its assumptions. For completeness however, the following section provides a qualitative discussion of possible discrepancies between that model and the reality it represents, and offers guidelines for interpreting results.

3.4 Qualitative model discussion

An important assumption of our model is that the amount of demand for medicines that may be satisfied by a given disbursement amount (*funding-to-demand ratio*) is constant and deterministic. That is, we assume that potential changes in demand and/or prices of health products potentially affecting the demand coverage associated with given funds are predictable and accounted for in the disbursement amounts. Although much attention and expertise is in principle dedicated to determining and reviewing the grant amounts requested from the Global Fund (see §1.1), in practice this assumption may or may not be perfectly satisfied. An important related observation however is that the demand for health products that is relevant to Global Fund grants occurs at the national level and therefore exhibits limited variability because it is obtained by pooling demand across multiple geographic regions of an entire country. In addition, that demand tends to be unaffected by sudden local epidemics (e.g., cholera, yellow fever, polio), because of limitations in the categories of products that can be purchased with Global Fund grants

as well as the time flexibility of these grants, so that other short-term funding mechanisms are typically used instead to fight these.

Furthermore, demand for health products supported by some Global Fund grant component may in some cases span multiple medicines with possible interactions among them. In addition, that demand may exhibit seasonality and unpredictable variability. In contrast, our simple model assumes a deterministic and constant funding-to-demand ratio and considers a single product at a time. Tender-related delays, which our model ignores, may also occur between fund disbursement and order placement. We believe that all assumptions just mentioned lead to under-estimating stockout risks. DITs and PLTs are also assumed to be independent from the inventory level, which ignores the possibility that specific actions by Global Fund or principal recipients when inventory levels are low (e.g., higher priority of disbursement request, expedited transportation) could reduce them. An argument in support of this assumption is that the Global Fund does not currently have centralized visibility of the inventory levels of relevant health products in recipient countries, so that its ability to rationally prioritize in the short term between different disbursement or procurement requests may be limited. Because some reliable inventory level information may still be communicated to the Global Fund in an ad-hoc manner however, this assumption may still result in an over-estimation of stockout risks.

This model also implicitly assumes that countries do not have access to alternative sources of funding when gaps in Global Fund grant disbursements occur. In principle, countries may be able to access emergency funds through temporary reallocations between different budget lines or between grants from different donors. In practice however, it is suggested in Kraiselburd and Yadav 2013 that these emergency fund reallocations are limited because of constraints linked to fund traceability and transparency. In addition, data suggests that in many low-income countries, available sources of funding for health programs other than Global Fund grants are often limited (see section A2 of the supplementary material).

We finally stress that, as a result of our model definition, the simulation results to be presented next in §4 do not constitute unqualified predictions of how much patient demand may actually be lost. Health product stockouts at the central level would only occur when alternative sources of funding cannot be accessed in time, and these stockouts would only affect patients when existing buffer inventories in the distribution system are insufficient. Developing such predictions would therefore require accurate models of alternative funding and distribution systems, models that would likely be both highly idiosyncratic and complex (Shretta and Yadav 2012). Rather, our results quantify intrinsic stockout risks, or coverage gaps in central level demand for health products that are to be expected from historical disbursement and procurement lead-times when implementing grants financed by the Global Fund. These findings are still meaningful, because intrinsic reliance on costly or disruptive backup mechanisms to guarantee supply

continuity is undesirable (Brugha et al. 2004). Furthermore, the substantial medicine stockouts reported in Global Fund recipient countries suggest that these backup mechanisms often fail in Africa (Global Fund 2009, Oliynyk 2011).

4. Results

We first review our DIT and PLT estimates in §4.1, then the results of our baseline simulations in §4.2 and policy intervention simulations in §4.3. Finally, we discuss related sensitivity analyses in §4.4.

4.1 Parameter estimates

Table 1 shows summary statistics of estimated PLT distributional forecasts. They show substantial variations of procurement lead-times across product types (HIV prevention and treatment products take 46 days less and 18 days more than malaria prevention products on average, respectively) and geographic conditions (deliveries to East Africa take 29 more days on average than to West & Central Africa, and landlocked countries take on average 20 more days than non-landlocked ones). The results also suggest that unpredictable variability of PLT within categories is substantial (average coefficient of variation is 0.657).

[Table 1]

Summary statistics of estimated DIT distributional forecasts in Table 2 also exhibit substantial variations across prior grant rating and geographic region. On average, DITs in East Africa are 40–45 days longer than in West & Central Africa; DITs of 180-day grants in Phase I are 33 days longer than in Phase II; and DITs of 90-day non-rated grants in Phase II were 80 days longer than those rated "A". Unpredictable variability of DIT within each category is also substantial (mean coefficient of variation is 0.508). Consistent with previous independent observations (Aidspan 2005), mean DIT is larger than grant reporting period in 19 out of the 24 categories, including all categories with 90-day reporting periods. Finally, no significant time trend of DIT during a grant's lifecycle is observed.

[Table 2]

4.2 Baseline simulations

Table 4 reports simulated average proportion of demand lost over three years under baseline assumptions. Mean lost demand across simulated scenarios is 18.8%, with values ranging from less than 3% for 180-day Malaria grants (used for procurement of anti-malarial and malaria prevention health products) in West & Central Africa to more than 48% for 90-day tuberculosis grants in East Africa. The most substantial variability driver is the grant reporting period, with expected lost demand for 90-day reporting grants ranging from 4 to 20 times that of 180-day grants for the same disease and country – 48% vs. 11 % for anti-tuberculous drugs in Ethiopia and 22% vs. 1% for ARV drugs in Ghana. Overall average lost demand is 5.3% for 180-day grants versus 32.4% for 90-day grants.

[Table 4]

Variability across regions is also substantial, with expected lost demand for 90-day (resp. 180-day) reporting grants ranging from around 21% (resp. 2.3%) in West and Central Africa to around 46% (resp. 10.6%) in East Africa. Within regions differences between countries are limited, and there were no systematic differences between landlocked and non-landlocked countries (full table of results for all countries available in the supplementary material). In North and West & Central Africa expected lost demand did not vary significantly across health product types. In South Africa however expected stockouts for anti-tuberculous drugs were more than 5 percentage points higher than all other health products. In East Africa this difference was not as high, but still significant at 2 percentage points.

4.3 Policy interventions

Table 5 reports expected stockouts over three years for the main baseline scenario and policy interventions considered. 90-day reporting grants in Phase I have similar expected stockouts as in Phase II, except in East Africa where they are markedly higher (55.1% vs. 40.8%). In contrast, 180-day reporting grants had lower stockouts in Phase I in all African regions.

[Table 5]

Instantaneous replenishment decreases expected stockouts between 4.8 and 7.3 percentage points for 90-day grants, and between 1.9 and 5.8pp for 180-day grants. Bridge financing achieves lower stockout reductions than instantaneous replenishment, also leaving stockout risks for 90-day grants at relatively high levels (minimum 16% in West and Central Africa). Finally, synchronized financing is the single most effective policy for reducing expected stockouts of 90-day reporting grants, achieving reductions between 13 percentage points in West & Central Africa and 16 percentage points in North Africa. Its stockout risks for 180-day grants are also low and comparable to those achieved by instantaneous replenishment.

Expected stockout levels in all instances are highest in East Africa due to the significantly longer historical PLTs and DITs as indicated in Tables 1-2, and Figures S4-S5. The large number of simulation replications ensures that the quantitative differences between SF and the other scenarios in Table 5 are statistically significant at 98% confidence level (and often higher).

4.4 Sensitivity analysis

Figure 4 reports the average simulated fraction of lost demand under baseline parameters over various time horizons, with results across different African countries weighted as before.

[Figure 4]

After an initial period of 6 months corresponding to the initial inventory assumed, the fraction of lost demand increases steadily over time for both types (90-day reporting and 180-day reporting) of grants and all interventions except synchronized financing. Contrasting with the 3-year results shown in Table 5,

expected lost demand under instantaneous replenishment is lower than with synchronized financing up to day 475 (resp. 960) for 90-day (resp. 180-day) reporting grants.

Figure 5 shows how the effects of the cash buffer level on simulated lost demand vary by geographic region. Due to specific DITs, expected stockout risks in East Africa remain at higher levels than in all other regions with increased cash buffer levels. Differences between simulated stockout risks in North, South and West Africa diminished for higher cash buffer levels, particularly for 180-day reporting grants. Given the small estimation sample sizes for some categories of DITs associated with East Africa seen in Table 2, we verified that these results are robust to the combination or exclusion of all DIT categories with less than 5 data points.

[Figure 5]

The analyses of sensitivity relative to the initial inventory and replenishment frequency included in section A3 of the supplementary material also suggested that the relative simulated impact of these interventions is robust to these parameters.

5. Discussion

5.1 The Global Fund procurement funding process from 2002 to 2013

Our distributional forecasting results show that both financial and physical flows related to the supply continuity of health products purchased with Global Fund grants exhibit substantial unpredictable variability - average coefficient of variation of 0.657 and 0.508 for DITs and PLTs, respectively. Furthermore, a high proportion of historical observations have DIT longer than the grant reporting period, particularly for 90-day period grants (see Table 2). This is meaningful because while the first disbursement in each Global Fund grant may include buffer funds, by default all subsequent disbursements cover health program needs defined in the initial grant agreement for exactly one reporting period (GFPSS 2012). Our empirical study of DITs therefore demonstrates that the Global Fund's disbursement schedules are highly heterogeneous across regions, exhibit substantial unpredictable variability and are frequently slower than the health programs they are designed to support.

Our simulation model is designed to evaluate the combined impact of these unpredictable financial and physical flows on the national stockouts of health products for African grant recipients of the Global Fund. The high level of national stockout risks that it predicts is striking (average simulated proportion of demand lost over three years was 28.7% across 90-day grants, and up to 45% for tuberculosis grants in East Africa), and the substantial variability of these stockout risks across geographic region and product type (e.g., 56.3% for TB 90-day reporting grants in Burundi vs. 40.0% for the corresponding anti-malaria procurement grants in Rwanda) seems hard to rationalize from a public health or performance monitoring standpoint. The most striking result from this study is arguably that the grants for which concerns about performance or implementation risks led the Global Fund to use a shorter

reporting period of 90 days clearly faced substantially higher national stockout risks (28.7% for 90-day vs. 5.3% for 180-day reporting grants). In other words, over the first 11 years of the Global Fund there was a clear effective trade-off between the extent of its performance monitoring activities and the effectiveness of the funds it disbursed; we further discuss this finding in §5.2.

Synchronized financing, which makes disbursement amounts commensurate with empirical DITs, is the only considered intervention substantially reducing stockout risks for 90-day grants (by between 13 and 16 percentage points over three years, depending on the region). Implementation of synchronized financing would require clear guidelines for determining more customized disbursement schedules, and the results from Figure 5 suggest that further benefits could be obtained with different cash buffer levels across regions.

Instantaneous replenishment, an idealized scenario eliminating PLT but leaving financial flows unchanged, would benefit 180-day grants but leave 90-day grants with high levels of stockout exposure. This poor targeting efficiency is consistent with the greater discrepancy between disbursement amounts and frequency observed for 90-day grants, which is unaffected by PLT reductions.

Finally, the predicted impact of bridge financing is also limited. Our explanation is that bridge financing, while making some funds available earlier, changes neither the amount nor the frequency of the underlying Global Fund disbursement schedule (consistent with the Pledge Guarantee for Health scheme promoted by the United Nations Development Fund, see §3.1 and United Nations Development Fund 2011). Hence, bridge financing does not address the structural problem of disbursement timing and amount and does not constitute a reliable process for preventing stockouts. Alternative mechanisms are conceivable, but any implementation increasing disbursement frequency would expose third-party lenders to financial liability accumulating over time.

5.2 Implications for policy and practice

A key implication of these results for the Global Fund is that adjusting disbursement amounts through a more systematic use of cash buffers reflecting actual disbursement schedules would substantially benefit public health, and appears more effective than other possible interventions considered here. Table 4 suggests countries to be targeted in priority for this intervention, and indicates that it may be very time-sensitive in many cases. More generally, under the performance monitoring processes used by the Global Fund from 2002 to 2013, any intervention effectively resulting in less frequent and larger disbursements and/or less variable DITs is likely to decrease stockout risks.

The highlighted substantial intrinsic stockout risks faced by many Global Fund recipients since 2002 seem significant to global health. This may motivate a more extensive redesign of the Global Fund's funding model than the changes we could evaluate in this paper on the basis of historical DIT data, and may have motivated the new funding model initiative announced by the Global Fund in 2013 (Global

Fund 2013a). Indeed, all the interventions considered in our quantitative study essentially assume that the process used by the Global Fund for the purpose of monitoring the performance of grant recipients would remain unchanged relative to the collection period of our DIT data from 2002 to 2013, or at least that any changes considered will not impact the distribution of disbursement inter-arrival times. However, our study and model do provide a framework for thinking about further redesign opportunities for this process in a systematic manner.

Firstly, the assumed lack of correlation between inventory level and DIT points to the current lack of centralized country stock level information accessible to the Global Fund on a routine basis for the health products that it is funding. This situation is particularly problematic when Global Fund managers are confronted with several competing solicitations for expediting disbursements or allocating limited stock or funds available to them in the short term, as this lack of information may contribute to inefficient decisions with severe consequences. This information scarcity also complicates the development of proactive and forward-looking approaches for allocating funds and resources, contrasting with the reactive "fire-fighting" environment generated by emergency solicitations of recipient countries facing an existing or imminent stock-out crisis (a key motivation for the support of this study by the Global Fund). Finally, this lack of reliable centralized stock level information makes it difficult for the Global Fund to evaluate the performance of recipient countries in relation to inventory management, and therefore hampers its core performance monitoring function.

Secondly, the substantially higher stockout risks associated with 90 day grants warrant a detailed examination of whether the relative benefits of these grants in terms of management incentives are commensurate. It is noteworthy that, because of the Global Fund's historical practices, the long DITs estimated in our study may have been caused by issues affecting any of the activities associated with the execution of a grant, including activities having nothing to do with the procurement of health commodities. For example, a delay with the complete documentation of expenses linked to the construction of a health clinic or an advertising program on condoms could conceivably postpone an incoming disbursement to be used primarily for procuring medicines. Because the short-term public health impact of delays affecting medicine procurement may be quite different from that of delays affecting other grant components, it would seem beneficial for the Global Fund to manage the schedule of procurement-related disbursements in a specific manner. We note that other donors also implementing performance-based funding principles such as the World Bank's Health Results Innovation Trust Fund and the GAVI Alliance already separate payments into fixed/predictable and performance-based portions, presumably for the same reasons (Fan et al. 2013). Following this model, the Global Fund could further protect procurement-related disbursements by reducing their dependence on performance considerations, particularly when these considerations are unrelated to procurement. More generally, the trade-off

between fund effectiveness and financing predictability on the one hand and performance incentives on the other hand could be systematically managed in a segmented manner across different grant components, increasing overall efficiency. Alternative mechanisms for preserving patient access to medicines without compromising fund integrity include letters of credit directly issued to manufacturers and central procurement services such as Voluntary Pooled Procurement. However, it is not clear that the Global Fund systematically uses such alternative mechanisms when performance concerns related to procurement arise.

Finally, another noteworthy result from our analysis is the high association of stockout risks and DITs with the geographic region of recipient countries. It is in principle possible that these geographic regions should actually coincide with some intrinsic features of recipient countries that would similarly affect the processes used for grant performance evaluations and disbursements. Given the heterogeneity of countries within these regions along many dimensions however, this explanation does not seem plausible (Berenguer et al. 2014). Rather, we have used for this analysis the exact definition of geographic regions used by the Global Fund for reporting purposes, and these regions are also reflected in its internal organizational structure (e.g., fund portfolio managers are predominantly only responsible for countries within a single region). These observations and our results therefore suggest instead that the processes used by the Global Fund for grant evaluation and disbursement purposes are inconsistent across regions, and that their inconsistencies have a predominant impact on DITs. This explanation aligns with observations made independently by Fan et al. (2013) on the basis of both econometric analysis of historical grant scores and detailed case studies of Global Fund decisions for several specific countries. Specifically, these authors highlight the lack of transparency and apparent subjectivity affecting the relationship between grant evaluation scores and actual disbursement decisions. Based on this collective evidence, it seems important for the Global Fund to develop measurements and processes for evaluating and acting upon grant management performance that are more objective, globally scalable, and immune from organizational idiosyncrasies.

6. Conclusion and Future Research

Our findings provide new evidence on the relationship between global health initiatives and national health systems by identifying and characterizing the link between the Global Fund's financing and disbursement processes and national drug stockout risks over the past decade (WHO 2009). These results complement observational studies on health product stockouts in Africa (e.g., Pasquet et al. 2010, Oliynyk 2011) and qualitative studies discussing their causes by providing a validated model generating quantitative predictions of stockout risks and characterizing the role of disbursement and procurement variability (Shretta and Yadav 2012). Finally, our study provides hitherto unavailable quantitative

predictions of the impact of potential interventions for reducing these risks, and points to several process redesign opportunities for the Global Fund.

This work and its context also motivate several opportunities for further research in the area of global health financing and procurement. As discussed in §3.4, the single-product model considered in this paper does seem appropriate for several categories of commodities purchased with Global Fund grants, and other related contexts such as the procurement of nutrition products by UNICEF (Natarajan and Swaminathan 2012). For other product categories (e.g. antibiotics) however, recipient countries may need to dynamically split incoming fund disbursements into procurement orders for different products on the basis of their currently available inventory, procurement lead-times and relative importance to public health; this motivates an interesting multi-product extension of the model presented here for which the assumptions in existing multi-product models such as Janakiraman et al. (2010) do not seem adapted.

Another relevant research direction concerns the coordination between multiple funding streams. While funding from the Global Fund does tend to be dominant in recipient countries for the procurement of products associated with Malaria, Tuberculosis and HIV (see section A2 of the supplementary material), for many other health-related financial needs multiple sources of funding are often used simultaneously. Related questions include the assessment of shadow costs associated with restrictions on the use of specific external funds, and the associated design of an optimal funding strategy across multiple funds (Fundafunda and Yadav 2008 and Kraiselburd and Yadav 2013 provide relevant contextual information).

Finally, the discussion in §5.2 illustrates that the relationship arising between an external donor such as the Global Fund and a recipient country in the context of performance-based funding also is a worthy object of study. A microeconomic model could shed some light on the optimal contractual form between donor and recipient in the context of performance-based funding, where the depth or frequency of auditing required by the donor to reduce the information asymmetry with the recipient country is an endogenous decision. While there exists a literature on principal-agent relationships with costly endogenous monitoring (e.g., Jost 1996), performance-based funding for health presents interesting specific features such as the impact of monitoring on the effectiveness of the funds provided, and the dynamic aspects of the relationship between donors and recipients.

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Figures

Figure 1: Diagram of overall methodology.

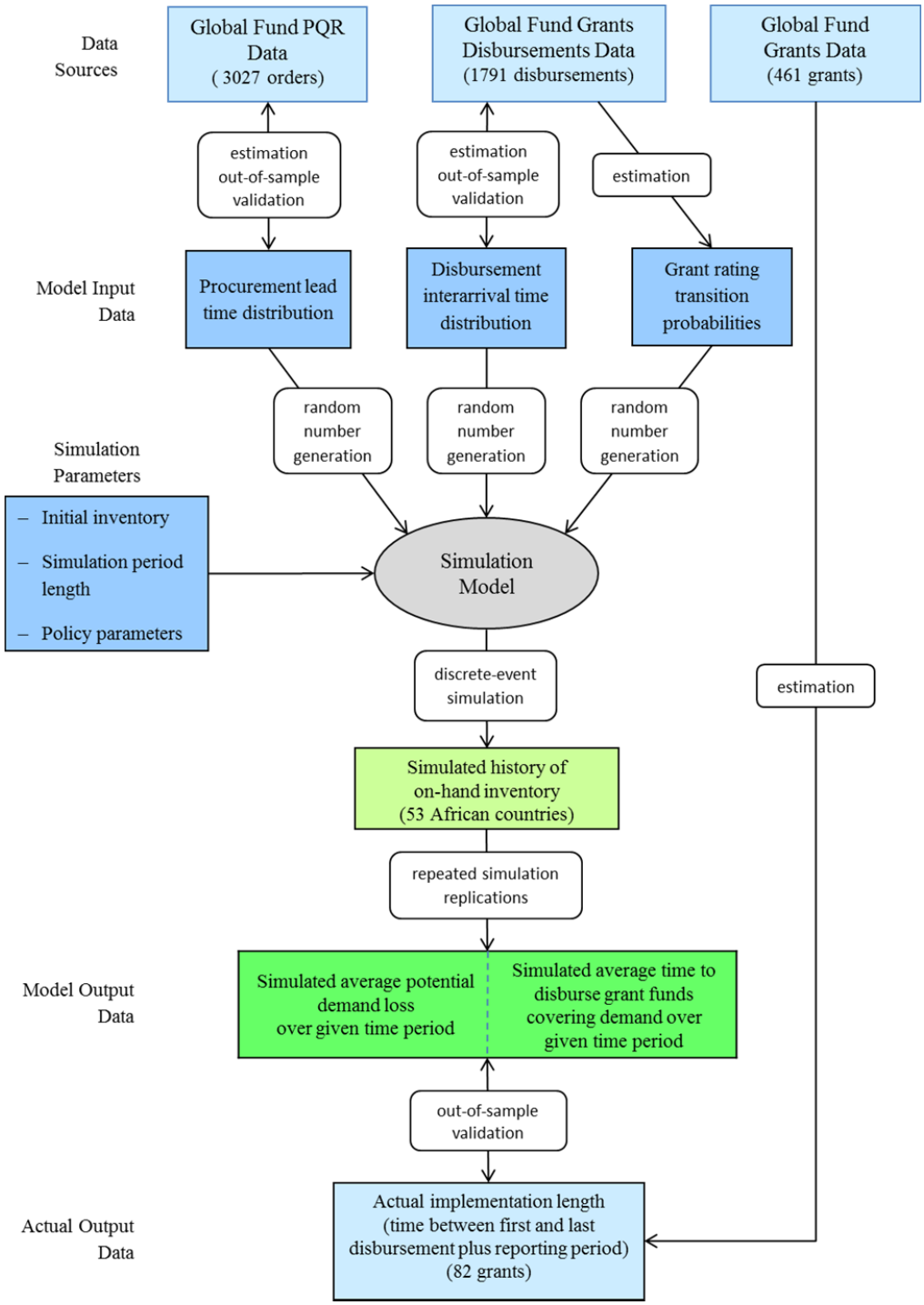
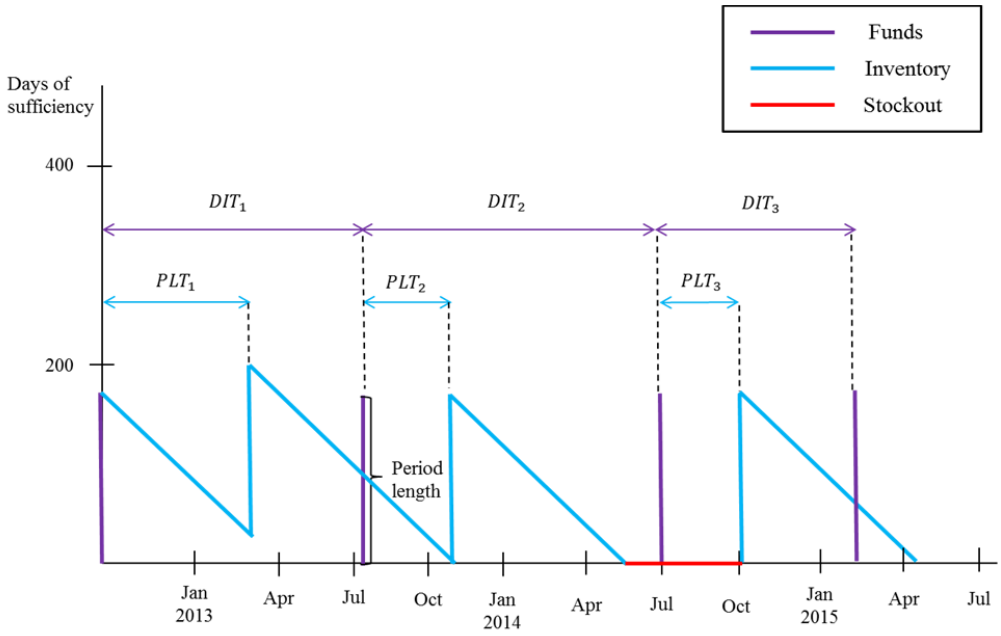
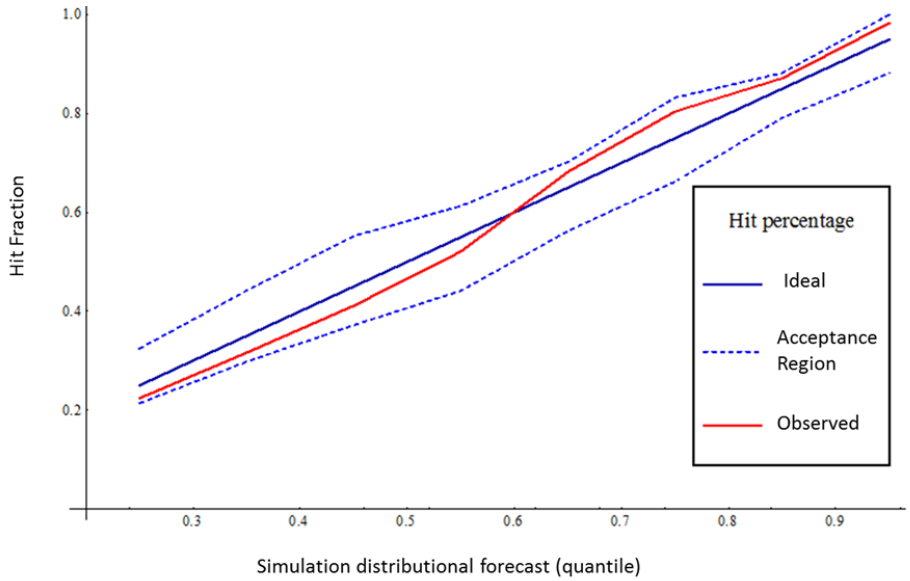


Figure 2: Illustrative simulated inventory sample path.



Notes: Grant period is 180 days. DIT_1, DIT_2, DIT_3 and PLT_1, PLT_2, PLT_3 denote successive realizations of DIT and PLT, respectively. In this illustration stockout occurs from May to July 2014 due to unavailability of funds and from July to October 2014 due to procurement lead time.

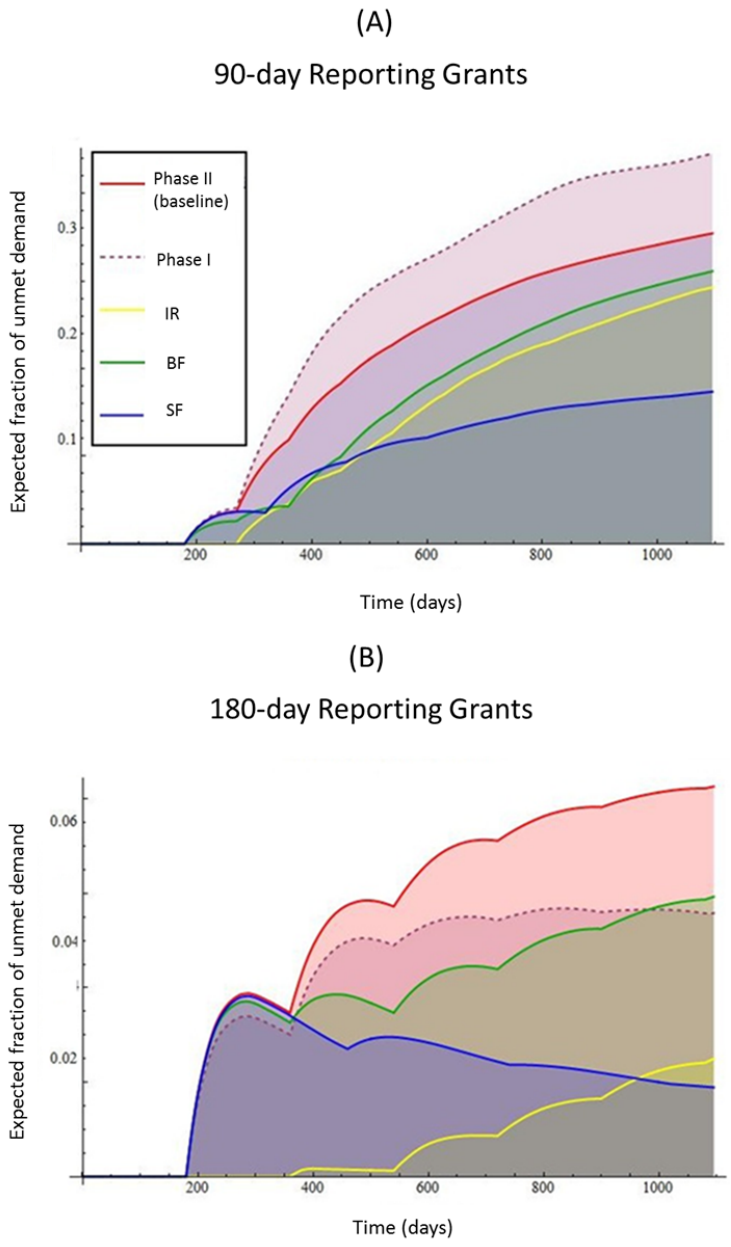
Figure 3: Hit fractions of out-of-sample observations of grant implementation lengths relative to in-sample simulated distribution.



Notes: Hit percentages – fraction of out-of-sample observations - below θ quantile of the corresponding predicted implementation length distribution for θ between 0.25 and 0.95 in increments of 0.1; 90%

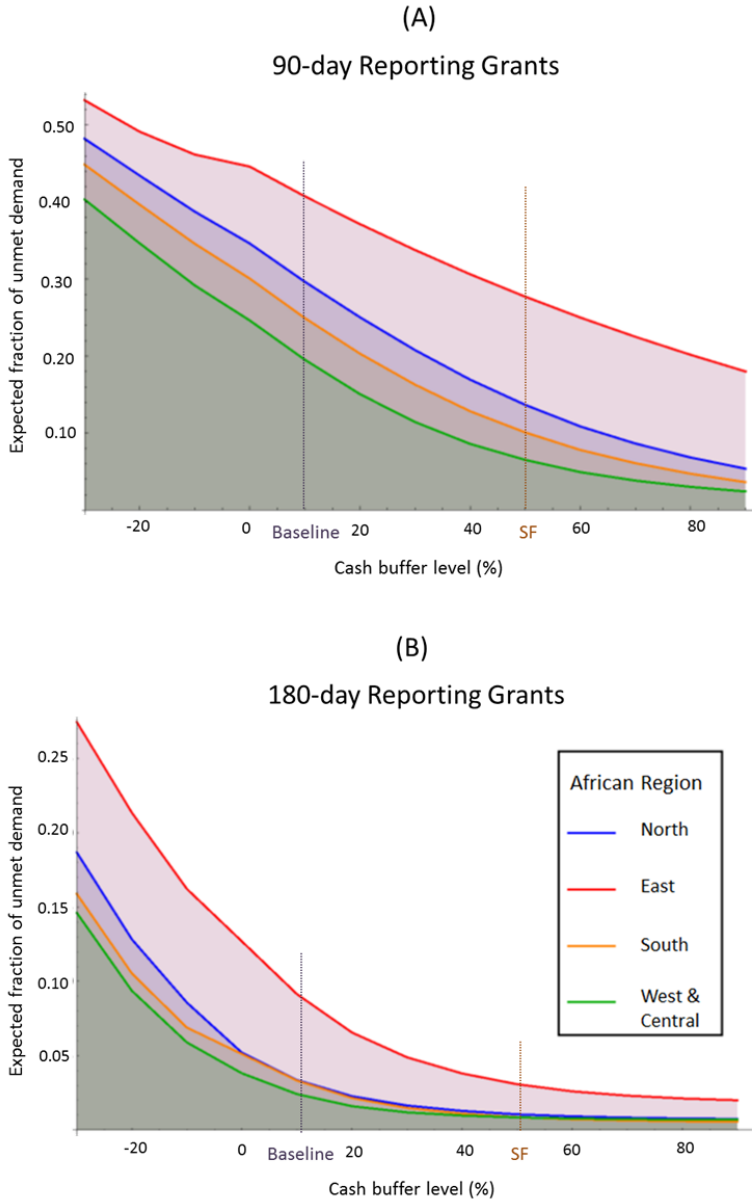
acceptance region for the null hypothesis that out-of-sample observations were realizations from the corresponding distributional forecasts of the simulation.

Figure 4: Average simulated fraction of lost demand over various time horizons under baseline parameters and different interventions, aggregated across African countries: 90-day reporting grants (A) and 180-day reporting grants (B)



Notes: National results weighted by estimated proportional demand; initial inventory of 6 months and cash buffer level of 10% for all scenarios except synchronized financing where it is 50% by definition; scenarios are Phase II (baseline), Phase I, IR – instantaneous replenishment, BF – bridge financing and SF – synchronized financing.

Figure 5: Average simulated fraction of lost demand for different cash buffer levels in each African region: 90-day reporting grants (A) and 180-day reporting grants (B)



Notes: Results within regions weighted by estimated proportion of demand; baseline parameters assumed except for cash buffer level. Highlighted baseline is an aggregation of the results in Table 5, and cash buffer level of 50% corresponds to the synchronized financing intervention; scenarios are Phase II (baseline), Phase I, IR – instantaneous replenishment, BF – bridge financing and SF – synchronized financing.

Tables

Table 1: Summary statistics of procurement lead times (PLT) in days.

African region	Landlocked (Y/N)	Health Product Type									
		Anti-Malarial		Anti-Tuberculous		Malaria Prevention		HIV Prevention		Anti-Retroviral	
		n	Mean Quantiles	n	Mean Quantiles	n	Mean Quantiles	n	Mean Quantiles	n	Mean Quantiles
East	No	222	162 (31, 347)	222	162 (31, 347)	38	231 (112, 289)	61	100 (14, 236)	273	133 (31, 241)
	Yes	87	128 (35, 266)	29	231 (112, 364)	29	231 (112, 364)	60	73 (13, 151)		
South	Yes			181	76 (18, 229)	†33	122 (52, 420)			166	98 (18, 243)
North	Yes	21	103 (29, 266)	11	160 (64, 234)	11	160 (64, 234)	86	74 (17, 179)		
	No	‡62	107 (23, 280)	69	122 (30, 263)	‡62	107 (23, 280)			184	90 (11, 241)
South	No	53	146 (13, 297)			†33	122 (52, 420)	110	54 (6, 151)	550	66 (8, 168)
West & Central	No	233	115 (13, 300)	233	115 (13, 300)	233	115 (13, 300)	115	84 (13, 217)	218	84 (9,243)
	Yes	36	165 (5, 351)	18	159 (76, 206)	18	159 (76, 206)	25	93 (14, 228)	100	150 (27, 331)

Notes: Number of observations, mean and (5%, 95%) quantiles of PLT in each category; categories were merged whenever the Kolmogorov-Smirnov test of common underlying distribution had a p-value larger than 0.5; merged categories are identified by either an omitted cell border, †, or ‡.

Table 2: Summary statistics of disbursement inter arrival times (DIT) in days.

	World Region	Grant Rating									
		A		B1		B2		NR		Phase I	
		n	Mean Quantiles	n	Mean Quantiles	n	Mean Quantiles	n	Mean Quantiles	n	Mean Quantiles
90-day Reporting Grants	West & Central	32	130 (35, 308)	†64	139 (28, 367)	19	146 (77, 222)	356	149 (39, 321)	356	149 (39, 321)
	North	17	184 (61, 359)	15	163 (42, 349)			2	275 (177, 373)	261	174 (44, 360)
	South			†64	139 (28, 367)			4	117 (76, 156)		
	East	3	261 (168, 335)			1	334			56	186 (28, 367)
180-day Reporting Grants	North	24	178 (34, 357)	64	179 (61, 354)	23	125 (20, 223)	23	125 (20, 223)	53	238 (67, 383)
	West & Central	57	159 (68, 294)	132	154 (33, 270)	11	135 (27, 211)	11	124 (40, 333)	95	192 (58, 369)
	South	77	231 (124, 377)			31	177 (26, 348)	23	154 (46, 323)	53	207 (66, 368)
	East			63	185 (35, 340)	11	260 (74, 391)	21	180 (31, 362)	103	206 (49, 371)

Notes: Number of observations, mean and (5%, 95%) quantiles of DIT in each category; categories were merged whenever the Kolmogorov-Smirnov Test of common underlying distribution had a p-value larger than 0.5; merged categories are identified by either an omitted cell border or †.

Table 3: Mean grant implementation length (days), observed and simulated 95% confidence intervals.

		Observed In-Sample			Observed Out of Sample			Simulated	
	Phase	n	Mean	95% CI	n	Mean	95% CI	Mean	95% CI
90-day Reporting Grants	I	96	841	(822, 860)	25	835	(800, 870)	811	(807, 815)
	II	47	1317	(1285, 1349)	12	1388	(1329, 1447)	1421	(1414,1428)
180-day Reporting Grants	I	251	779	(771, 787)	57	748	(734, 762)	798	(795, 801)
	II	105	1097	(1077, 1117)	18	1103	(1058, 1148)	1147	(1142,1152)

Notes: Mean implementation length and 95% CI by phase and reporting frequency for actual in-sample and out-of-sample against simulated predictions generated from in-sample data using baseline parameter values.

Table 4: Simulated average proportion of demand lost over three years by world region and country, type of drug and reporting frequency under baseline assumptions (percentage).

	Health Product Type									
	Anti-Malarial		Anti-Retroviral		Anti-Tuberculous		HIV Prevention		Malaria Prevention	
African region &	Reporting Frequency (days)									
Country	90	180	90	180	90	180	90	180	90	180
North Africa										
Landlocked										
Chad	28.05	3.11	27.91	2.81	31.43	5.15	29.61	2.17	31.24	5.28
Mali	29.42	3.67	29.06	3.36	32.12	5.58	29.95	2.43	33.06	5.33
Niger	31.16	3.88	31.76	3.19	33.42	5.46	31.14	2.02	34.57	5.25
South Sudan	30.82	3.46	30.25	3.04	33.19	5.36	30.02	2.38	35.18	5.37
Non-landlocked										
Algeria	26.11	2.63	26.76	2.13	26.81	3.08	25.41	2.36	26.66	2.86
Djibouti	29.27	2.75	28.12	1.82	29.90	3.20	28.54	1.42	29.92	2.47
Egypt	29.92	3.05	30.33	1.94	32.17	3.81	30.18	1.83	32.12	3.14
Jordan			33.29	3.44	32.06	4.67	32.41	2.98		
Mauritania	31.37	4.64	32.28	3.97	33.62	4.81	32.47	2.70	34.61	4.56
Morocco			31.47	3.85	32.05	3.62	30.12	2.51		
Somalia	30.61	3.42	30.38	2.51	32.14	3.29	30.37	2.11	31.62	3.72
Tunisia			29.19	3.28	33.55	4.23	29.81	3.02		
Yemen	29.09	2.35	32.13	3.72	30.41	2.71	32.06	2.96	30.72	2.91
East Africa										
Landlocked										
Burundi	43.49	12.61	49.83	12.88	56.34	12.90	51.27	9.21	50.17	11.62
Ethiopia	42.61	9.04	40.14	9.25	48.13	11.17	40.15	8.93	49.31	12.17
Rwanda	39.97	10.18	38.65	10.09	44.27	10.05	45.83	8.14	44.53	11.48
Uganda	41.17	9.68	41.06	10.53	48.16	10.69	40.18	7.65	39.19	12.29
Non-landlocked										
Comoros	43.21	10.58	43.69	11.68			44.66	9.82	42.23	9.04
D.R. Congo	45.78	12.31	45.20	12.17	47.31	12.68	44.18	10.38	46.07	11.37
Eritrea	43.96	11.45	43.68	10.82	45.52	12.41	43.95	11.03	44.19	10.13
Kenya	46.57	12.74	53.21	11.94	54.26	12.90	53.08	11.64	54.28	10.97
Madagascar	46.79	10.18	46.37	12.18	47.20	11.65	46.79	11.92	52.31	7.14
Mauritius			54.37	9.02			52.80	8.29		
Tanzania	43.19	10.03	48.21	8.26	48.26	10.23	47.16	7.51	45.92	7.83
Zanzibar	40.22	11.66	42.05	10.31			41.83	10.03	39.70	8.27

South Africa										
Landlocked										
Botswana			33.26	4.13	41.57	5.78	32.72	3.91		
Lesotho			33.41	5.58	41.49	6.13	32.46	4.12		
Malawi	31.54	4.52	27.04	4.11			25.72	3.82	22.38	3.89
Swaziland	35.12	5.68	32.62	4.18	41.62	6.42	32.19	3.70	34.55	3.55
Zambia	32.39	4.12	28.71	3.78	40.35	6.68	27.12	3.41	32.20	4.25
Zimbabwe	32.70	6.45	30.47	4.82	41.70	6.35	29.77	4.14	30.61	4.61
Non-landlocked										
Angola	35.37	6.72	31.22	5.27	34.63	6.80	31.50	4.37	34.24	4.74
Mozambique	27.65	5.79	25.38	4.24	34.08	5.56	22.02	3.87	24.64	4.28
Namibia	29.37	5.37	26.34	4.45	27.62	5.41	25.17	3.65	27.57	4.80
South Africa			28.26	4.71			27.16	3.30		
West &Central										
Landlocked										
Burkina Faso	22.61	4.13	24.05	4.38	21.31	2.29	22.32	1.39	21.38	2.90
CAR	26.74	2.63	25.81	3.15	26.74	2.37	24.27	1.11	27.16	2.27
Non-landlocked										
Benin	25.29	4.52	23.25	1.69	22.38	2.19	22.47	1.26	25.18	4.38
Cameroon	23.10	2.80	22.06	3.14	24.40	3.45	22.52	2.65	24.62	3.55
Cape Verde	21.38	2.16	17.83	2.19			18.06	1.93	22.45	2.18
Congo	19.26	2.76	22.45	1.23	18.83	1.79	23.26	1.36	18.32	2.63
Côte d'Ivoire	24.72	2.04	24.58	1.69	22.68	1.63	23.61	1.62	25.59	2.03
Guinea	22.05	2.17	21.29	1.75	22.15	2.31	21.46	1.41	22.36	2.20
Equat. Guinea	24.17	2.08	21.57	2.02			22.73	1.75	23.71	2.16
Gabon	18.29	2.74	18.04	2.50			18.16	1.80	18.48	2.72
Gambia	20.16	2.28	18.58	1.31	22.84	2.17	17.03	1.38	21.14	2.36
Ghana	22.31	2.01	21.62	1.26	22.58	1.42	20.41	1.02	23.58	1.52
Guinea-Bissau	19.73	3.07	17.32	1.88	20.05	2.24	17.37	1.95	18.26	1.99
Liberia	18.57	2.89	17.14	2.13	19.26	2.87	18.13	1.89	19.48	2.73
Nigeria	21.42	2.52	22.45	1.92	23.78	2.18	21.69	1.74	21.53	2.19
Senegal	18.25	2.71	20.18	1.81	18.66	2.91	18.53	1.68	18.73	2.65
Sierra Leone	19.34	2.39	20.92	1.74	21.47	2.53	20.03	1.72	19.96	2.78
Togo	18.47	2.40	19.11	2.03	19.75	2.78	18.27	1.79	22.62	2.69

Notes: Results based on 5,000 simulated replications yielding a 95% CI length less than 0.8% of the estimated mean estimate in each scenario. Results from several PRs in same country were weighted by relative volume of approved GF grant amounts. Scenarios with no grant approved historically for a given country and disease were not simulated.

Table 5: Simulated average proportion of demand lost over three years for baseline scenario (Phase II) and policy interventions (percentage).

		Policy									
		Phase I		Phase II		IR		BF		SF	
	Reporting Frequency (days)	90	180	90	180	90	180	90	180	90	180
World Region	North	29.9%	1.1%	29.7%	3.4%	22.7%	0.8%	26.4%	2.1%	13.7%	1.06%
	East	55.1%	5.8%	40.8%	9.1%	33.5%	3.3%	37.5%	6.8%	27.7%	3.08%
	South	29.3%	2.3%	24.9%	3.3%	20.1%	1.1%	22.3%	2.0%	10.1%	0.86%
	West & Central	23.7%	2.0%	19.5%	2.4%	13.5%	0.5%	16.0%	1.7%	6.5%	0.85%

Notes: Results based on 5,000 replications ensuring the length of the 95% confidence interval is less than 1% of the estimated expected stockouts in each scenario; results across different drugs and within African region weighted by the number of reported malaria cases in 2010 for anti-malaria and malaria prevention drugs; sum of people in need of and on ARV treatment for ARV drugs; number of people living with AIDS for HIV prevention drugs; new TB cases in 2011 for anti-TB drugs (The Henry Kaiser Foundation 2012).