

Measurement failure and farm gate income loss in Tanzania: A practitioner based study of legal metrology enforcement

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Abstract

Measurement inaccuracies in informal and semi formal markets pose a persistent but poorly documented threat to consumer welfare across Sub Saharan Africa. Although legal metrology frameworks exist in many countries in the region, enforcement capacity remains uneven, and the economic impact of measurement failure on vulnerable market participants has rarely been systematically assessed. This paper examines how measurement inaccuracies affect consumer welfare in Tanzanian retail and agricultural commodity markets, and evaluates the regulatory mechanisms through which the Weights and Measures Agency (WMA) of Tanzania seeks to mitigate measurement related trade disputes. Using a convergent mixed methods design, the study integrates fifteen years of practitioner generated field inspection data from urban retail markets, fuel dispensing points, and agricultural buying centres in the Lake Zone (Kagera Region) with structured observation of trader and buyer behaviour and documentary analysis of WMA enforcement records, OIML technical standards, and East African Community (EAC) regulatory instruments. The evidence identifies four principal pathways through which measurement failure harms market participants: scale drift and deliberate tampering in retail settings, non standard volumetric measures in rural commodity trade, underdispensing at fuel points through electronic manipulation and foam inflation, and digital transaction discrepancies in mobile money and prepackaged goods systems. Smallholder farmers selling cotton and maize at Lake Zone buying centres emerge as among the most exposed groups, with compounded errors in weighing, tare deduction, and moisture assessment estimated to reduce effective farm gate income by 3 to 8 percent per transaction cycle. The findings indicate that effective consumer protection through measurement governance requires stronger field inspection capacity, harmonised metrological standards at the EAC and SADC level, and formal integration of legal metrology into agricultural value chain oversight, offering practical lessons for national metrology authorities across Sub Saharan Africa.

Keywords: Legal Metrology, Consumer Protection, Market Fairness, Measurement Fraud, Tanzania, Informal Markets, Smallholder Farmers, Sub Saharan Africa

JEL Classification: D18, D82, K23

1. Introduction

Markets function on the assumption that quantities exchanged correspond to quantities declared. When that assumption fails — because a scale is unverified, a container is non-standard, a fuel pump is electronically manipulated, or a prepackaged product is systematically underweight — the consequent harm is diffuse, cumulative, and disproportionately borne by the least empowered party in the transaction. In Sub-Saharan Africa, where a substantial proportion of consumer goods and agricultural commodities are traded through informal channels with limited regulatory oversight, measurement failure constitutes a structural form of economic injustice that has attracted inadequate scholarly attention. Legal metrology — the branch of metrology that establishes mandatory technical and legal requirements for measuring instruments and measurements used in trade, health, safety, and environmental protection — provides the primary institutional response to measurement-related market failure. In Tanzania, this function is vested in the Weights and Measures Agency (WMA), established under the Weights and Measures Act (Cap. 340) and operating under the Ministry of Industry and Trade. WMA inspectors are mandated to verify measuring instruments, investigate complaints, enforce compliance, and educate market participants on their rights and obligations. Despite fifteen years of enforcement activity spanning diverse commodity sectors and geographic settings, the systemic impact of WMA's operations on consumer welfare has not been formally documented in the peer-reviewed literature. This paper addresses that gap. Drawing on practitioner-generated field evidence accumulated across Tanzania's retail, fuel, and agricultural markets — and grounded in the International Organisation of Legal Metrology (OIML) framework and East African Community (EAC) harmonisation commitments — it asks: How do measurement inaccuracies affect consumer welfare in Tanzanian markets, and what regulatory mechanisms can effectively mitigate measurement-related trade disputes? The paper makes three original contributions. First, it provides the first systematic, practitioner-anchored empirical account of measurement failure pathways in a major East African economy. Second, it quantifies, in indicative terms, the income exposure of smallholder farmers to compounded measurement errors in agricultural commodity trade. Third, it identifies institutional and policy gaps in Tanzania's legal metrology framework and draws implications for regional harmonisation under EAC and SADC instruments. The paper is structured as follows. Section 2 reviews relevant literature on legal metrology, consumer protection, and market governance in Sub-Saharan Africa. Section 3 presents the conceptual framework. Section 4 describes the mixed-methods research design. Section 5 presents findings organised around the four principal measurement failure pathways identified in the field. Section 6 discusses implications for policy and practice. Section 7 concludes.

2. Literature Review

2.1 Legal Metrology as Consumer Protection Infrastructure

Legal metrology is recognised internationally as a foundational element of market governance. The International Organisation of Legal Metrology (OIML), established in 1955 and headquartered in Paris, develops model regulations and technical recommendations that member states adapt into national law (OIML, 2020). The VIM — the International Vocabulary of Metrology — provides the terminological foundation on which both scientific and legal metrology rest (BIPM et al., 2012). At its core, legal metrology is a consumer protection instrument: it ensures that the buyer receives what the seller declares, and that the seller is not penalised by inaccurate instruments that under-read. The literature on measurement and consumer welfare in developed economies is relatively well developed. Studies in the European context have documented how metrological harmonisation within the EU Single Market reduces transaction costs and supports cross-border trade (Birch et al., 2015; WELMEC, 2019). In the United States, NIST's Office of Weights and Measures provides a national framework within which state-level enforcement agencies operate (NIST, 2020). However, the literature specific to low- and middle-income countries — and Sub-Saharan Africa in particular — remains thin. A systematic search of Scopus and Web of Science for "legal metrology" AND "Africa" yields fewer than 40 peer-reviewed articles as of 2024, of which fewer than 15 deal with enforcement outcomes.

2.2 Measurement Failure and Market Inequity in Africa

The conceptual link between measurement failure and market inequity in African contexts has been addressed, in passing, within broader literatures on informal trade, value chain governance, and smallholder agriculture. The World Bank's Doing Business indicators have historically included trading standards as a dimension of market regulatory quality (World Bank, 2020). FAO studies of agricultural value chains in East Africa have noted that inconsistent weighing practices at buying centres reduce farm-gate prices and depress farmer incomes (FAO, 2019). UNCTAD's work on trade facilitation in Africa has identified measurement harmonisation as a non-tariff barrier with significant trade-cost implications (UNCTAD, 2021). Within the legal metrology literature, Kang'ethe and Kamau (2018) documented scale non-compliance rates in Kenyan retail markets, finding that over 30% of instruments sampled failed verification requirements. Ndegwa et al. (2020) examined prepackaged goods compliance in the Nairobi metropolitan area, concluding that systematic underfilling by manufacturers imposed significant aggregate costs on consumers. In Tanzania specifically, prior scholarship has largely focused on standards and conformity assessment through the Tanzania Bureau of Standards (TBS), with relatively little attention to the enforcement dimension of WMA's mandate (Mlawa, 2017).

2.3 Regional Frameworks: EAC, SADC, and the PAQI

At the regional level, the East African Community has progressively developed a metrology harmonisation framework under its Quality Infrastructure programme. The EAC Standardisation, Quality Assurance, Metrology and Testing (SQMT) Act of 2006 establishes the legal basis for mutual recognition of metrological standards across EAC Partner States (EAC, 2006). The Southern African Development Community Metrology programme (SADCMEI) and the Pan African Quality Infrastructure (PAQI) — operating under AUDA-NEPAD — provide complementary frameworks for continental harmonisation (PAQI, 2021; SADCMEI, 2020). The African Organisation for Standardisation (ARSO) coordinates standards work across AU member states. Despite these institutional frameworks, implementation gaps remain significant. Mutual Recognition Arrangements (MRAs) for measuring instruments remain partial, and cross-border market surveillance is inconsistently resourced. The EAC Metrology Programme through peer assessment has identified traceability chain gaps in several Partner States as a priority concern (EAC Metrology, 2022). Tanzania's WMA participates in SADCMEI technical working groups, but the practical implications of regional commitments for domestic enforcement practice have not been studied.

3. Conceptual Framework

This paper adopts an integrated framework that situates legal metrology enforcement within a broader theory of market fairness as a public good. Three theoretical pillars support this framework. The first is the public goods theory of measurement infrastructure. Measurement standards — and the institutional arrangements that maintain them — share characteristics of public goods: they are non-rivalrous (one trader's use of a verified scale does not diminish its availability to another) and their benefits extend beyond the immediate transaction to market-wide trust and efficiency. This is consistent with the analysis of standards as "club goods" in the trade literature (Blind, 2004), and supports the case for state provision of legal metrology enforcement rather than sole reliance on private ordering. The second is information asymmetry theory, following Akerlof's (1970) foundational analysis of markets under uncertainty. In a trade transaction where the seller controls the measuring instrument, the buyer faces a fundamental information disadvantage: they cannot independently verify the quantity received at the moment of exchange. This asymmetry creates conditions for both deliberate fraud and inadvertent error. Legal metrology inspection functions, in this framework, as a third-party verification mechanism that reduces information asymmetry and restores market equilibrium. The third pillar is the regulatory capacity framework developed by Levi-Faur (2011) and applied to developing country contexts by Jordana and Levi-Faur (2004). This framework distinguishes between *de jure* regulatory authority (the legal mandate to enforce standards) and *de facto* regulatory capacity (the resources, skills, and institutional reach necessary to do so). In many Sub-Saharan African contexts, the gap between *de jure* authority and *de facto* capacity is the primary driver of

measurement-related market failure, rather than the absence of legal frameworks per se. Together, these pillars yield a three-dimensional analytical model for this paper: (1) the nature and pathways of measurement failure (Akerlof); (2) the institutional conditions under which measurement enforcement can correct market failure (public goods theory); and (3) the capacity constraints that limit enforcement effectiveness in practice (regulatory capacity framework). This model is applied to the Tanzanian evidence in Sections 5 and 6.

4. Methodology

4.1 Research Design

A convergent parallel mixed-methods design (Creswell & Plano Clark, 2018) is employed, in which qualitative practitioner observations and quantitative enforcement data are collected independently and integrated at the interpretation stage. This design is appropriate where the phenomenon under investigation (measurement failure and its welfare consequences) produces both quantifiable outcomes, weight discrepancies, enforcement action rates, complaint volumes, and qualitative dimensions that quantitative data alone cannot capture, such as trader attitudes, dispute dynamics, and the exercise of inspector discretion.

4.2 Primary Data Sources

The primary data source for this paper is the systematic field observation and enforcement documentation accumulated by the lead author in fifteen years of deployment as a WMA inspector across multiple Tanzanian regions, including Dar es Salaam, Pwani, Mwanza, Geita, Shinyanga, and Kagera. This body of evidence includes: inspection records of weighing instruments across retail, fuel, and agricultural settings; field notes on buyer and seller behaviour during disputes; documentation of complaint investigations; and direct observation of buying centre operations during cotton and maize procurement seasons in the Lake Zone. In methodological terms, this practitioner evidence is treated as a form of participant observation data (Dewalt & Dewalt, 2011), distinguished by its longitudinal character and the inspector's institutional authority to document and act on measurement failures. It is supplemented by documentary analysis of WMA enforcement records, OIML technical recommendations (including R 76-1 on non-automatic weighing instruments, R 79 and R 87 on prepackaged goods, and R 117-1 on liquid measuring systems) and EAC SQMT Act (2006) instruments.

4.3 Analytical Approach

Qualitative data were analysed using thematic analysis (Braun & Clarke, 2006), with themes derived inductively from field observations and deductively from the conceptual framework. Quantitative data — where available in the form of inspection statistics, complaint counts, and weight discrepancy measurements — are reported descriptively. Where quantification is indicative rather than statistically precise (as in the farm-gate income exposure estimate in Section 5.2), this is explicitly flagged and the basis for the estimate explained.

4.4 Positionality and Reflexivity

The lead author's dual position as a WMA inspector and academic researcher requires explicit acknowledgement. This positionality confers significant advantages — unmediated access to field settings, institutional knowledge, and professional relationships that enable data collection not accessible to external researchers — but also introduces potential for confirmation bias and institutional loyalty effects. These risks are mitigated through transparent documentation of analytical procedures, explicit flagging of interpretive judgements, and grounding of claims in documented standards (OIML, WMA regulations) rather than solely in personal observation.

5. Findings and Analysis

Field evidence reveals four principal pathways through which measurement failure harms market participants in Tanzania. These are presented in turn, drawing on inspection observations, enforcement records, and commodity sector data.

5.1 Scale Drift and Deliberate Tampering in Retail Settings

The most pervasive form of measurement failure encountered in field inspections is inaccuracy in weighing instruments at the point of retail sale. WMA field practice distinguishes between two categories: passive inaccuracy, arising from calibration drift, environmental factors (uneven surfaces, battery depletion in electronic scales), and inadequate maintenance; and active manipulation, involving deliberate alteration of scale mechanics, obstruction of the tare function, or programming of false zero offsets in digital instruments. Passive inaccuracy is structurally embedded in the operating conditions of Tanzanian retail markets. Many market stalls are situated on uneven surfaces, and vendors routinely move portable scales between locations without re-verification. Electronic scales operating on depleted batteries exhibit systematic negative drift — that is, they progressively under-read — until the battery fails entirely. Field observations confirm that this form of "battery theft," as it is termed in practitioner usage, can impose losses of 50–150 grams per kilogram weighed on buyers who do not monitor the display carefully. The OIML maximum permissible error (MPE) for Class III instruments in service is ± 1 scale interval; battery-driven drift routinely exceeds this threshold without triggering any visible error indication. Active manipulation is less common but more difficult to detect and more damaging per transaction. Inspection techniques for identifying tampered instruments include: systematic comparison against reference weights carried by inspectors; examination of the lead seal for evidence of removal or substitution; visual inspection of the display under identical load conditions across multiple trials; and behavioural observation of the operator's handling of the instrument (including obstruction of the buyer's view of the display). The OIML R 76-1 framework defines the verification scale interval (e) and sets out the conditions under which an instrument fails verification; WMA inspection protocols operationalise these criteria in the field.

A critical gap identified in the evidence is the absence of a systematic national database of instrument failure rates by type, region, and commodity sector. Such a database would enable WMA to allocate surveillance resources on a risk-assessed basis — a practice adopted by well-resourced national metrology authorities in the EU (WELMEC, 2019) — rather than on the reactive basis that currently prevails.

5.2 Non-Standard Measures in Rural Agricultural Trade

In rural and peri-urban market settings — and particularly in agricultural commodity trade — a second and distinct pathway of measurement failure operates through the use of non-standard volumetric measures. Buckets (ndoo), tins (debe), sacks (gunia), and heap measures (mafungu) are widely used across Tanzania's smallholder trading system as proxies for standardised units. These measures are non-standard in two respects: their physical dimensions are not defined by any legal instrument, and their actual volume varies between individual containers of the same nominal type. Field observations at cotton and maize buying centres in the Lake Zone — particularly in Mwanza and Kagera Region, where the lead author conducted repeated inspection seasons — document the welfare consequences of this practice. At a typical cotton buying centre, the weighing sequence involves four distinct measurement operations, each carrying its own potential for error: (1) gross weighing of the farmer's cotton on a suspended or platform scale; (2) tare deduction for the sack; (3) moisture content assessment using a verified moisture meter; and (4) grading assessment by a buying centre officer. Drawing on observed measurement discrepancies across multiple buying centre seasons, it is possible to develop an indicative estimate of the cumulative farm-gate income exposure of smallholder cotton farmers to compounded measurement errors. If a suspended or platform scale exhibits a systematic negative error of 0.5 kg per 100 kg weighed (within OIML R 76-1 maximum permissible error limits but compounded across a season), a tare deduction is applied as a fixed standard (e.g., 1.0 kg per sack) rather than by actual weighing, and the moisture meter reads 1 percentage point high (causing a quality downgrade), the combined effect on a farmer selling 500 kg of seed cotton in a season may be a reduction in effective income of 3–8%, depending on prevailing prices. This estimate is indicative and would require formal validation through a controlled measurement audit at buying centres.

5.3 Electronic Manipulation and Underdispensing at Fuel Points

Fuel dispensing presents a third, technically distinct pathway of measurement failure with significant consumer welfare implications. Tanzania's petroleum sector is regulated jointly by the Energy and Water Utilities Regulatory Authority (EWURA) and WMA, with EWURA responsible for petroleum product quality and ATG (Automatic Tank Gauge) systems, and WMA responsible for the metrological verification of dispensing pump meters under OIML R 117-1 (Measuring Systems for Liquids other than Water). Field inspections at fuel stations across Dar es Salaam and coastal regions identify three recurrent manipulation techniques. The first is pre-priming: beginning dispensing before the display is zeroed, so that the buyer pays for fuel dispensed during

the zero-reset interval. The second is air injection into the delivery line, which inflates the volumetric reading without delivering equivalent fuel. Detection requires a clear-glass test on the dispenser nozzle. The third, and most technically sophisticated, is electronic manipulation of pump firmware to systematically dispense less than the metered volume — typically 90–95 ml per litre. This form of manipulation leaves no physical trace detectable without a reference measure (a verified test measure, typically a 20-litre verification vessel used by WMA inspectors). The regulatory gap in this sector relates to the incomplete integration of ATG data with WMA inspection schedules. ATG systems installed at large fuel depots (and increasingly at retail stations, under EWURA requirements) generate continuous dispensing volume data. If this data were systematically shared with WMA's surveillance section, anomalous dispensing patterns — consistent with electronic manipulation — could be flagged for targeted inspection. As of 2024, this data integration is not systematically operational.

5.4 Prepackaged Goods and Digital Measurement Discrepancies

A fourth pathway operates through prepackaged goods — products whose quantity is determined before the point of sale and declared on the label — and through digital transaction systems including mobile money and electronic price-per-unit displays. Both represent domains in which the measurement act is physically removed from the transaction point, making real-time verification by the buyer impossible. Tanzania's prepackaged goods regulatory framework applies WMA general regulation of 2019 and OIML R 79 and R 87 requirements. The tolerable negative error (TNE) concept in R 87 permits controlled shortfalls below the nominal quantity, provided they fall within defined limits and are not systematic. Field experience suggests that systematic underfilling is more prevalent in domestically produced goods (cooking oil, flour, sugar, rice) than in imported goods, partly because imported goods are more likely to have undergone conformity assessment in the country of origin. Digital measurement fraud presents an emerging challenge. Electronic scales with remote price-per-unit programming — increasingly common in Tanzanian urban retail — allow operators to alter the price per kilogram while maintaining the appearance of a verified weighing instrument. Similarly, mobile money transaction discrepancies — where the amount deducted from the buyer's account differs from the amount displayed at the point of sale — fall outside the current WMA mandate and are regulated, by the Tanzania Communications Regulatory Authority (TCRA).

6. Discussion

6.1 Implications for Consumer Protection Policy

The evidence presented in Section 5 establishes that measurement failure in Tanzanian markets is not an isolated or incidental phenomenon but a structural feature of market operation arising from the intersection of inadequate instrument maintenance, uneven enforcement capacity, non-standard practice in rural trade, and emerging digital vulnerabilities. The four pathways identified — retail scale inaccuracy, non-standard agricultural measures, fuel dispensing manipulation, and

digital/prepackaged discrepancies — affect different market segments and require tailored regulatory responses.

A unifying implication is that consumer protection through measurement governance requires more than the existence of a legal metrology authority with a mandate to verify instruments. It requires systematic surveillance based on risk assessment rather than reactive complaint response; extension of formal measurement standards into agricultural value chains where non-standard practice is most prevalent; cross-agency coordination in sectors (fuel, telecommunications, food) where measurement functions are shared across multiple regulators; and sustained market education programmes that equip buyers and sellers with the knowledge to identify and report measurement failures without reliance on formal inspection. Market education initiatives that translate metrological standards into plain language accessible to traders and buyers represent one approach to these imperatives. Systematic treatment of measurement concepts, scale operation, dispute resolution procedures, and sector-specific risks, communicated directly to market participants, constitutes a form of regulatory outreach that complements formal enforcement. The evidence from legal literacy programmes in other regulatory domains (Decker et al., 2008) suggests that informed market participants function as a form of distributed enforcement, reporting violations and asserting rights in ways that multiply WMA's effective reach beyond its inspector headcount.

6.2 Implications for Regional Harmonisation

Tanzania's participation in EAC, SADC, and PAQI frameworks creates both obligations and opportunities that the evidence in this paper helps to specify. The EAC SQMT Act requires mutual recognition of calibration and verification results across Partner States — but this is only meaningful if the underlying national metrology infrastructure is robust enough to produce results that partner states can rely upon. The evidence of systematic scale inaccuracy, unverified buying centre instruments, and electronic manipulation in the fuel sector suggests that Tanzania's de facto metrology infrastructure does not yet fully support the de jure commitments made at the regional level. The priority implication for regional policy is investment in national metrology infrastructure as a prerequisite for meaningful regional harmonisation, rather than harmonisation as a substitute for national capacity. In the OIML framework, this translates to ensuring that Tanzania's primary reference standards are traceable to SI units through an unbroken calibration chain, that WMA's working standards are maintained in conditions that support valid field verification, and that inspector training and competence assessment meet the requirements of OIML D 1 (Legal Metrology — General principles) and D 2 (Legal Units of Measurement). Progress on all three dimensions would strengthen Tanzania's position within SADC MEL Mutual Recognition Arrangements and reduce the transaction costs that measurement uncertainty currently imposes on intra-regional trade.

6.3 Limitations

Three principal limitations constrain the conclusions that can be drawn from this study. First, the quantitative evidence base is largely indicative rather than statistically derived. The income exposure estimate for smallholder cotton farmers in Section 5.2 is constructed from observed measurement errors rather than from a formally sampled measurement audit, and should be treated as a hypothesis-generating finding rather than a settled estimate. Second, the practitioner positionality of the lead author — while a source of unparalleled field access — introduces the risks of selection bias (towards sectors and settings that are known to WMA) and advocacy bias (towards findings that support expanded metrology enforcement). These risks are acknowledged and partially mitigated but cannot be fully eliminated. Third, the absence of a comparator group or counterfactual means that the causal attribution of welfare losses to measurement failure rather than other market imperfections cannot be formally established.

7. Conclusion

This paper has presented the first systematic, practitioner-anchored empirical account of measurement failure pathways and their welfare consequences in Tanzanian retail, agricultural, and fuel markets. Drawing on fifteen years of WMA field inspection evidence and grounded in the OIML regulatory framework, it has identified four principal pathways through which measurement inaccuracies harm consumers: scale drift and tampering in retail settings, non-standard measures in agricultural trade, electronic manipulation at fuel dispensing points, and digital discrepancies in prepackaged goods and mobile money systems. The paper's central finding — that smallholder farmers trading cotton and maize at buying centres in Tanzania's Lake Zone are among the most exposed groups, facing compounded measurement errors that may reduce effective farm-gate income by 3–8% per transaction cycle — deserves priority attention from WMA, the Tanzania Cotton Board, the Ministry of Agriculture, and development partners engaged in agricultural value chain improvement. Three contributions to the legal metrology literature are claimed. First, the identification and systematic description of four distinct measurement failure pathways in a major East African economy fills a significant empirical gap in the regional literature. Second, the analytical integration of Akerlof's information asymmetry framework, public goods theory, and regulatory capacity analysis into a coherent conceptual model for legal metrology research offers a foundation for comparative studies across Sub-Saharan Africa. Third, the specific institutional and policy recommendations — risk-based inspection targeting, ATG-WMA data integration, a multi-agency digital measurement governance review, and investment in national metrology infrastructure as a prerequisite for regional MRAs — are grounded in field evidence and actionable within existing institutional mandates. Future research should pursue three priorities: a formally sampled measurement audit at Lake Zone buying centres to validate the farm-gate income exposure estimate; a longitudinal instrument surveillance study to generate a national database of scale failure rates by sector and region; and a comparative study of legal metrology enforcement

outcomes across EAC Partner States to assess the effectiveness of regional harmonisation arrangements under the SQMT Act.

A fair market — one in which every transaction reflects what was declared — is not an aspirational abstraction. It is a regulatory and institutional achievement, one that requires sustained investment, rigorous measurement governance, and the integration of practitioner knowledge into the academic and policy record.

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