A framework for assessing import costs of medical supplies and results for a tuberculosis program in Karakalpakstan, Uzbekistan

Short title: Import costs of medical supplies

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Abstract

Background
Import of medical supplies is common, but limited knowledge about import costs and their structure introduces uncertainty to budget planning, cost management, and cost-effectiveness analysis of health programs. We aimed to estimate the import costs of a tuberculosis (TB) program in Uzbekistan, including the import costs of specific imported items.

Methods
We developed a framework that applies costing and cost accounting to import costs. First, transport costs, customs-related costs, cargo weight, unit weights, and quantities ordered were gathered for a major shipment of medical supplies from the Médecins Sans Frontières (MSF) Procurement Unit in Amsterdam, the Netherlands, to a TB program in Karakalpakstan, Uzbekistan, in 2016. Second, air freight, land freight, and customs clearance cost totals were estimated. Third, total import costs were allocated to different cargos (standard, cool, frozen), items (e.g., TB drugs), and units (e.g., one tablet) based on imported weight and quantity. Data sources were order invoices, waybills, the local MSF logistics department, and an MSF standard product list.

Results
The shipment contained 1.8 million units of 85 medical items of standard, cool and frozen cargo. The import cost for the TB program was 9.0% of the shipment value. Import cost varied substantially between cargos (8.9–28% of the cargo value) and items (interquartile range 4.5–35% of the item value). The largest portion of the total import cost was caused by transport (82–99% of the cargo import cost) and allocated based on imported weight. Ten (14%) of the 69 items imported as standard cargo were associated with 85% of the standard cargo import cost. Standard cargo items could be grouped based on contributing to import costs predominantly through unit weight (e.g., fluids), imported quantity (e.g., tablets), or the combination of unit weight and imported quantity (e.g., items in powder form).

Conclusion
The cost of importing medical supplies to a TB program in Karakalpakstan, Uzbekistan, was sizable, variable, and driven by a subset of imported items. The framework used to measure and account import costs can be adapted to other health programs.

Keywords: Central Asia; Cost Analysis; Freight Costs; Import Costs; Health program; Humanitarian Aid; Shipping Costs; Supply Chain; Transportation Costs; Tuberculosis; Uzbekistan

1 Introduction

Medical supplies (e.g., pharmaceutical products, diagnostic tests, or test reagents) are often procured on international markets and then imported. The World Trade Organization estimated that medical goods accounted for more than 5.3% of the global trade value in 2019, with more than half that value coming from medicines trade [1]. Reasons to import medical supplies include limited in-country sales and distribution, limited production capabilities, rights or quality, or more efficient production elsewhere [2-6]. The Global Fund, which supports health programs in low-resource settings, for instance, purchases health products only if these comply with quality standards (e.g., anti-tuberculosis drugs prequalified under the World Health Organization Prequalification Programme) [7].

Health programs encounter import costs, which this study defined as international transport costs, customs clearance costs, and national transport costs, when they pay transport or customs-related charges for the procurement of medical supplies on international markets. Importing to low-resource or landlocked countries has been associated with higher costs than importing to other countries [8-11], which potentially adds to the health financing challenges that low-resource countries face [12, 13]. Consistent with the notion that the import of medical goods can substantially increase their costs, World Health Organization guidelines recommend assessing international transport costs, import duties and subsidies, local transport costs, and distribution costs in cost-effectiveness analyses [14]. Other international organizations, like the United Nations Development Programme and Stop TB Partnership request optimized packaging from supply partners to minimize freight costs in medical supply procurement [15, 16]. In addition to being of interest in program evaluation and medical supply procurement of donor agencies, import cost data can inform program planning and cost management. Knowing import costs as well as their composition may, for instance, improve budget calculations when program activities change, like a tuberculosis (TB) program expanding or shifting its focus from drug-susceptible to multidrug-resistant TB treatment.

Few studies to date have assessed import costs in health programs, to our knowledge, and none of these allocated import costs to specific imported medical supplies or suggested a framework for this process. Previous studies assessing import costs in a health program examined procurement data and/or conducted key informant interviews [17-21]. Local transportation and distribution costs [22-25], people’s cost to access a health program [26-28], or sample collection costs in health programs [29-32], all seem to have been more frequently assessed for health programs than import costs. Cost and cost-effectiveness analyses of health programs have ignored import costs or made ad hoc assumptions [33-35], assessed billing records and/or asked key informants [19-21], or assumed an average derived for a country [36-38].

Country import costs have been estimated by comparing a country’s trade inflows at the cost, insurance, and freight (CIF) value with corresponding trade outflows of exporting countries at the free on board (FOB) value, assuming the difference between these values resembles international transport costs [39-41]. Average markups for international transport of, for instance, 16%, 26% and 49% have been estimated for imports to Denmark, the Russian Federation and Burkina Faso, respectively [41]. CIF/FOB ratios are often the only available transport cost estimates, but they have been found to deviate considerably from directly measured transport costs [42], and they exclude
 customs-related charges. Both limits the usefulness of CIF/FOB data for program evaluation and planning. Direct measurement of import costs in a health program, as conducted in our study, overcomes these limitations and, in addition, allows to investigate the composition of import costs.

We applied costing and cost accounting principles to ordering and shipping information of a TB program in Karakalpakstan, Uzbekistan, to assess its average import costs and the import costs of individual items and units imported. Our broader aims are to share a framework for assessing import costs and to illustrate the type of information that import cost measurement and accounting can generate.

2 Material and methods

2.1 Study setting and design

Uzbekistan is landlocked and belongs to the 30 high multidrug-resistant TB burden countries [43]. Médecins Sans Frontières (MSF) has been supporting TB control in Karakalpakstan, a republic in Uzbekistan’s northwest, since 1998. The TB program in Karakalpakstan is an active research site and has been previously described [44-46]. Medical supplies for the TB program are imported to Nukus, the capital of Karakalpakstan, from the MSF Amsterdam Procurement Unit in the Netherlands [47]. Typical shipments originate from a central storage in Amsterdam and are flown from Amsterdam to Tashkent. In Tashkent, cargo is kept in storage for customs clearance, which can take several weeks. Humanitarian goods are exempted from customs duties, but the imported item lines need to be declared, for which a customs agent is hired. After customs clearance, cargo to the TB program in Karakalpakstan is transported by truck to a central storage in Nukus.

We studied the transport and customs clearance costs of one major shipment of drugs and laboratory items to the TB program in Karakalpakstan. The shipment, which arrived by truck in Nukus on December 29, 2016, combined 18 individual field orders and consisted of three different types of cargo (standard, cool, frozen). The three different cargos were flown from Amsterdam to Tashkent via Frankfurt on two separate flights in November and December 2016. The standard cargo was composed of two parts; one part was forwarded to Nukus, the other part remained in Tashkent. The cargo part remaining in Tashkent was excluded from import cost assessment (Figure 1 and supplementary Table S1).

2.2 Data sources

Order invoices and waybills for air and road transport were obtained from the local MSF logistics department. Order invoices contained information about ordered items, including a short item description, ordered quantities, item lines and unit prices at the time of ordering. Separate air waybills were available for each cargo type and contained the total air freight cost, cargo gross weight, cargo volume, the chargeable weight (i.e., the maximum of gross weight and volumetric weight), the rate charged by kilogram chargeable weight, and surcharges. An MSF waybill for the in-country road transport included a packing list as well as the gross weight and volume of each cargo. Road transport cost for the shipment and an estimate of the customs clearance costs per item line were gathered through written and oral communication with MSF logistic coordinators in Tashkent, who co-organized MSF shipments to Uzbekistan.

Average weight for one unit of an item (e.g., 0.9 g for one tablet of the antibiotic pyrazinamide packaged in a blister of 672 units) was extracted from the MSF Green List for all ordered items. The MSF Green List is a standard product list of MSF for frequently used and ordered medical items. It is similar to the Global Drug Facility Product Catalog and contains information about an item’s active ingredient, pharmaceutical form, packaging type and size, as well as unit weights, volumes, and prices [48, 49].
Orders and air waybills were issued in Euro (€). Customs clearance charges were estimated in US dollar ($), land freight costs in Uzbekistani Som (UZS). All currencies were converted to Euro using World Bank annual exchange rates for the year 2016: €1 = $1.107 = UZS 3282 [50].

2.3 Import cost assessment framework

To assess import costs in the TB program, we derived the following steps from general principles of costing and cost accounting (also called cost assignment; see, e.g., [51, 52]):

**Step 1:** Description of the import process and identification of the causes of import costs from the perspective (or viewpoint) assumed in the assessment.

**Step 2:** Collection and inspection of data on import costs for at least one shipment and cargo type.

**Step 3:** Choice of a cost allocation base for each import cost.

**Step 4:** Allocation of import cost totals in proportion to the allocation bases:

- a. to parts of a shipment with different final destinations.
- b. to different cargo types in a shipment.
- c. to units in a shipment.

**Step 5:** Calculation of allocated import cost totals (and repetition of steps 4–5 until reaching step 4c).

**Steps 1–2** guide import cost measurement, whereas **steps 3–5** guide the allocation of import cost totals to parts of a shipment. We describe next how we applied these steps to a shipment of medical supplies to a TB program.

**Steps 1:** The import process to the TB program was discussed with staff who were familiar with the procurement process. Afterwards, a simplified import process that includes the presumed main causes of import costs (air freight, customs-related, land freight) was described (Figure 1).

**Steps 2–3:** Import cost data were collected (see 2.2 Data sources) and inspected for variable and fixed costs to understand cargo characteristics that determine import costs. Air freight charges included per-kg costs and fixed costs. We chose weight as the cost allocation base. For land freight, a truck was rented at a fixed cost and hence no characteristic of the imported items correlated with land freight costs. Again, we chose weight as the cost allocation base. Customs-related costs excluded customs duties, as only humanitarian goods were imported, but involved customs clearance costs. For customs clearance, customs agent fees were paid per customs declaration and number of pages of each declaration. We chose the units per cargo and item line as the cost allocation base for the estimated semi-fixed customs clearance cost.

**Step 4a:** The standard air cargo contained two parts, of which one part remained in Tashkent and the other part was forwarded to Nukus. As only the cargo shipped to Nukus caused import costs from the perspective of the TB program in Karakalpakstan, the air freight cost for the standard cargo part shipped to Nukus was estimated by splitting the total amount billed proportionally to the gross weight distribution between the two cargo parts (grey and dark blue lines in Figure 2a).

**Step 4b:** Standard cargo for the TB program in Karakalpakstan was transported to Nukus in a truck together with the cool and frozen cargo. The land freight cost was allocated to the three cargos proportionally to their gross weight (grey and dark blue lines in Figure 2d).

**Steps 4c:** For each cargo type, the transport cost totals were allocated to units by multiplying unit weight (i.e., the weight of one unit of an item) with the average cost of transporting the net weight. Average net weight transport costs were calculated by dividing total transportation costs by the order net weight for each cargo (light and dark blue lines in Figures 2a-d). Order net weight excluded the weight of cargo-specific packaging. It was estimated by multiplying unit weights with ordered
quantities and summing-up over all items in a cargo. Unit customs clearance costs, in turn, were calculated separately for each cargo by dividing the estimated customs clearance costs of €45 per item line by the number of units imported within a line (Figure 2e).

**Step 5:** Import costs totals were calculated for each cause of import costs, each cargo type, and the whole shipment. Air freight costs of the cool and frozen cargos shipped to the TB program corresponded to the total charges invoiced. Other transportation cost for cargo had to be obtained through cost allocation steps 4a and 4b. Total customs clearance costs were calculated by multiplying the number of item lines in a cargo with the estimated customs clearance costs of €45 per item line. The total import cost of the shipment to the TB program was calculated by adding up the import costs of all cargos delivered to Nukus.

### 2.4 Data analysis

Import cost accounting generated unit import costs for each of the 85 imported items (e.g., the cost of importing 1 tablet levofloxacin). Item import costs (e.g., the cost of importing an order quantity of 1200 tablets levofloxacin) were calculated by multiplying unit import cost and quantity for the imported items. Measured and generated import costs were described using univariate statistics and bar, surface, and box plots, and histograms. In bivariate analyses, items were grouped by cargo type and/or pharmaceutical form (capsule, fluids <100 ml, fluids ≥100 ml, tablet, ointment, powder, test/test kit, and wipe) or item packaging (ampulla, bottle, capsule or tablet, fluid bag, sachet, tube, vial, and test/test kit). The group test/test kit was used in both groupings. Fluids belonging to a test or test kit were included in the test/test kit group. To compare the equality of the distributions of continuous variables across cargo types and/or item groups, Kruskal-Wallis tests were applied. For multiple pairwise comparisons following a Kruskal-Wallis test, Dunn’s test with Bonferroni adjustment was applied. Shapiro-Wilk tests were applied to evaluate normal distribution of data. Regression models with log 10-transformed continuous variables (i.e., unit import cost, weight, and price) were used to assess how much of the variation in the unit import costs is explained by the following item characteristics or combinations thereof: unit weight, unit price, pharmaceutical form, item packaging, and cargo type.

Import costs were analyzed in absolute terms and relative terms (% of an imported value). For two items in the shipment with unit prices that did not reflect an item’s value, no percentage import costs were calculated: The first item, a reagent set, was shipped as frozen cargo and freely available to the TB program through the Stop TB Partnership. The second item was a test kit consisting of two parts that were separately shipped as cool and frozen cargos. While the full item price of the test kit was reported on the invoice for cool cargo, only a nominal unit price of €0.01 was reported on the frozen cargo invoice. Multiple orders of the same item were combined before analysis by summing up ordered quantities and determining a quantity-weighted average price across orders. Statistical significance was assumed at P < 0.05. All analyses were performed in Stata 15.1 SE.

### 2.5 Cost assessment assumptions

For all import costs that were allocated, an assumption about what constitutes a reasonable allocation base was made. A reasonable cost allocation base would be an item characteristic for which data is available and which correlates strongly with the import cost of the TB program. Latter property can be difficult to assess and to fulfill. For instance, while the largest portion of the air freight costs (64–84%) was charged based on chargeable weight, of which 93% to 100% was gross weight, only 20% to 90% of the gross weight was net weight. The land freight cost was charged lump-sum without any indicative cost breakdown. Yet, we chose gross weight and net weight as allocation bases for all transport costs.
Unit weight was not available for 6 of 69 standard cargo items, 2 of 14 cool cargo items, and 2 of 2 frozen cargo items. For standard and cool cargo items, four missing unit weights of drugs were substituted with available unit weights of the same active ingredient in a similar concentration after reviewing the plausibility of this substitution based on item concentration and packaging; the other four missing values were replaced by the median unit weight of similarly packaged items. The same unit weight was assumed for the frozen cargo items, which is equivalent to allocating import costs based on the imported number of units. Item lines were defined using Harmonized Commodity Description and Coding System (HS) codes reported in the order invoices.

Transportation from manufacturers to a central storage of the MSF Procurement Unit in Amsterdam, storage in Amsterdam, transportation from the central storage to the airport in Amsterdam, storage at Tashkent airport during customs clearance, storage in Nukus, and transportation from the central storage in Nukus to clinics in Karakalpakstan (i.e., the point of care) are part of the supply chain of the TB program. Costs for these parts of the supply chain, indirect import costs (e.g., administrative costs or disposal of cargo packaging), or non-financial import costs (e.g., the lead time to import) were excluded from this import cost assessment.

3 Results

3.1 Shipment characteristics

The studied shipment contained standard, cool, and frozen cargo for a TB program in Karakalpakstan. It combined 18 orders for medical supplies from the MSF Procurement Unit in Amsterdam. In total, over 1.8 million units (e.g., a single tablet or test) of 85 items of pharmaceutical and diagnostic supplies (e.g., antibiotics or test reagents) were delivered jointly to a central storage of the TB program in Nukus. Unit value (€0.003–289) and weight (0.1 g–1.5 kg) varied within and across cargos. Over 95% of the imported gross weight and 98% of the imported net weight resulted from the standard cargo. The number of item lines to be declared by the customs agent ranged from one line of items in the frozen cargo to seven lines in the standard cargo. Most standard cargo items were delivered in higher quantity and had less weight and lower unit prices than the cool or frozen cargo, which contained tests or test kit materials and insulin vials. The ordered items were estimated to weigh, net of cargo packaging, 7168 kg in the standard cargo, 121 kg in the cool cargo, and 5 kg in the frozen cargo. Corresponding cargo gross weights that include cargo packaging exceeded the estimated net weights by factors of 1.1, 3.5, and 5, respectively (Table 1).

3.2 Total and average import costs

Air freight costs varied by cargo type (€199–31,155 per cargo) due to different cargo gross weights, freight rates, and surcharges. Estimated customs clearance costs accumulated to €45 to €316 for the different cargos. Land transport costs €2985 for the truckload, of which €9 to €2826 were allocated to each cargo based on gross weight. Total import cost amounted to €34,297 (8.9% of the order value) for standard cargo, €2072 (10%) for cool cargo, and €253 (28%) for frozen cargo, respectively. Average import costs were €5 per kg order net weight for standard cargo, €17 per kg for cool cargo, and €51 per kg for frozen cargo, reflecting different air freight rates and fuel surcharges, different amounts of weight added to the order net weight by packaging (e.g., 20 out of 25 kg dry ice), and a varying number of units per imported item line and weight (Table 2 and Figure 3a).

3.3 Unit import costs

Total import cost allocation generated unit import costs. The median unit import cost was €0.007 (interquartile range [IQR] 0.003–0.07) for standard cargo items, €2.16 (IQR 1.80–8.98) for cool cargo items, and €2.53 (IQR 2.53–2.53) for frozen cargo items (Kruskal-Wallis test P < 0.001). Related to, on average, higher unit prices of cool and frozen cargo items, median unit import costs as a percentage of unit prices were more similar than absolute unit import costs across standard cargo items (median
12%, IQR 4.6–35), cool cargo items (8.7%, IQR 3.8–21), and frozen cargo items (5.6%, IQR 5.6–5.6, P = 0.67).

Figure 4 shows the variation in absolute and relative unit import costs for all medical supply items in the shipment and by items’ cargo type and pharmaceutical form. Median unit import cost ranged from €0.003 per capsule imported as standard cargo to €2.61 per fluid <100 ml (i.e., per 10 ml vial of insulin) imported as cool cargo. For comparison, median unit import cost as a percentage of the unit price ranged from 3.1% per capsule imported as standard cargo to 149% per fluids ≥100 ml imported as standard cargo. Comparing standard cargo items only, the median import cost of €2.06 per unit of fluids ≥100 ml was 600-times more than the median import cost of €0.003 for a capsule. In terms of percentage unit import costs, a more than 45-fold import cost difference remained (145% versus 3.1%).

Regression analyses indicate that knowing the cargo type of an item as well as its pharmaceutical form or packaging, would have given a good indication of the magnitude of an item’s unit import cost. Approximately 90% of the variation in the log-transformed unit import cost is explained by the cargo type and either an imported item’s pharmaceutical form or packaging. Cargo type and knowing if an item contains ≥100 ml fluid explained 69% of the variation in unit import cost, similar to knowing an item’s cargo type and unit price (67%). Percentage unit import costs (IQR 4.5–35%) varied less than unit import costs (IQR €0.004–1.14) and were predicted with lower explanatory power. Knowing an item’s price, its cargo type, and its pharmaceutical form or packaging would have explained 72% and 75% of the variation in the percentage unit costs of the imported medical supplies, respectively (Supplementary Tables S5–6).

3.4 Import cost structure

Item import cost were calculated by multiplying order quantities and unit import costs. Figure 3b illustrates the contribution of individual order items to the total import cost of the standard cargo. Circles represent items. The position of a circle shows the item import cost. The color of a circle indicates the pharmaceutical form of an item. Items closer to the upper right corner cause larger import costs than items closer to the lower left corner. The highest cost band (€1000–10,000) contains fluids, powders, and two types of antibiotic tablets. Cost accounting associated €29,057 (85%) of €34,297 of the standard cargo import cost with the items found in the highest import cost band. These items represented ten (14%) of 69 standard cargo items and 901,879 (49%) of 1.8 million ordered units. The item associated with the highest import costs in the standard cargo were 15,000 units of 0.9% sodium chloride solution in a 100 ml flexible bag, to which €9246 (27%) of the standard cargo import cost was attributed.

3.5 Import cost contributors

Due to using net weight as the base to allocate transport costs to items and the fact that the bulk of the import cost to the TB program was related to transport, most imported items contributed to the costs of importing through their net weight. Figure 3b suggests that four groups of imported items can be distinguished within the standard cargo:

1. “Costly by number” items with relatively low unit weights but ordered in higher numbers (approximately lower-right quadrant)
2. “Costly by weight” items ordered in lower numbers but with relatively high unit weights (approximately upper-left quadrant)
3. “Costs by unit weight × number” items with medium-high unit weights and ordered in medium-high numbers (approximately upper-right quadrant)
4. “Low import cost” items with relatively low unit weights and ordered in relatively low numbers within an item line already existing in the cargo (approximately lower-left quadrant)
All but one “costly by number” items were tablets or capsules. They contributed to the imported weight, and thus import costs, predominantly through the ordered quantity (e.g., pyrazinamide or isoniazid/rifampicin fixed-dose combination tablets). Most imported fluids, in turn, were “costly by unit weight” items; particularly large-volume fluids, which cause high import costs already when ordered in low quantity due to the weight of each unit (e.g., 500 ml Ringer’s lactate or 1 l sodium chloride solutions). “Costs by unit weight × number” items were items in powder form and some fluids. While on average lighter than the “costly by unit weight” items and ordered in lower quantity than “costly by number” items, the items in this group contributed to import costs through their combination of unit weight and the quantity ordered (e.g., 15,000 units of 0.9% sodium chloride solution in a 100 ml flexible bag). The six “costs by unit weight × number” items in the shipment were associated with €21,179 (62%) of €34,297 of the standard cargo import costs. Finally, some items had low unit weight, were ordered in low quantity, and had low per-unit customs clearance costs due being imported within an item to that, overall, contained a high number of units (e.g., risperidone and levothyroxine sodium tablets). We classified these items as “low import cost” items.

4 Discussion

4.1 Summary of findings

Import costs are context-specific and cargo-specific, and they can be substantial relative to the value of an imported good [8-10]. Applying general costing and cost accounting principles, we assessed the transport and custom-related costs of a major shipment from the MSF Procurement Unit in Amsterdam, the Netherlands, to a TB program in Karakalpakstan, Uzbekistan.

We estimated that the total import cost of the shipment was 9.0% of its value. The largest portion of the TB program’s total import cost was related to transport (82–99% of a cargo’s import cost). Import costs varied when assigned to the different types of cargo (8.9%, 10% and 28% of standard, cool and frozen cargo value) or to the different units and items imported (median 12% of the imported value, IQR 4.5–35). While import costs were expected to differ by cargo type, we were surprised by how much more the allocated import costs varied between items and units within the same cargo type.

Import costs of standard cargo were analyzed further with respect to cost structure and cost contributors. The ten items that were most costly to import in the standard cargo were associated with 85% of the standard cargo import costs. Import cost contributors could be categorized in four groups: (1) “Costly by number” items, (2) “costly by unit weight” items, (3) “costly by unit weight × number” items, and (4) “low import cost” items. The relatively large contribution of “costly by unit weight × number” items to import costs might have been the most difficult to detect without import cost accounting, as it resulted from a combination of two item characteristics. In turn, additional “low import cost” items could have been added for a small additional cost to the shipment as their per-item transport and customs clearance costs would have been both relatively low.

4.2 Comparison with previous findings

Studies that assessed import costs on a country level based on trade flows reported higher international transport costs to landlocked and low-resource countries than for other countries [9, 53]. Hence, health programs in low-resource countries can be at risk for a high dependency on import of medical supplies in a context of high import costs. Yet, we found few studies that assessed import costs or similar costs (e.g., international transport costs, procurement costs, supply chain costs) in health programs [17-20]. One study interviewed procurement officers in two international organizations and a non-governmental organization about the import costs to countries with deworming programs. The costs for international transport and customs of the deworming drug were estimated at 10% of drug value [20]. More similar data to ours has been assembled by the
Global Fund, which published reference freight costs based on its 2018/19 transactional data. Median air freight costs of 12% (IQR 7–23) of the item value were reported for HIV rapid diagnostic tests, 19% (IQR 10–65) for antiretroviral drugs, and 115% (IQR 107–125) for condoms [18]. In contrast to our analysis of various items and diverse cargo that were imported by one TB program, the Global Fund study analyzed the procurement of similar items for different programs.

4.3 Practical implications

Understanding import costs can be used to assess program costs, aid in budget planning, and inform cost management. Areas of application for import cost assessment in health programs include:

1. Measuring import costs to quantify the import costs of a health program.
2. Unveiling medical supplies to which relatively high import costs are allocated. While cost allocation relies on assumptions, its results can be a sound starting point for further investigation.
3. Assessing the full costs of purchasing and importing medical supplies based on unit import costs. Using the presented framework and results, we estimated in another study that one course of drug-sensitive or multidrug-resistant TB treatment requires 0.7 kg to 40 kg of drugs. Importing this weight to the TB program in Karakalpakstan could add between €3.39 and €189 to the purchasing cost of a drug regimen [54].
4. Optimizing packaging has been associated with import cost savings [55]. Import cost assessment quantifies the difference between cargo net and gross weight, which is indicative for the transport costs of packaging.
5. Identifying high-cost contributors among imported supplies. If alternative procurement options were available (e.g., local purchasing, land, or ocean transport) and feasible (e.g., timely, safe, and reliable shipping, reasonable administrative costs), then two-tier international transport (e.g., air shipping for time-critical, volatile supplies and land/maritime shipping otherwise) could be used to save import costs. For long-term programs, developing local supply sources or production of items that cause high import costs might be an opportunity for supply chain optimization (see also [6]).

For health programs that operate in low-resource settings, assessing and optimizing import costs may help to reduce a potential triple burden of costly import, a high level of dependency on imported medical supplies, and a large health financing gap. As import cost assessment itself is costly, mainly through personnel time, systematic import cost measurement could be performed as a first step. If costs measurement indicates import costs that are considered sizable and import processes that are modifiable, then import cost allocation could be performed as a second step.

4.4 Adaptivity of import cost assessment framework

The presented framework to assess the import costs of the TB program in Uzbekistan describes general principles that can be applied to other health programs. Going through the five framework steps will help unveil which import costs to measure and how to allocate them to specific units also when the import process differs from our example (e.g., land transportation only, transportation via rail or sea freight, multiple final destinations, cargo subject to customs duties, or different customs clearance costs). While we used unit weights from the MSF Green List, such unit weights can be self-generated through weighing an item (once in stock) and dividing the weight by the number of units an item contains. Manufacturers or distributors may also be able to provide unit weight data. On another practical note, we received all required data from the local MSF logistics department. For import cost assessment in other health programs, data collection might require consulting several administrative units, suppliers, or manufactures, or data collection might rely more on key informant interviews (e.g., if import bills and order invoices are unavailable or incomplete, or if informal
4.5 Limitations of the framework and case study

As allocated import costs are generated data which are subject to assumptions and limitations, we see their value in pointing to differences in magnitude (e.g., import costs of 1% vs. 10% vs. 100% of the value of an imported good) rather than in their exact quantitative interpretation.

Specific limitations include that we only assessed financial costs of drugs and laboratory items in one major shipment to a TB program. While the shipment allowed to assess three typical cargo types, we could not evaluate if the analyzed mix of imported items, which co-determined the allocated import costs, or the utilization of the rented truck was similar to other shipments to the program. The precision of the unit weights was variable, some unit weights were missing and imputed, and it remained unclear if unit weights included item packaging. Imprecise unit weights could thus have introduced unknown error to allocated unit and derived item import costs.

Data was collected in late 2016. Import costs relative to import value could be robust estimates if costs and prices change similarly. However, shortly after data collection, the Uzbekistani Som substantially devalued against the US dollar and the Euro [50]. Due to the exchange rate change, the relative cost of land freight for the TB program may have decreased since the time of data collection. On the other hand, the COVID-19 pandemic may have raised the TB program’s international transport cost, at least temporarily, as a reduction in cargo capacity in passenger flights during the pandemic resulted in a global increase in air freight costs [56]. Continuous import cost assessment would allow to address several of these limitations.

Notwithstanding challenges that can be addressed through collecting more or better data, the cost accounting also included normative choices. To assign import costs to individual items, we used the item net weight for air and land transport costs and the number of units per item line for customs clearance costs as allocation bases. Further, certain elements of import costs were not included in this study, such as storage, transport of goods to the exporting airport, optional freight insurance, distribution from the local warehouse to the point of care, administration, or possibly costly import lead time or time delays. Customs clearance at Tashkent airport required, for instance, 36 days for the standard cargo and 21 days for the cool cargo.

5 Conclusion

Import cost measurement and accounting for a TB program in Karakalpakstan, Uzbekistan, suggested average import cost of 9.0% (of the imported value) and a broad variation in the import costs of specific medical supply items (median 12% of the imported value, IQR 4.5–35). The uneven distribution of import costs, which import cost accounting generated, exemplifies how cost accounting provided detailed import cost information that can be used in program evaluation, planning, and cost management.

We found import costs to be an important yet understudied cost of health programs, and we hope that the presented framework and results from Uzbekistan will encourage others to assess import costs and share their findings. Health programs are in principle well-positioned to assess their own transportation and customs-related costs based on procurement data.

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NP and SK thank the staff of Médecins Sans Frontières (MSF) in Berlin, Tashkent, and Nukus. They especially thank the deputy logistic coordinator in Tashkent at the time of data collection and the logistic coordinator at the time of the manuscript completion for insightful discussions about the import process of the TB program and facilitating import cost data collection.

Funding: None.

Author contributions: NP conceived and conducted the study in collaboration with SK. NP collected data and performed the initial data analysis. SK performed the presented extended analysis of the data. SK and NP wrote and revised the manuscript. All authors provided critical revisions to the manuscript.

Competing interests: SK and NP consulted for MSF. NS works as a Medical Operations Manager for MSF.

Data Availability: Available from the authors upon request.
References

Table 1: Characteristics of a shipment of medical supplies to a tuberculosis program in Uzbekistan

<table>
<thead>
<tr>
<th></th>
<th>Standard cargo</th>
<th>Cool cargo</th>
<th>Frozen cargo</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Order</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orders combined</td>
<td>10</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Items</td>
<td>69</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>Item lines</td>
<td>7</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Units</td>
<td>1,840,928</td>
<td>1218</td>
<td>100</td>
</tr>
<tr>
<td>Units per item(^*)</td>
<td>4000 (450–24,000)</td>
<td>4 (2–55)</td>
<td>50 (20–80)</td>
</tr>
<tr>
<td>Units per item line</td>
<td>35,000 (8000–595,172)</td>
<td>55 (20–1143)</td>
<td>100</td>
</tr>
<tr>
<td>Unit price (€)(^*)</td>
<td>0.10 (0.03–0.58)</td>
<td>26 (9.35–57)</td>
<td>24 (0.01–45)</td>
</tr>
<tr>
<td>Unit weight (g)(^*)</td>
<td>1.2 (0.7–15)</td>
<td>126 (100–550)</td>
<td>50</td>
</tr>
<tr>
<td>Order net weight (kg)</td>
<td>7168</td>
<td>121</td>
<td>5</td>
</tr>
<tr>
<td>Order value (€)</td>
<td>385,167</td>
<td>20,228</td>
<td>901</td>
</tr>
</tbody>
</table>

**Cargo**

|                  |                |            |              |
| Gross weight (kg) | 7987           | 428        | 25 (20 dry ice) |
| Gross-to-net weight ratio | 1.11          | 3.53       | 5            |

Median (IQR). *Kruskal-Wallis test rejects the equality across cargo types (P < 0.001). Handling information: standard cargo = store 15–25°C, cool cargo = keep cool 2–8°C and do not freeze, frozen cargo = 1 piece with dry ice (UN1845). Order net weight and value were estimated by multiplying the unit weight and unit price, respectively, with the ordered quantity and summing-up over the items in a cargo. The same unit weight was assumed for frozen cargo items.
Table 2: Costs of importing medical supplies to a tuberculosis program in Uzbekistan

<table>
<thead>
<tr>
<th>Cargo Type</th>
<th>Standard Cargo</th>
<th>Cool Cargo</th>
<th>Frozen Cargo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air freight (€)</td>
<td>31,155</td>
<td>1785</td>
<td>199</td>
</tr>
<tr>
<td>Customs clearance (€)</td>
<td>316</td>
<td>136</td>
<td>45</td>
</tr>
<tr>
<td>Land freight (€)</td>
<td>2826</td>
<td>151</td>
<td>8.84</td>
</tr>
<tr>
<td>Total</td>
<td>34,297</td>
<td>2072</td>
<td>253</td>
</tr>
</tbody>
</table>

Average import costs

<table>
<thead>
<tr>
<th>Cargo Type</th>
<th>Average Import Cost (€/kg net weight)</th>
<th>Average Import Cost (€/item line)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air freight (€/kg net weight)</td>
<td>4.35</td>
<td>15</td>
</tr>
<tr>
<td>Customs clearance (€/item line)</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Land freight (€/kg net weight)</td>
<td>0.39</td>
<td>1.25</td>
</tr>
<tr>
<td>Total (€/kg net weight)</td>
<td>4.78</td>
<td>17</td>
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</table>

Unit import costs (€/unit)

<table>
<thead>
<tr>
<th>Cargo Type</th>
<th>Unit Import Cost (€/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air freight</td>
<td>0.005 (0.003–0.06)</td>
</tr>
<tr>
<td>Customs clearance</td>
<td>0.00008 (0.00008–0.00008)</td>
</tr>
<tr>
<td>Land freight</td>
<td>0.0005 (0.0003–0.006)</td>
</tr>
<tr>
<td>Total</td>
<td>0.007 (0.003–0.07)</td>
</tr>
</tbody>
</table>

Percentage unit import cost (% of unit price)

<table>
<thead>
<tr>
<th>Cargo Type</th>
<th>Percentage Unit Import Cost (% of Unit Price)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air freight</td>
<td>11 (4.2–27)</td>
</tr>
<tr>
<td>Customs clearance</td>
<td>0.08 (0.01–0.3)</td>
</tr>
<tr>
<td>Land freight</td>
<td>1.0 (0.4–2.4)</td>
</tr>
<tr>
<td>Total</td>
<td>12 (4.6–35)</td>
</tr>
</tbody>
</table>

N = 85 and 83. Median (IQR). Percentage import costs exclude a donated item in the cool cargo and the frozen part of a test kit with unit prices of 0€ and 0.01€. Kruskal-Wallis tests reject equality of the unit import cost distribution across cargo types for air freight, customs clearance, land freight and total import costs (all P < 0.001). Equal distribution across cargo types was not rejected for percentage unit import costs (air freight P = 0.46, customs clearance P = 0.12, land freight P = 0.24, and total unit import cost P = 67). Unit import cost distributions are shown in supplementary Figures S3–4 and summarized in Table S2–4.
Figure 1: Transport route, customs point, and means of transport for medical supplies imported by a tuberculosis program in Uzbekistan.

Import costs to a tuberculosis program in Nukus were assessed for a shipment of medical supplies that contained standard cargo, cool cargo, and frozen cargo. Cargos drawn in the same plane or truck were transported and billed together. Only cargo shipped to Nukus caused import costs for the TB program in Karakalpakstan.
Figure 2: Graphical representation of import cost accounting

(a) Standard air cargo

(b) Cool air cargo

(c) Frozen air cargo

(d) Land freight for all cargo

(e) Customs clearance

(a) Standard air cargo contained two parts. One part was forwarded to the TB program. (d) Land freight to the TB program contained standard, cool, and frozen cargo. Cost allocation is illustrated for standard cargo. €/kg net weight are shown for standard cargo (long dashed line), cool cargo (medium-long dashed line) and frozen cargo (short dashed line). Shown values for unit net weights and units per item line exemplify how unit import costs were generated through cost allocation. Import costs allocated to standard cargo units and items are shown in Figures S1–2.
Figure 3: Import costs of medical supplies for a tuberculosis program in Uzbekistan

(a) Average import costs

(b) Import cost structure of standard cargo

(b) Each circle represents one of the 69 standard cargo items. Background colors represent how much of the total import cost, including transport and customs clearance costs, has been attributed to the item. Import costs between circles are interpolations.
Figure 4: Unit import costs of medical supplies for a tuberculosis program in Uzbekistan, by pharmaceutical form of imported items

(a) Unit import costs

(b) Percentage unit import cost

N = 85 and 83. Logarithmic y-axis. Tablets (38 items), fluids (19 items), test or test kit materials (15 items), capsules (5 items), powder (4 items), ointments (3 items), and wipe (1 item). Unit import costs by item packaging are shown supplementary Figure S5.
Supplementary material

Table S1: Order and shipping details of medical supplies imported by a tuberculosis program in Uzbekistan in 2016

<table>
<thead>
<tr>
<th></th>
<th>Standard cargo (part 1)</th>
<th>Standard cargo (part 2)</th>
<th>Cool cargo</th>
<th>Frozen cargo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin</td>
<td>MSF Procurement Unit Amsterdam</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Destination</td>
<td>MSF Tashkent</td>
<td>MSF Nukus (TB program Karakalpakstan)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orders combined</td>
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<td>5</td>
<td>3</td>
<td></td>
</tr>
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<td>14</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Item lines</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
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<td>1218</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Units per item</td>
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<td>4</td>
<td>2</td>
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<tr>
<td>Units per item line</td>
<td>35,000 (8000–59,172)</td>
<td>55</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Unit price (€)</td>
<td>0.10 (0.03–0.58)</td>
<td>26</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Unit weight (g)</td>
<td>1.2 (0.7–15)</td>
<td>126</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Order weight</td>
<td>7168</td>
<td>121</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Order value</td>
<td>385,167</td>
<td>20,228</td>
<td>901</td>
<td></td>
</tr>
</tbody>
</table>

Air freight cargo (Amsterdam to Tashkent)

<table>
<thead>
<tr>
<th></th>
<th>Pieces</th>
<th>Volume (m³)</th>
<th>Gross weight (kg)</th>
<th>Chargeable weight (kg)</th>
<th>Freight rate (€/kg)</th>
<th>Other charges (€)</th>
<th>Total costs (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1486</td>
<td>107.018</td>
<td>16,553.5 [8566.2+7987.3]</td>
<td>428</td>
<td>2.97</td>
<td>11,594</td>
<td>64,568 [33,413+31,155]</td>
</tr>
<tr>
<td>Customs (Tashkent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1785</td>
</tr>
</tbody>
</table>

Land freight cargo (Tashkent to Nukus)

<table>
<thead>
<tr>
<th></th>
<th>Pieces</th>
<th>Volume</th>
<th>Gross weight (kg)</th>
<th>Total costs (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>491</td>
<td>28,924</td>
<td>7987.3</td>
<td>2985</td>
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</table>

Median (IQR) [range]. [Tashkent+Nukus parts]. MSF = Médecins Sans Frontières. Handling information: standard cargo = store 15–25°C, cool cargo = keep cool 2–8°C and do not freeze, frozen cargo = 1 piece with dry ice (UN1845). Chargeable weight is the maximum of gross weight and volumetric weight. Other charges were fuel surcharges plus, for frozen cargo, dangerous good fee. Cool cargo contained an item made available through the Stop TB Partnership at no charge. Frozen cargo contained the frozen part of a two-part test kit to which a unit price of €0.01 was assigned. Unit weights are based on the MSF Green List. Missing unit weights for 6 of 69 items in standard cargo and 2 of 14 items in cool cargo were imputed using the median unit weight of comparable items. The same unit weight was assumed for all frozen cargo items.
Table S2: Unit air freight, customs clearance, and land freight costs of medical supplies for a tuberculosis program in Uzbekistan

<table>
<thead>
<tr>
<th>Import cost</th>
<th>Cargo</th>
<th>Median</th>
<th>Interquartile range</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Unit import cost (€ per unit) *</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air freight</td>
<td></td>
<td>Shipment</td>
<td>0.02</td>
<td>.003–0.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Standard cargo</td>
<td>0.005</td>
<td>0.003–0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cool cargo</td>
<td>1.85</td>
<td>1.47–8.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frozen cargo</td>
<td>1.99</td>
<td>1.99–1.99</td>
</tr>
<tr>
<td>Customs clearance</td>
<td>Shipment</td>
<td>0.00008</td>
<td>0.00008–0.0007</td>
<td>0.00004–2.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Standard cargo</td>
<td>0.00008</td>
<td>0.00008–0.0008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cool cargo</td>
<td>0.04</td>
<td>0.04–0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frozen cargo</td>
<td>0.45</td>
<td>0.45–0.45</td>
</tr>
<tr>
<td>Land freight</td>
<td>Shipment</td>
<td>0.002</td>
<td>0.0003–0.08</td>
<td>0.00004–1.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Standard cargo</td>
<td>0.0005</td>
<td>0.0003–0.006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cool cargo</td>
<td>0.16</td>
<td>0.16–0.69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frozen cargo</td>
<td>0.09</td>
<td>0.09–0.09</td>
</tr>
<tr>
<td>Total</td>
<td>Shipment</td>
<td>0.02</td>
<td>0.004–1.14</td>
<td>0.0006–24</td>
</tr>
<tr>
<td></td>
<td>Standard cargo</td>
<td>0.007</td>
<td>0.003–0.07</td>
<td>0.0006–6.43</td>
</tr>
<tr>
<td></td>
<td>Cool cargo</td>
<td>2.16</td>
<td>1.80–8.98</td>
<td>0.29–24</td>
</tr>
<tr>
<td></td>
<td>Frozen cargo</td>
<td>2.53</td>
<td>2.53–2.53</td>
<td>2.53–2.53</td>
</tr>
<tr>
<td>Percentage unit import cost (% of unit price)†</td>
<td></td>
<td>Shipment</td>
<td>10</td>
<td>4.1–23</td>
</tr>
<tr>
<td></td>
<td>Standard cargo</td>
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<td>4.2–27</td>
<td>0.1–907</td>
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<td>Cool cargo</td>
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<td>0.6–81</td>
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<td>4.4</td>
<td>4.4</td>
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<td>Customs clearance</td>
<td>Shipment</td>
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<td>0.02–0.4</td>
<td>0.0001–205</td>
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<tr>
<td></td>
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<td>0.07–0.4</td>
<td>0.01–36</td>
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<td>1.0</td>
</tr>
<tr>
<td>Land freight</td>
<td>Shipment</td>
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<td>0.4–2.1</td>
<td>0.01–82</td>
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<tr>
<td></td>
<td>Standard cargo</td>
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<td>0.4–2.4</td>
<td>0.01–82</td>
</tr>
<tr>
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<td>Cool cargo</td>
<td>0.5</td>
<td>0.3–1.3</td>
<td>0.05–6.9</td>
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<td>0.2–2.4</td>
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<td>Total</td>
<td>Shipment</td>
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<td>4.5–35</td>
<td>0.1–989</td>
</tr>
<tr>
<td></td>
<td>Standard cargo</td>
<td>12</td>
<td>4.6–35</td>
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</tr>
<tr>
<td></td>
<td>Cool cargo</td>
<td>8.7</td>
<td>3.8–21</td>
<td>0.7–88</td>
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<tr>
<td></td>
<td>Frozen cargo</td>
<td>5.6</td>
<td>5.6</td>
<td>5.6</td>
</tr>
</tbody>
</table>

N = 85 and 83. Percentage import costs exclude a donated item and the frozen cargo part of a test kit that was split across cargos. Kruskal-Wallis tests reject equality of the unit import cost distribution across cargo types for air freight, customs clearance, land freight and total import costs (all P < 0.001). Equal distribution across cargo types was not rejected for percentage unit import costs (air freight P = 0.46, customs clearance P = 0.12, land freight P = 0.24, and total unit import cost P = 0.67).
Table S3: Unit import costs of medical supplies for a tuberculosis program in Uzbekistan, by pharmaceutical form of imported items

<table>
<thead>
<tr>
<th>Group</th>
<th>Pharmaceutical form of item (N)</th>
<th>Median</th>
<th>Interquartile range</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit import cost (€ per unit)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard cargo</td>
<td>Fluid ≥100 ml (8)</td>
<td>2.06</td>
<td>1.04–3.97</td>
<td>0.62–6.43</td>
</tr>
<tr>
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<td>Ointment (3)</td>
<td>0.19</td>
<td>0.05–1.01</td>
<td>0.05–1.01</td>
</tr>
<tr>
<td></td>
<td>Powder (4)</td>
<td>0.15</td>
<td>0.10–0.15</td>
<td>0.06–0.16</td>
</tr>
<tr>
<td></td>
<td>Fluid &lt;100 ml (10)</td>
<td>0.07</td>
<td>0.04–0.28</td>
<td>0.02–6.07</td>
</tr>
<tr>
<td></td>
<td>Wipe (1)</td>
<td>0.005</td>
<td>0.005–0.005</td>
<td>0.005–0.005</td>
</tr>
<tr>
<td></td>
<td>Tablet (38)</td>
<td>0.004</td>
<td>0.002–0.007</td>
<td>0.0006–0.04</td>
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<tr>
<td>Cool cargo</td>
<td>Fluid &lt;100 ml (1)</td>
<td>2.61</td>
<td>2.61–2.61</td>
<td>2.61–2.61</td>
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<tr>
<td></td>
<td>Test/Test kit (13)</td>
<td>2.05</td>
<td>1.8–8.98</td>
<td>0.29–24</td>
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<tr>
<td>Frozen cargo</td>
<td>Test/Test kit (2)</td>
<td>2.53</td>
<td>2.53–2.53</td>
<td>2.53–2.53</td>
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<tr>
<td><strong>Percentage unit import cost (% of unit price)</strong></td>
<td></td>
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<tr>
<td>Standard cargo</td>
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<td>Fluid &lt;100 ml (10)</td>
<td>13.2</td>
<td>9.9–31</td>
<td>4.6–104</td>
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<td>Tablet (38)</td>
<td>11.4</td>
<td>5.0–23</td>
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<td>Capsule (5)</td>
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<td>0.1–15</td>
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<tr>
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<td>41.4</td>
<td>41–41</td>
<td>41–41</td>
</tr>
<tr>
<td></td>
<td>Test/Test kit (12)</td>
<td>7.58</td>
<td>3.4–19</td>
<td>0.7–88</td>
</tr>
<tr>
<td>Frozen cargo</td>
<td>Test/Test kit (1)</td>
<td>5.62</td>
<td>5.6–5.6</td>
<td>5.6–5.6</td>
</tr>
</tbody>
</table>

N = 85 and 83. Percentage import costs exclude a donated item and the frozen cargo part of a test kit that was split across cargos. For unit import cost, Kruskal-Wallis tests reject the equality of the distribution across the pharmaceutical form of items in the standard cargo (P < 0.001) but not in the cool cargo (P = 0.71). Within standard cargo items, tablets and capsules had significantly lower median unit import costs than fluids ≥100 ml (both Dunn tests P < 0.001) and fluids <100 ml (P < 0.001 and P = 0.024). Percentage unit cost were significantly different between capsules and fluids ≥100 ml (P < 0.017).
<table>
<thead>
<tr>
<th>Group</th>
<th>Packaging of item (N)</th>
<th>Median</th>
<th>Interquartile range</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit import cost (€ per unit)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard cargo</td>
<td>Fluid bag (3)</td>
<td>2.70</td>
<td>0.64–6.43</td>
<td>0.62–6.43</td>
</tr>
<tr>
<td></td>
<td>Bottle (8)</td>
<td>1.27</td>
<td>0.59–3.97</td>
<td>0.23–6.07</td>
</tr>
<tr>
<td></td>
<td>Tube (3)</td>
<td>0.19</td>
<td>0.05–1.01</td>
<td>0.05–1.01</td>
</tr>
<tr>
<td></td>
<td>Vial (4)</td>
<td>0.15</td>
<td>0.10–0.15</td>
<td>0.06–0.16</td>
</tr>
<tr>
<td></td>
<td>Ampulla (6)</td>
<td>0.04</td>
<td>0.03–0.07</td>
<td>0.02–0.08</td>
</tr>
<tr>
<td></td>
<td>Sachet (2)</td>
<td>0.03</td>
<td>0.005–0.06</td>
<td>0.005–0.06</td>
</tr>
<tr>
<td></td>
<td>Capsule/Tablet (43)</td>
<td>0.004</td>
<td>0.002–0.007</td>
<td>0.0006–0.04</td>
</tr>
<tr>
<td>Cool cargo</td>
<td>Vial (1)</td>
<td>2.61</td>
<td>2.61–2.61</td>
<td>2.61–2.61</td>
</tr>
<tr>
<td></td>
<td>Test/Test kit (13)</td>
<td>2.05</td>
<td>1.80–8.98</td>
<td>0.29–24</td>
</tr>
<tr>
<td>Frozen cargo</td>
<td>Test/Test kit (2)</td>
<td>2.53</td>
<td>2.53–2.53</td>
<td>2.53–2.53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Percentage unit import cost (% of unit price)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard cargo</td>
</tr>
<tr>
<td>Fluid bag (3)</td>
</tr>
<tr>
<td>Sachet (2)</td>
</tr>
<tr>
<td>Tube (3)</td>
</tr>
<tr>
<td>Ampulla (6)</td>
</tr>
<tr>
<td>Bottle (8)</td>
</tr>
<tr>
<td>Capsule/Tablet (43)</td>
</tr>
<tr>
<td>Vial (4)</td>
</tr>
<tr>
<td>Cool cargo</td>
</tr>
<tr>
<td>Vial (1)</td>
</tr>
<tr>
<td>Test/Test kit (12)</td>
</tr>
<tr>
<td>Frozen cargo</td>
</tr>
<tr>
<td>Test/Test kit (1)</td>
</tr>
</tbody>
</table>

N = 85 and 83. Percentage import costs exclude a donated item and the frozen cargo part of a test kit that was split across cargos. For unit import cost, Kruskal-Wallis tests reject the equality of the distribution across the packaging of items in the standard cargo (P < 0.001) but not in the cool cargo (P = 0.71). Within standard cargo items, tablets/capsules had a significantly lower median unit import cost than fluid bags (Dunn test P = 0.040).
Table S5: Predictors of unit import cost of medical supplies for a tuberculosis program in Uzbekistan

<table>
<thead>
<tr>
<th>Cargo type</th>
<th>Unit import cost (€)</th>
<th>Weight model</th>
<th>Price model</th>
<th>Form model (short)</th>
<th>Form model</th>
<th>Packaging model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cool cargo</td>
<td>0.6 (0.49 to 0.7)**</td>
<td>0.4 (−0.19 to 0.98)**</td>
<td>2.49 (2.06 to 2.92)**</td>
<td>1.42 (0.49 to 2.35)**</td>
<td>1.34 (0.42 to 2.25)**</td>
<td></td>
</tr>
<tr>
<td>Frozen cargo</td>
<td>1.01 (0.78 to 1.24)**</td>
<td>0.22 (−1.26 to 1.7)</td>
<td>2.4 (1.37 to 3.43)**</td>
<td>1.33 (0.18 to 2.47)**</td>
<td>1.24 (0.13 to 2.35)**</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cargo type</th>
<th>Unit weight (g)</th>
<th>Unit price (€)</th>
<th>Item packaging</th>
<th>R-squared (%)</th>
<th>Adj. R-squared (%)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cool cargo</td>
<td>0.98 (0.95 to 1.02)**</td>
<td>0.77 (0.59 to 0.94)**</td>
<td>Fluid bag</td>
<td>2.76 (2.27 to 3.25)</td>
<td>98.6</td>
<td>85</td>
</tr>
<tr>
<td>Frozen cargo</td>
<td></td>
<td></td>
<td>Bottle</td>
<td>2.52 (2.21 to 2.84)**</td>
<td>70.3</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tube</td>
<td>1.74 (1.25 to 2.23)**</td>
<td>70.5</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Test/Test kit</td>
<td>1.58 (0.62 to 2.53)</td>
<td>89.7</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vial</td>
<td>1.5 (1.07 to 1.92)**</td>
<td>91.1</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ampulla</td>
<td>1.03 (0.67 to 1.38)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sachet</td>
<td>0.68 (0.09 to 1.28)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Constant</td>
<td>−2.28 (−2.32 to −2.24)**</td>
<td>98.5</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>−1.08 (−1.3 to −0.86)**</td>
<td>69.1</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>−2 (−2.18 to −1.81)**</td>
<td>69.4</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>−2.4 (−2.54 to −2.26)**</td>
<td>88.4</td>
<td>85</td>
</tr>
</tbody>
</table>

Coefficient (95% Confidence Interval). *P < 0.05, **P < 0.01, ***P < 0.001. Unit import cost, weight and price were log 10-transformed. Weight has been the allocation base for transport costs, which represented 99% of the total import cost. The price model excludes a donated item and the frozen cargo part of a test kit that was split across cargos.
**Table S6**: Predictors of percentage unit import cost of medical supplies for a tuberculosis program in Uzbekistan

<table>
<thead>
<tr>
<th>Cargo type</th>
<th>Weight model</th>
<th>Price model</th>
<th>Form model (short)</th>
<th>Form model</th>
<th>Packaging model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cool cargo</td>
<td>0.62 (0.49 to 0.75)***</td>
<td>0.4 (-0.19 to 0.98)</td>
<td>1.08 (0.57 to 1.59)***</td>
<td>1.19 (0.31 to 2.06)***</td>
<td>1.25 (0.37 to 2.13)**</td>
</tr>
<tr>
<td>Frozen cargo</td>
<td>1.04 (0.7 to 1.38)***</td>
<td>0.22 (-1.26 to 1.7)</td>
<td>0.95 (-0.26 to 2.15)</td>
<td>1.13 (-0.1 to 2.36)</td>
<td>1.2 (0.01 to 2.4)</td>
</tr>
</tbody>
</table>

**Unit weight and price**

<table>
<thead>
<tr>
<th>Cargo type</th>
<th>Weight model</th>
<th>Price model</th>
<th>Form model (short)</th>
<th>Form model</th>
<th>Packaging model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cool cargo</td>
<td>0.99 (0.94 to 1.05)***</td>
<td>-1.02 (-1.07 to -0.96)***</td>
<td>-0.23 (-0.41 to -0.06)**</td>
<td>-0.45 (-0.6 to -0.3)***</td>
<td>-0.77 (-0.92 to -0.62)***</td>
</tr>
<tr>
<td>Frozen cargo</td>
<td>0.99 (0.94 to 1.05)***</td>
<td>-1.02 (-1.07 to -0.96)***</td>
<td>-0.23 (-0.41 to -0.06)**</td>
<td>-0.45 (-0.6 to -0.3)***</td>
<td>-0.77 (-0.92 to -0.62)***</td>
</tr>
</tbody>
</table>

**Pharmaceutical from**

<table>
<thead>
<tr>
<th>Cargo type</th>
<th>Weight model</th>
<th>Price model</th>
<th>Form model (short)</th>
<th>Form model</th>
<th>Packaging model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid ≥ 100 ml</td>
<td>0.99 (0.94 to 1.05)***</td>
<td>-1.02 (-1.07 to -0.96)***</td>
<td>-0.23 (-0.41 to -0.06)**</td>
<td>-0.45 (-0.6 to -0.3)***</td>
<td>-0.77 (-0.92 to -0.62)***</td>
</tr>
<tr>
<td>Ointment</td>
<td>1.04 (0.7 to 1.38)***</td>
<td>0.22 (-1.26 to 1.7)</td>
<td>0.95 (-0.26 to 2.15)</td>
<td>1.13 (-0.1 to 2.36)</td>
<td>1.2 (0.01 to 2.4)</td>
</tr>
<tr>
<td>Fluid&lt;100ml</td>
<td>1.09 (0.59 to 1.59)***</td>
<td>0.98 (0.03 to 1.92)</td>
<td>0.35 (-0.5 to 1.19)</td>
<td>0.35 (-0.5 to 1.19)</td>
<td>0.35 (-0.5 to 1.19)</td>
</tr>
<tr>
<td>Powder</td>
<td>1.04 (0.7 to 1.38)***</td>
<td>0.22 (-1.26 to 1.7)</td>
<td>0.95 (-0.26 to 2.15)</td>
<td>1.13 (-0.1 to 2.36)</td>
<td>1.2 (0.01 to 2.4)</td>
</tr>
<tr>
<td>Wipe</td>
<td>-0.25 (-0.65 to 0.15)</td>
<td>1.04 (0.7 to 1.38)***</td>
<td>0.22 (-1.26 to 1.7)</td>
<td>0.95 (-0.26 to 2.15)</td>
<td>1.13 (-0.1 to 2.36)</td>
</tr>
<tr>
<td>Capsule</td>
<td>-0.25 (-0.65 to 0.15)</td>
<td>1.04 (0.7 to 1.38)***</td>
<td>0.22 (-1.26 to 1.7)</td>
<td>0.95 (-0.26 to 2.15)</td>
<td>1.13 (-0.1 to 2.36)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cargo type</th>
<th>Weight model</th>
<th>Price model</th>
<th>Form model (short)</th>
<th>Form model</th>
<th>Packaging model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid bag</td>
<td>0.62 (0.49 to 0.75)***</td>
<td>0.4 (-0.19 to 0.98)</td>
<td>1.08 (0.57 to 1.59)***</td>
<td>1.19 (0.31 to 2.06)***</td>
<td>1.25 (0.37 to 2.13)**</td>
</tr>
<tr>
<td>Test/Test kit</td>
<td>1.04 (0.7 to 1.38)***</td>
<td>0.22 (-1.26 to 1.7)</td>
<td>0.95 (-0.26 to 2.15)</td>
<td>1.13 (-0.1 to 2.36)</td>
<td>1.2 (0.01 to 2.4)</td>
</tr>
<tr>
<td>Bottle</td>
<td>1.04 (0.7 to 1.38)***</td>
<td>0.22 (-1.26 to 1.7)</td>
<td>0.95 (-0.26 to 2.15)</td>
<td>1.13 (-0.1 to 2.36)</td>
<td>1.2 (0.01 to 2.4)</td>
</tr>
<tr>
<td>Tube</td>
<td>1.04 (0.7 to 1.38)***</td>
<td>0.22 (-1.26 to 1.7)</td>
<td>0.95 (-0.26 to 2.15)</td>
<td>1.13 (-0.1 to 2.36)</td>
<td>1.2 (0.01 to 2.4)</td>
</tr>
<tr>
<td>Vial</td>
<td>1.04 (0.7 to 1.38)***</td>
<td>0.22 (-1.26 to 1.7)</td>
<td>0.95 (-0.26 to 2.15)</td>
<td>1.13 (-0.1 to 2.36)</td>
<td>1.2 (0.01 to 2.4)</td>
</tr>
<tr>
<td>Ampulla</td>
<td>1.04 (0.7 to 1.38)***</td>
<td>0.22 (-1.26 to 1.7)</td>
<td>0.95 (-0.26 to 2.15)</td>
<td>1.13 (-0.1 to 2.36)</td>
<td>1.2 (0.01 to 2.4)</td>
</tr>
<tr>
<td>Sachet</td>
<td>1.04 (0.7 to 1.38)***</td>
<td>0.22 (-1.26 to 1.7)</td>
<td>0.95 (-0.26 to 2.15)</td>
<td>1.13 (-0.1 to 2.36)</td>
<td>1.2 (0.01 to 2.4)</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.3 (-0.38 to -0.22)***</td>
<td>0.92 (0.7 to 1.14)***</td>
<td>0.55 (0.34 to 0.76)***</td>
<td>-0.08 (-0.33 to 0.16)</td>
<td>-0.2 (-0.42 to 0.02)</td>
</tr>
<tr>
<td>R-squared (%)</td>
<td>95.4</td>
<td>9.1</td>
<td>42.6</td>
<td>71.6</td>
<td>74.5</td>
</tr>
<tr>
<td>Adj. R-squared (%)</td>
<td>95.1</td>
<td>5.7</td>
<td>39.6</td>
<td>67.7</td>
<td>70.9</td>
</tr>
<tr>
<td>N</td>
<td>83</td>
<td>83</td>
<td>83</td>
<td>83</td>
<td>83</td>
</tr>
</tbody>
</table>

Coefficient (95% Confidence Interval). *P < 0.05, **P < 0.01, ***P < 0.001. Unit import cost, weight and price were log 10-transformed. Weight has been the allocation base for transport costs, which represented 99% of the total import cost. Model exclude a donated item and the frozen cargo part of a test kit that was split across cargos.
Figure S1: Unit import costs of medicines imported as standard cargo by a tuberculosis program in Uzbekistan, by item

![Bar chart showing unit import costs of various medicines imported as standard cargo by a tuberculosis program in Uzbekistan, broken down by item, with categories Air freight, Customs clearance, and Land freight.]

- **SODIUM CHLORIDE, 0.9%, 1 L, flexibag g, PVC free**
- **ONDANSETRON HCL, 4 mg/5 mL base, oral susp, 50 mL, bot.**
- **CHLORHEXIDINE digluconate 5%, solution, 1 L, bot.**
- **SUSPENDING VEHICLE (Ora-Blond 5 F) 473 mL, oral sol, sugar free**
- **RINGER lactate, 500 mL, flexibag g, PVC free**
- **IBUPROFEN, 100 mg/5 mL, oral susp, 150 mL, bot.**
- **POTASSIUM chloride, 75% w/v, 1 mmol/KI mL oral sol, 500 mL, bot.**
- **HYDROCORTISONE acetate, 1%, ointment, 15 g, tube**
- **PARACETAMOL (acetaminophen), 120 mg/5 mL, oral susp, 100 mL, bot.**
- **SODIUM CHLORIDE, 0.9%, 100 mL, flexibag g, PVC free**

HaloPeridol, 2mg/ml/20 drops, 30mL, bot.
Salbutamol sulfate, eq. 1mg base/2 puff, 200 puffs, aerosol.
Antihaemorrhoid, ointment, 25g, tube.
Capreomycin sulfate, eq. 1g base, powder, vial.
Kanamycin sulfate, eq. 1g base, powder, vial.
Imipenem 500mg/cilastatin sodium 500mg, powder, vial.
Lidocaïne hydrochloride, 1%, preservative-free, 5ml, plastamp.
Water for injection, 10ml, plastic amp.
Para-aminosalicylate sodium, 552mg, powder oral sol, sachet.
Sodium chloride 6%, for nebulizer, 4ml, vial.
Tetracycline hydrochloride, 1%, eye ointment, ster, 5g, tube.
Sodium chloride, 0.9%, 5ml, amp.
Metformin hydrochloride, 500mg, tab.
Promethazine hydrochloride, eq. 25mg/ml base, 2ml, amp.
Ondansetron hydrochloride, eq. 2mg/ml base, 2ml, amp.
Epinephrine (adrenaline) lactate, eq.1mg/ml base, 1ml amp IV.
Isoniazid (H), 100mg, breakable tab, blister.
Amoxicillin 875mg/Clavulanic acid 125mg, tab.
Amoxicillin 500mg/Clavulanic acid 125mg, tab.
Bedaquiline, 100mg, tab.
Moxifloxacin hydrochloride, eq. 400mg base, tab.
Ondansetron hydrochloride, eq. 4mg base, tab.
Erythromycin stearate, eq. 500mg base, tab.
Pyridoxine hydrochloride (vitamin B6), 50mg, tab.
Cotrimoxazole, 800mg/160mg, tab.
Rifampicin (R), 150mg, caps, blister.
Ondansetron hydrochloride, eq. 8mg base, tab.
Ipsen, 70% isopropyl alcohol, sachet, small.
H 50mg/Z 150mg/R 75mg, disp. tab, blister.
Rifampicin (R), 300mg, caps, blister.
Isoniazid (H), 300mg, tab, blister.
Delamanid, 50mg, tab, blister.
Levofloxacin, 250mg, tab.
Cotrimoxazole, 400mg/80mg, tab.
Pyrazinamide (Z), 400mg, tab, blister.
H 75mg/R 150mg, tab, blister.
Amoxicillin, 500mg, tab.
Prothionamide, 250mg, tab.
Ethambutol hydrochloride (E), eq. 400mg base, tab, blister.
Erythromycin stearate, eq. 250mg base, tab.
Paracetamol (acetaminophen), 500mg, tab.
Omeprazole, 20mg, gastro-resistant caps.
Omeprazole, 10mg, disp gastro-resistant tab.
Ibuprofen, 400mg, tab.
Enalapril maleate, 5mg, tab.
H 50mg/R 75mg, disp. tab, blister.
Risperidone, 1mg, tab.
Mirtazapine, 30mg, tabs.
Ferrous salt eq. 60mg iron / Folic acid 0.4mg, tab.
Ibuprofen, 200mg, tab.
Clofazimine, 50mg, soft caps.
Amoxicillin, 250mg, tab.
Promethazine hydrochloride, eq. 25mg base, tab.
Ethambutol hydrochloride (E), eq. 100mg base, tab, blister.
Carbamazepine, 200mg, tab.
Paracetamol (acetaminophen), 100mg, tab.
Metoclopramide hydrochloride anhydrous, 10mg, tab.
Clofazimine, 100mg, soft caps.
Levotyroxine sodium, 0.1mg, tab.

**N = 69.**
Figure S2: Percentage unit import costs of medicines imported as standard cargo by a tuberculosis program in Uzbekistan, by item

- N = 69.
Figure S3: Distribution of the unit import costs in a tuberculosis program in Uzbekistan

(a) Unit import cost

(b) Unit air freight cost

(c) Unit customs clearance costs

(d) Unit land freight cost

N = 85. Logarithmic x-axis. Normal distributions of unit import, air freight, and land freight costs on a decadic logarithm scale are not rejected for cool cargo (Shapiro-Wilk test $P = 0.17$, $P = 0.41$, and $P = 0.41$). The frozen cargo contained not enough items to test its unit import cost distribution.
Figure S4: Distribution of the percentage unit import costs in tuberculosis program in Uzbekistan

(a) Percentage unit import cost

(b) Percentage unit air freight cost

(c) Percentage unit customs clearance costs

(d) Percentage unit land freight cost

N = 83. Logarithmic x-axis. Normal distributions of percentage unit import, air freight, customs clearance, and land freight costs on a decadic logarithm scale are not rejected for standard cargo (all four Shapiro-Wilk tests $P > 0.4$), cool cargo ($P > 0.1$), and frozen cargo ($P > 0.4$). The frozen cargo contained not enough items to test its unit import cost distribution.
Figure S5: Unit import costs of medical supplies for a tuberculosis program in Uzbekistan, by packaging of imported items

(a) Unit import costs

(b) Percentage unit import costs

Median

---

Standard cargo

Cool cargo

Frozen cargo

---

N = 85 and 83. Logarithmic y-axis. Tablets Capsule/Tablet (43 items), test or test kit materials (15 items), bottle (8 items), ampulla (6 items), vial (5 items), fluid bag (3 items), tube (3 items), and sachet (2 items).