

Measuring Institutional Intensity in Smallholder Potato Farmers' Marketing Arrangements: A Principal Component Approach

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Abstract

Studies of smallholder market participation typically measure institutional arrangements using binary channel-participation indicators or equal-weight additive indices. Both discard information: binary indicators lose discriminating power once a channel is used almost universally, and additive indices impose an arbitrary equal-weight structure that is empirically unjustified. This paper develops a principal component approach to measuring institutional intensity: the latent, multi-dimensional way farmers engage with, assess, and transact through alternative marketing channels. Using survey data from 577 smallholder potato farmers in Elgeyo Marakwet County, Kenya, we subjected sixteen channel-specific indicators (benefits, challenges, opportunities, governance, and transaction volume, across spot-market, broker, cooperative, and contract channels) to principal component analysis. The data were suitable for dimension reduction ($KMO = 0.74$; Bartlett's test $p < 0.001$). Five orthogonal components emerged. Two broker-dominated components were separated from this structure and were excluded, reflecting the pervasive, distinctive role of broker intermediation in this value chain. We discuss construct validity and transferability to other value chains. The contribution is methodological: a replicable framework for measuring market governance in smallholder settings.

Keywords: Institutional intensity, Market governance, Principal component analysis, Smallholder agriculture, Potato value chain.

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INTRODUCTION

How smallholder farmers are linked to markets is among the most consequential questions in agricultural development, because the institutional form of a transaction, that is who the buyer is, how the exchange is governed, how prices are set, and how disputes are resolved, shapes the prices farmers receive, the risks they bear, and the investments they are willing to make (Spithoven, 2019; Sgroi & Sciancalepore, 2022). Across a wide range of developing-country settings, the marketing channel a farmer relies on is now well established as a central determinant of market participation, trade intensity, and the price and welfare outcomes households experience (Nyarindo & Mugeru, 2025; Musafiri et al., 2026; Villacis et al., 2024; Naik & Mohan, 2023; Amfo et al., 2022; Bekata et al., 2023). Compliance with, and the durability of, such arrangements is itself shaped by the interests and relative power of the actors involved (Owusu et al., 2026).

This is nowhere more evident than in East Africa's potato sub-sector, where marketing arrangements vary sharply in structure and outcome even within the same production area. In Kenya, Irish potato commercialisation and market participation are shaped by the specific mix of spot, broker, cooperative and contract channels available to a farmer (Wakaba et al., 2022). In neighbouring Uganda, potato market access and marketing efficiency differ substantially depending on which arrangement predominates (Kyumugisha et al., 2021). In Elgeyo Marakwet County, smallholder farmers already display considerable heterogeneity in cropping and marketing behaviour even within a single ward (Kemboi et al., 2020), underscoring that institutional arrangements, not production conditions alone, are a first-order source of variation in farmer outcomes.

Yet the way this institutional dimension is measured in applied work has lagged behind its conceptual and empirical importance. Studies typically record whether a farmer uses a given channel as a binary indicator, or combine several such indicators into an equal-weight additive index. Both approaches are limited. A binary indicator collapses what is, in practice, a graded pattern of engagement into a single yes/no distinction, and where a channel is used by nearly everyone, it carries almost no power to discriminate among farmers, a problem documented across cooperative, contract, and mixed-channel settings from Ghana to Benin to Tanzania (Bokumbo et al., 2023; Ibikoule et al., 2024; Gramzow et al., 2018). An additive index avoids the first problem but introduces another: it assumes, without empirical justification, that every indicator contributes equally to the underlying construct and that the indicators are independent of one another. Existing comparative work on cooperative versus contract arrangements (Gramzow et al., 2018) and on governance arrangements within agricultural supply chains more broadly (Kusnandar et al., 2024; Delaquis et al., 2024; Pali et al., 2023; Angela & Birkenberg, 2024) illustrates the range of institutional structures such a measure must accommodate, but none of these studies addresses the measurement problem itself.

This paper asks how institutional intensity, the latent, graded dimension of engagement with alternative marketing channels, can be measured in a way that preserves gradation, lets the data determine how indicators combine, and yields dimensions that are interpretable in governance terms.

We answer this by applying principal component analysis (PCA) (Ji & Ji, 2021; Li et al., 2020) to sixteen channel-specific indicators, including benefits, challenges, opportunities and governance perceptions, together with transaction volumes, covering spot-market, broker, cooperative and contract engagement among 577 smallholder potato farmers in Elgeyo Marakwet County, Kenya. The object this procedure yields, a set of continuous, orthogonal

component scores, is what we term the *institutional-intensity* representation of a farmer's marketing behaviour. We set out, justify, and validate a replicable measurement procedure, and we find that the resulting components separate direct-market, cooperative, and coordinated-channel engagement cleanly from a structurally distinct broker dimension.

Institutional Intensity as a Latent Measurement Target

The conceptual starting point is the new institutional economics view that markets are not frictionless and that exchange is organised through institutional arrangements that economise on transaction costs (Spithoven, 2019). Applied work on agricultural governance structures shows that these arrangements range from arm's-length spot exchange through intermediary-brokered trade to more coordinated cooperative and contractual forms, each carrying a distinct cost and risk profile for the farmer (Sgroi & Sciancalepore, 2022; Escobal & Caverro, 2012; Mbapila et al., 2019). Hybrid forms that combine features of market and hierarchy, such as cooperative marketing arrangements with embedded contractual elements are increasingly recognised as governance structures in their own right rather than as an intermediate stage between purely spot and purely contractual exchange (Lin et al., 2023; Ghosh & Wolf, 2021), and comparative evidence from vegetable and cooperative value chains confirms that cooperative and contract arrangements are empirically distinguishable channels rather than close substitutes (Gramzow et al., 2018; Abate, 2018).

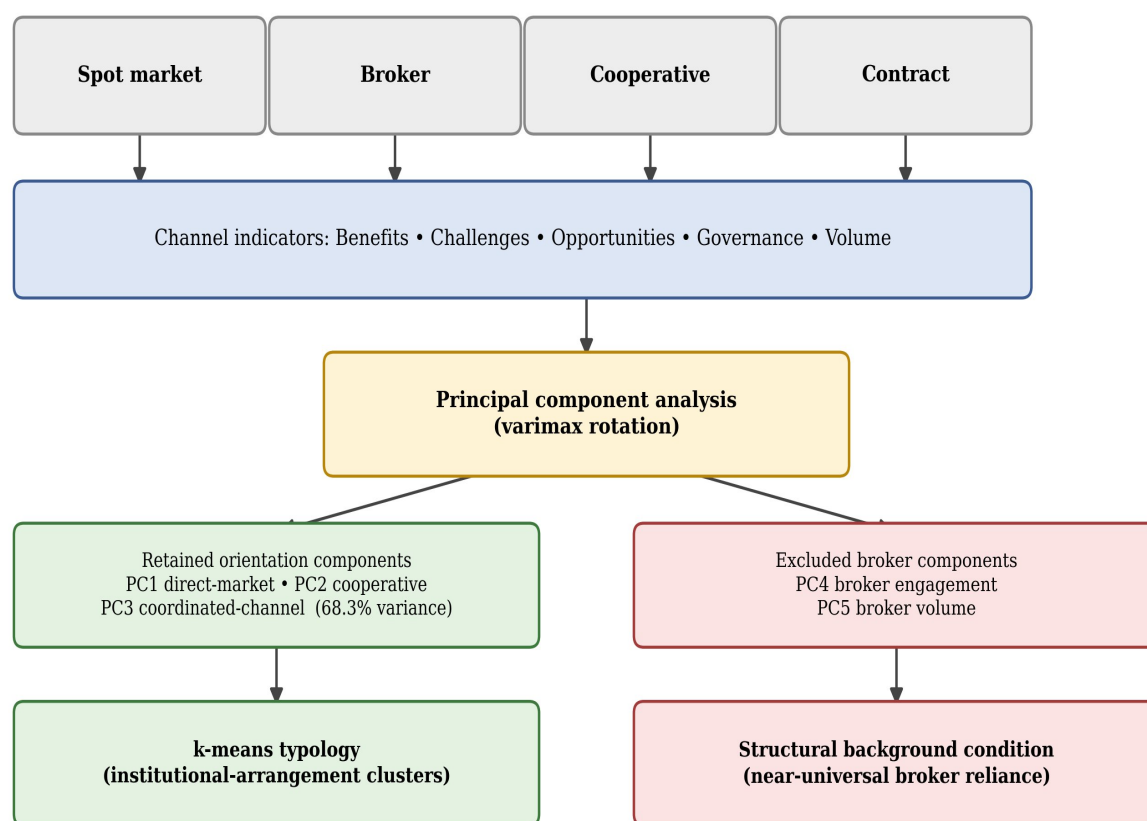
Arrangements differ in their governance structure: in the degree to which exchange is personalised or anonymous, relational or arm's-length, formally contracted or informally enforced. These properties are not separate channels so much as dimensions along which engagement with any channel can be positioned. A farmer's orientation towards spot markets, brokers, cooperatives and contracts is expressed not only in whether each is used but in how its benefits, challenges, opportunities and governance are assessed and in how much produce flows through it (Escobal & Caverro, 2012). Brokers in particular occupy a distinctive position in many smallholder value chains: rather than a residual or inferior channel, broker intermediation is often a durable, trust-based arrangement that persists alongside more formal channels (Kato Isaka et al., 2026), which is consistent with the structurally distinct broker components recovered later in this paper.

If market orientation is multi-dimensional in this way, then no single observed variable measures it. What the analyst observes are manifestations like perceived benefits and challenges, judgments about governance, and transaction volumes for each channel. Each manifestation reflects one or more underlying orientation dimensions with error. This is the classic structure of a latent-variable measurement problem, and it motivates a dimension-reduction model in which a manageable number of components stand in for the unobserved dimensions (Ji & Ji, 2021).

Framing the problem this way clarifies what a good measure must do. It must, first, preserve gradation rather than dichotomise, so that the intensity of engagement is retained; second, let the data, rather than the analyst, determine how indicators combine, so that weighting is not arbitrary; third, yield dimensions that are interpretable in governance terms, so that the measure connects to theory; and fourth, produce farmer-level scores that can serve as inputs to subsequent typological and causal analysis. PCA satisfies these requirements, and the remainder of the study shows how.

Conceptual Framework

Figure 1 shows the measurement framework that follows from this discussion. Farmers' engagement with each of the four marketing channels (spot market, broker, cooperative, and contract) is captured through a common set of indicators (benefits, challenges, opportunities, governance, and transaction volume). These sixteen indicators are subjected to principal component analysis. This framework is deliberately generalizable; it is not specific to potatoes, and Section 5 discusses its transferability to other smallholder commodity value chains.



Institutional-intensity measurement framework

Figure 1: Conceptual framework for measuring institutional intensity in smallholder marketing arrangements (self-conceptualisation).

MATERIALS AND METHODS

Study Area and Data

The data come from a cross-sectional survey of smallholder potato farmers in Elgeyo Marakwet County, Kenya, conducted in 2024. Elgeyo Marakwet is an established setting for smallholder crop-marketing research, with documented heterogeneity in cropping and market behaviour among farmers even within a single ward of the county (Kemboi et al., 2020). A multi-stage sampling design was used, with the sample drawn across four wards in Keiyo South and Marakwet West sub-counties; the analytical sample for the present analysis comprises 577

farmers (of 606 surveyed) with complete responses on the marketing-arrangement module. Because the focus of this study is on measurement rather than population inference.

Indicators

The indicators were drawn from the survey's marketing-arrangement module. For each of the four principal channels, the module captured the farmer's assessment of the channel's benefits, challenges and opportunities and, for cooperatives, its governance, together with the volume of produce transacted through it. Sixteen such indicators entered the analysis, listed in the rows of Table 2. Treating each channel's perception and volume items as separate indicators, rather than reducing each channel to a single 'use' dummy, is what allows the analysis to recover gradations of orientation rather than mere incidence of use.

Estimation Procedure

The sixteen indicators were subjected to principal component analysis with varimax rotation. Sampling adequacy was assessed using the Kaiser–Meyer–Olkin (KMO) measure, and factorability was confirmed using Bartlett's test of sphericity. Components were retained using the eigenvalue-greater-than-one criterion, corroborated by inspection of the scree plot and by cross-loading diagnostics recommended for determining how many factors to retain (Li et al., 2020). The retained components were rotated (varimax) to improve interpretability, and the rotated loadings were used to assign substantive labels to each component. Farmer-level component scores were computed and retained as inputs to a downstream k-means typology (Bardhoshi et al., 2020); the two broker-dominated components were set aside at the clustering stage for the reason given in Section 4.3. All computations were performed in Stata 18 (StataCorp, 2023), the version licensed to the authors' institution at the time of analysis; Stata 18 was retained for consistency with the companion typology paper (Mworia et al., under review), which uses the same dataset and the same PCA and cluster-analysis routines, and its implementation of the relevant 'pca', 'rotate', and 'cluster kmeans' commands is unchanged in substance from earlier Stata releases used in comparable studies, so the choice of version does not affect the reported results.

RESULTS

Sampling Adequacy and Factorability

The data were suitable for dimension reduction. The KMO measure of sampling adequacy was 0.74, comfortably above the conventional minimum of 0.50 and within the range usually described as 'middling-to-good', indicating that the partial correlations among indicators were small relative to the zero-order correlations. Bartlett's test of sphericity was significant ($p < 0.001$), confirming that the correlation matrix departed sufficiently from an identity matrix for extraction to be meaningful.

Component Retention

Applying the eigenvalue-greater-than-one criterion, five components were retained, corroborated by the scree plot. Of these, three — direct-market orientation (PC1), cooperative engagement (PC2), and coordinated-channel orientation (PC3) — were carried forward as inputs to the downstream k-means clustering and together explained 68.3% of the total variance in the sixteen indicators. The remaining two components (PC4, PC5) were structurally distinct broker-dominated dimensions and were excluded from the clustering for the reasons set out in

Section 4.3. Table 1 summarises the retained components, the excluded components, and the associated diagnostics.

Table 1: Component retention and diagnostic summary (author-generated, 2026)

Diagnostic	Value	Note
Components retained for clustering	3 (PC1–PC3)	Orientation dimensions carried into the k-means typology
Cumulative variance (three retained components)	68.3%	Acceptable for exploratory PCA
Components isolated but excluded from clustering	2 (PC4, PC5)	Broker-dominated dimensions; see Section 4.3
KMO measure of sampling adequacy	0.74	Above the conventional minimum of 0.50
Bartlett's test of sphericity	$p < 0.001$	Correlation matrix departs from the identity matrix
Silhouette coefficient (k-means, $k = 5$)	0.42	Reasonable cluster separation using PC1–PC3 scores

The Rotated Component Solution

Table 2 reports the rotated component loadings (loadings below $|0.20|$ suppressed; loadings $\geq |0.30|$ treated as substantive). The five components admit a clear interpretation in terms of channel orientation.

Table 2: Rotated component loadings, institutional-intensity index, $n = 577$ (author-generated, 2026)

Indicator	PC1	PC2	PC3	PC4	PC5
Spot-market benefits	0.31	0.28	−0.27	0.21	
Spot-market challenges	0.30	0.28	−0.26	0.23	
Spot-market opportunities	0.30	0.28	−0.26	0.24	
Broker benefits	−0.30			0.49	
Broker challenges	−0.28			0.49	
Broker opportunities	−0.27			0.50	
Cooperative benefits		0.42	0.30		
Cooperative challenges		0.40	0.30		
Cooperative governance		0.40	0.30		
Contract benefits	0.33		0.35		

Indicator	PC1	PC2	PC3	PC4	PC5
Contract challenges	0.33		0.35		
Contract opportunities	0.33		0.35		
Spot-market volume	0.20	0.21			
Broker volume					0.98
Cooperative volume		0.36	0.24		
Contract volume	0.25		0.27		

The first component (PC1) loads positively on the spot-market and contract perception items and on spot-market and contract volumes, and negatively on the broker items. It contrasts engagement with direct and formal channels against reliance on broker intermediation, and is labelled *direct-market orientation*. The second (PC2) loads most heavily on the cooperative items and cooperative volume, with secondary positive loadings on the spot-market items, and is labelled *cooperative engagement*. The third (PC3) loads positively on the contract and cooperative items and their volumes and negatively on the spot-market items, distinguishing coordinated, formally governed channels from arm's-length spot trade; it is labelled *coordinated-channel orientation*. The fourth (PC4) loads almost exclusively on the broker items (0.49–0.50), with small positive loadings on the spot-market items, and is labelled *broker engagement*. The fifth (PC5) is defined by a single, very high loading on broker volume (0.98) and essentially nothing else; it isolates the quantity of produce moved through brokers as a dimension in its own right, and is labelled *broker volume*.

The most consequential structural feature of this solution is that the two broker-dominated components, PC4 and PC5, separate cleanly from the spot–cooperative–contract structure that organises PC1 to PC3. Whereas spot-market, cooperative and contract engagement interweave across the first three components, broker engagement and broker volume stand apart as their own orthogonal dimensions. This is consistent with the pervasive and structurally distinctive role of broker intermediation in this value chain: because broker use is near-universal among sampled farmers, the broker dimensions co-vary little with the gradations that differentiate farmers across the other channels, and consequently carry limited power to distinguish farmer types along the spot–cooperative–contract continuum.

For this reason, PC4 and PC5 were excluded from the downstream k-means clustering, which was built on the three orientation components (PC1–PC3) that together capture the substitutable, gradated dimensions of direct, cooperative, and coordinated-channel engagement. The typology is therefore organised around direct-market, cooperative, and coordinated-channel orientations rather than around broker use as such, which is better understood as a near-universal background condition than as a source of differentiation among farmers, consistent with evidence that broker-mediated trade often persists as a durable, trust-based arrangement alongside more formal channels rather than functioning as a differentiating choice variable (Kato Isaka et al., 2026).

Construct Validation

Two pieces of evidence support the validity of the component scores. First, the solution is interpretable: every retained component maps onto a recognisable channel-orientation dimension, and indicators load where theory would predict (spot, cooperative and contract items grouping coherently; broker items isolating), which is the principal qualitative test of a

PCA measurement model. Second, the scores discriminate. When the three retained orientation components were carried forward as inputs to a k-means cluster analysis (500 random starts), they produced a five-group typology with a silhouette coefficient of 0.42, indicating reasonable separation, and the resulting groups differed systematically in their orientation profiles. That the institutional-intensity scores yield a coherent, well-separated typology is external evidence that they capture real structure in the data rather than noise.

A KMO of 0.74 indicates good but not exceptional common variance, consistent with indicators that span genuinely distinct channel domains.

DISCUSSION

The results bear on three issues. The first is the measurement of market participation more generally. The near-universal use of broker channels in this setting is a concrete illustration of why incidence and intensity must be distinguished: a measure that records only whether a channel is used will, wherever use is common, mistake a near-constant for a variable. The institutional-intensity representation restores the relevant variation by measuring how farmers assess and how much they transact through each channel, and it shows that the broker dimension is best treated as structurally distinct rather than as one option among equivalents. This distinction matters practically: studies of marketing outlets and channel choice in other commodity and country settings have repeatedly found that channel-specific welfare and price outcomes diverge sharply even where overall market participation rates look similar (Amfo et al., 2022; Naik & Mohan, 2023; Saini & Ubba, 2025), which is precisely the kind of variation a binary or additive measure would obscure.

The second issue is the relationship between measurement and downstream inference. Typological and analyses inherit the properties of the measures they are built on. Because the three retained components here are theoretically interpretable and empirically discriminating, a typology built on them (as demonstrated in Section 4.4) rests on firmer ground than one built on binary channel-use dummies. The clean separation of the broker components from the orientation structure is itself informative for applied researchers: it suggests that in value chains where one intermediary channel is near-universal, analysts should expect and explicitly test for this kind of structural isolation, rather than assume that all channel indicators will load onto a single common factor.

The third issue is transferability. The four-channel, benefits–challenges–opportunities–governance–volume structure used here is not specific to potatoes; it reflects a generic way of characterising farmer engagement with any set of competing marketing channels, and could be applied with minimal adaptation to other smallholder commodity value chains in which spot, intermediary, cooperative and contract arrangements co-exist, including the governance-arrangement settings documented for cassava seed systems (Delaquis et al., 2024), coordinated crop intensification (Pali et al., 2023), and supply-chain adaptation practices (Kusnandar et al., 2024). Digitalisation is also changing how value is created and captured along such chains (Klingenberg et al., 2022), which may, in time, add further channel-specific indicators to the framework. Researchers adapting the approach elsewhere should expect the precise number and composition of components to vary with the local channel structure, but the underlying logic preserving gradation, letting the data determine weighting, and testing for structurally distinct dimensions such as the broker components found here should hold generally.

The channel-specific structure recovered here also resonates with findings elsewhere in the smallholder marketing literature. Cooperative engagement (PC2) is consistent with evidence that farmers join and remain in cooperative arrangements for reasons that go beyond price — including social and institutional considerations captured only weakly by transaction volume alone (Iyioku et al., 2024; Abate, 2018; Bokoumbo et al., 2023), and with member-level evidence that cooperative resilience and profitability shape continued engagement (Michels & Schmidt, 2026; Mauki et al., 2023). Similarly, the coordinated-channel orientation (PC3), which groups contract and cooperative engagement against arm's-length spot trade, mirrors evidence that participation in contract farming arrangements is shaped by farmer-level capacities distinct from simple market access (Dogeje et al., 2024), and that cooperative and contract arrangements remain empirically distinguishable channels even where both offer more coordinated governance than spot trade (Gramzow et al., 2018; Ibikoule et al., 2024). The isolation of the broker components (PC4, PC5) is consistent with work showing that access to timely market information, often mediated through informal intermediaries can itself substitute for, rather than complement, more formal channel engagement (Zant, 2023), and with evidence from other potato value chains in Kenya that digital and informal marketing channels operate on a partly separate track from formal cooperative and contract arrangements (Maina et al., 2023).

The approach also has limitations. PCA is a linear, variance-maximising technique and does not itself test a pre-specified theoretical measurement model in the way that confirmatory factor analysis does; the labels attached to components are interpretive rather than confirmed by a fitted structural model. The cross-sectional nature of the data means that the component structure describes the sample at one point in time and cannot speak to how institutional intensity evolves as farmers' market engagement changes. Finally, a KMO of 0.74, while acceptable, indicates that a meaningful share of variance in the sixteen indicators is not captured by the retained components, and future applications with a larger indicator set might recover additional, finer-grained dimensions.

CONCLUSION

Measuring how smallholders are linked to markets is a prior question to explaining or evaluating those linkages, and it has been underserved by the binary and additive measures in common use. This paper has set out a principal component approach that treats market orientation as a latent, multi-dimensional construct and recovers it as a set of interpretable, continuous institutional-intensity scores. Applied to 577 potato farmers in Kenya, the procedure yielded five orientation dimensions, showed that broker engagement and broker volume form structurally distinct components, and produced scores via the three retained orientation components that supported a coherent downstream typology (Mworia et al., under review). The framework is replicable, theory-disciplined, and transferable to other commodity value chains, and it offers a more faithful measurement foundation for the analysis of smallholder market participation. For policy and practice, the clean separation of broker engagement from the other orientation dimensions suggests that interventions aimed at strengthening cooperative or contract channels should not be expected, by themselves, to reduce reliance on brokers, since broker use appears to function as a largely independent, near-universal feature of this value chain rather than a substitutable choice.

Future Research

Three extensions follow directly from this paper. First, the cross-sectional component structure reported here should be re-estimated with panel data to test whether institutional intensity, and in particular the separation of the broker dimension, is stable over time or responsive to shocks such as price volatility or policy change. Second, the framework should be applied to other smallholder commodity value chains, particularly those, like cassava seed systems (Delaquis et al., 2024) and irrigated crop systems (Pali et al., 2023), where spot, intermediary, cooperative and contract arrangements co-exist, to establish how generally the observed component structure, and specifically the isolation of intermediary channels, replicates outside the potato sector.

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Data availability: The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request, subject to participant confidentiality and Egerton University data governance protocols.

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