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How reliable are national accounts estimates of agricultural output?

Sam Jones* and Marcelo Mucocana*

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Abstract: Measurement errors in macroeconomic aggregates such as GDP have been widely lamented, particularly in low-income contexts. This study investigates the reliability of one component of national accounts, agricultural sector output. Focusing first on the case of Mozambique, we use a series of 12 harmonized national agricultural micro-surveys to construct estimates of gross annual output in the sector. Compared to corresponding national accounts values for the period 2002–20, the micro-survey estimates are about 50% lower. A decomposition exercise indicates this gap is primarily driven by differences in base year levels, offset by higher rates of inflation observed in survey-based producer prices. Triangulating these estimates using household budget surveys, market price, and FAO production data, we find consistent support for the agricultural micro-survey estimates, suggesting real rates of total GDP growth may have been overestimated by 1 percentage point over the period. A cross-country comparison of national accounts and FAO production data indicates positive differences between estimates of agricultural output from the two sources are not unique to Mozambique, but with larger discrepancies among lower-income countries. Systematic investment in reliable and timely agricultural statistics is essential to track progress in the sector.

Key words: measurement error, GDP, national accounts, agriculture, micro-surveys, Mozambique, data reliability

JEL classification: C82, E01, O13, Q10

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* UNU-WIDER, Maputo, Mozambique; corresponding author: jones@wider.unu.edu

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Information and requests: publications@wider.unu.edu

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Katajanokanlaituri 6 B, 00160 Helsinki, Finland

1 Introduction

In many low-income countries, the agricultural sector is of fundamental importance, representing the main source of income for a large share of the population. Given the structure of the sector in these contexts, often dominated by smallholders who may not be fully engaged with the market, accurate measurement of total agricultural output and incomes is a major challenge (Carletto et al. 2015; FAO 2018; Kelly et al. 1995). As such, scope for mis-measurement of the contribution of the agricultural sector to economy-wide value-added is a material challenge (Angrist et al. 2021; Heston 1994). Nonetheless, despite scholarly attention to discrepancies between estimates of macroeconomic aggregates and micro-survey counterparts on the income and expenditure sides of GDP, such as consumption (e.g. Prydz et al. 2022), potential errors in sector-specific measures of aggregate production in the national accounts have not received similar attention.

The present study addresses this gap and interrogates national accounts estimates of agricultural output using a variety of survey-based and external data sources. Given the detailed data work this entails, we primarily focus on the specific case of Mozambique, which has a number of characteristics in common with other low-income countries, especially in the Sub-Saharan African region. Around three-fifths of Mozambique's population currently resides in rural areas, among which the vast majority identify agriculture as their primary economic activity. In urban areas, nearly 30% of the economically active urban population also depend on agriculture (INE 2022b), implying more than 60% of the total population are reliant on this sector today. Furthermore, estimates of consumption poverty are highest among rural households (Jones and Tarp 2016), reinforcing the critical importance of monitoring trends in agricultural performance.

Mozambique also serves as a valuable case since existing economy-wide evidence on the agricultural sector is mixed. On the one hand, data from the system of national accounts (SNA) indicate that real value-added in agriculture has grown steadily over the past 30 years, averaging almost 5% per annum since 2000. These figures imply that the total real value of agricultural production has grown around threefold since the millennium. Administrative data from the Ministry of Agriculture also paints a broadly positive picture, indicating high rates of growth in yields for certain major crops. For instance, yields for cassava are estimated to have grown from 6 to 16 tonnes per hectare over the period 2005–20 (see also below).

On the other hand, experts have consistently raised concerns regarding developments in the family agricultural sector (Benfica et al. 2019; Carrilho and Ribeiro 2020; Carrilho et al. 2021), which accounts for the vast bulk of total production. Evidence collated from surveys of agricultural smallholders suggests average yields for staple crops have remained stubbornly low (e.g. Araneda-Cabrera et al. 2021; Mabiso et al. 2014), even relative to other low-income African countries where performance has been weak (Wollburg et al. 2024). Also, rates of child malnutrition and (rural) food insecurity are high and there is little evidence of structural transformation within the sector (Cunguara et al. 2012; Leonardo et al. 2015). For instance, use of modern inputs such as improved seeds or fertilizer remain extremely low. Estimates compiled by IGM (2024) indicate that in 2020 over 80% of smallholders used no such inputs whatsoever, a rate approximately unchanged since 2002. Added to this, climatic shocks are increasing in frequency and severity, placing many households in situations of extreme vulnerability. These challenges are corroborated by household consumption surveys, which suggest that monetary poverty rates have increased significantly since the mid-2010s, reaching around two-thirds of the population in recent years (Salvucci and Tarp 2024).

To investigate the apparent discrepancy in this evidence concerning performance in Mozambique's agricultural sector, we begin by building a survey-based counterpart to the SNA series. Drawing on a harmonized set of 12 smallholder micro-surveys collected over the period 2002–20, we estimate total agricultural production values (gross output values) in current and constant prices, which we also adjust for potential under-reporting. Comparing these values to estimates of output (in basic prices) from the corresponding SNA series, we decompose the nominal gap into differences due to price indexes, quantity indexes, and residual levels. Our main result is that income levels (in base year prices) taken from the national accounts are almost double those found in micro-survey data; and the implicit producer price index in the SNA is considerably more conservative (shows lower inflation) than an elementary price index estimated from the micro-survey data. As such, both levels and growth trends in the national accounts substantially exceed those from the survey data.

To clarify this contrasting evidence, we pursue a triangulation approach. With respect to prices, we build an elementary price index from data on agricultural market prices and estimate the spread between consumer and producer prices for a range of staples. Applied to estimates of total (real) agricultural production derived from both FAO statistics and administrative production reports, these alternative nominal and real series track the aggregates from the microdata more closely than the national accounts. Separate estimates of agricultural production, calculated from household survey food consumption and balance of payments data, are even less optimistic as regards trends in domestic agricultural production. In short, four separate estimates suggest production levels and growth trends for the sector are likely to be lower than those in the national accounts. Pulling this together, we derive a simple ensemble estimate of (real) agricultural production, which places the real value of current production about 40% lower than that found in the national GDP aggregate.

This study speaks to three main strands of literature. The first are critiques of the quality and coverage of official statistics in low-income contexts (Devarajan 2013; Jerven 2010, 2014). Here, particular emphasis has been given to the agricultural sector, where data collection is notoriously difficult due to the wide variety of activities encompassed as well as the prevalence of (non-market) own-account production (Carletto et al. 2015; FAO 2018). In Mozambique, despite positive external assessments of agricultural statistical capacity, this study highlights significant blind spots, including incomplete coverage of agricultural micro-surveys, out-dated (activity- or area-based) sampling frames, and highly incomplete data on farm-gate prices. Consequently, significant uncertainty regarding total agricultural production values is to be expected, reinforcing the need for triangulation approaches as developed here (Kelly et al. 1995).

The second strand is literature seeking to validate national accounts aggregates using alternative sources, including micro-survey data. As noted, a predominant focus has been on comparing estimates of total private consumption from national accounts and household surveys. In a recent exercise spanning over 2,000 different surveys from multiple countries, Prydz et al. (2022) find average per capita consumption is around 22% lower in surveys compared to national accounts, with material implications for estimates of aggregate growth rates (also Ravallion 2003; Robilliard and Robinson 2003). Related analyses using nighttime lights from satellites also point to significant mis-measurement of economic growth in various low- and middle-income countries (Henderson et al. 2012).

Despite these findings, this literature has given little attention to the agricultural sector. Perhaps the closest attempts are those that validate FAO aggregate estimates against micro-surveys. For example, Desiere et al. (2018) compare FAO and household survey estimates of meat and fish consumption in multiple Sub-Saharan African countries (see also Kulshreshtha and Kar 2002); and Gollin et al. (2014) compare crop yields derived for different sets of countries and periods. Both studies confirm strong consistency across the sources,[1] but in part this likely reflects the fact that the FAO uses the same underlying survey data to build its estimates. In short, while accurate representation of agriculture in the national accounts is a recognized challenge (Heston 1994), systematic calibration and triangulation

[1] Gollin et al. (2014: 168) remark: ‘we find essentially no disagreement between the FAO yield data and these micro estimates of grain yields’.

of estimates of agricultural production found in the national accounts is rare. Thus, a main contribution of this study is to extend this strand of literature to the agricultural sector. Echoing other studies that question the accuracy of real GDP estimates in different contexts (for the Indian case, see Subramanian 2019), we find that if survey-based measures of agricultural production are used in place of national accounts estimates, the level of nominal GDP would have been about 10% lower over the period 2002–20 and the median real annual GDP growth rate (for the entire economy) would fall by over 1 percentage point, from 6.8% to 5.6%.

A third and closely related literature concerns studies that question official statistics from a political economy perspective. For instance, Sandefur and Glassman (2015) note that the shift to per-pupil education transfers weakened the incentives of public schools to accurately report pupil numbers, leading to optimistic data on performance (enrolment rates) in the sector. With respect to agriculture, Desiere et al. (2016) point to large gaps between survey-based and official estimates of yields for major crops in Rwanda. As also discussed by Jerven (2014), a plausible driver of these discrepancies is political pressure to demonstrate the success of reforms to both domestic and external stakeholders. This paper supports the need for further investments in the collection of independent, timely, and low-cost (sustainable) agricultural statistics. A greater role for satellite-based monitoring approaches would seem to be relevant here (e.g. Angrist et al. 2021; Burke and Lobell 2017), but also robust farm-gate price data is critical for valuation purposes.

2 Framework

Before diving into the Mozambican case, it is helpful to reflect on exactly *what* goes into generic measures of agricultural production. In simple terms, the nominal value of total production (V) is just the product of the quantity produced (Q) and the producer price (p), covering the universe of producers and products, which for present purposes refer to food crops only.[2] Indexing producers by i and crops by j, we have:

$$V_t = \sum_{i \in \mathscr{I}} \sum_{j \in \mathscr{J}} q_{ijt} p_{ijt} \tag{1a}$$

$$\approx \sum_{j \in \mathscr{J}} Q_{jt} \bar{p}_{jt} \tag{1b}$$

where t indexes time and we employ the convention that capital letters denote aggregates. Thus, in the second line, where $Q_{jt} = \sum_{i \in \mathscr{I}} q_{ijt}$, we assume that producers are price-takers and that total production values can be approximated by aggregating the total production quantity of each crop multiplied by its average farm-gate price.

[2] This includes food-related tree crops, such as fruits and nuts. For details on sectoral classifications in the UN SNA, see: https://unstats.un.org/unsd/classifications/Econ/Detail/EN/27/01. In this analysis, our focus is on subsectors A.011 and A.012, namely growing of non-perennial and perennial crops.

Another way to state the same definition is in terms of the relation between crop area (where A_t is the total area harvested in hectares covering all crops and producers) and yields:

$$V_t = A_t \sum_{i \in \mathscr{I}} \underbrace{\frac{A_{it}}{A_t}}_{\text{Producer weight}} \sum_{j \in \mathscr{J}} \underbrace{p_{ijt} \frac{a_{ijt}}{A_{it}}}_{\text{Crop weight}} \frac{\overbrace{q_{ijt}}^{\text{Yield}}}{a_{ijt}} \tag{2a}$$

$$\approx A_t \underbrace{\sum_{j \in \mathscr{J}} \bar{p}_{jt} \frac{A_{jt}}{A_t} \frac{Q_{jt}}{A_{jt}}}_{\text{Gross yield per ha.}} \tag{2b}$$

This expression illuminates some of the statistical information typically used to derive aggregate estimates of the total value of agricultural production. Moving from left to right in Equation (2a), four main ingredients are: (1) the total area farmed, also equal to the number of producers multiplied by the mean farm size; (2) the relative importance of each individual producer in total farmland; (3) the relative importance of each crop in a given farmers' portfolio, given by the product of the basic price and allocated land share; and (4) crop-specific yields. In turn, the approximation in Equation (2b) simply applies an estimate of the gross yield per unit of land (hectare) (see also Desiere et al. 2016).

If nothing else, these expressions hint at some of the challenges involved in accurate estimation of agricultural production aggregates. Micro-based estimates of crop yields and land allocations must be expanded upward to the population level, based on information on the overall scope of agricultural activity across space. In contexts dominated by smallholder production, this is a formidable task—detailed administrative data on land usage and production is generally absent, inter-cropping is prevalent, subjective assessments of land size and production may be systematically distorted, and crop loss may also be significant. Furthermore, reliable data on prices received by producers are often unavailable, especially for crops that are substantially produced for own consumption and thus for which competitive market conditions may not prevail.[3]

Alongside nominal values, real metrics of production also are of interest, particularly to evaluate trends in factor productivity. A natural approach here is to substitute current prices for each crop for prices observed in a fixed base year (e.g. $p_{jt} \to p_{j0}$), equivalent to dividing the nominal value of production per crop by its own price index. While conceptually attractive, this has two drawbacks. First, in both micro- and macrodata, it is often the case that we have information on production values but not constituent information on both prices and quantities. Quintessential examples are national accounts and balance of payments data, where quantities are not generally reported (as they would be meaningless). Second, as discussed by Fenoaltea (1976), application of product-specific deflators can distort the relative importance of individual products in any given period, substantially altering their ranking. As such, rather than deflating from the bottom-up using individual fixed prices, deflation from the top-down with a single (aggregate) price index is often recommended (also Amendola et al. 2023; Fenoaltea 2020). Among other things, this ensures that the value shares associated with different products (activities) are the same in each period, whether stated in real or nominal terms. We prefer the latter approach here since it also facilitates comparison between macro and micro sources of agricultural data.

[3] For further discussions of measurement challenges in agricultural surveys, see (*inter alia*) Carletto et al. (2015), Abay et al. (2019), and Wollburg et al. (2021).

3 Agricultural data in Mozambique

Turning to Mozambique, at first glance the agricultural statistical system in the country appears comparatively well organized. Following reforms in the late 1990s, the first post-conflict agricultural census was completed in 2000, followed by a series of agricultural surveys covering both smallholders and larger commercial farmers (see below; also see Donovan 2008; Kiregyera et al. 2008). Various external assessments have rated the country's (agricultural) statistical system positively, particularly in comparison to peer countries. For instance, the AfDB (2014) assessed the availability of agricultural statistical information in the country as 'strong', ranking the country 6th out of 52 with respect to statistical methods and practices, despite only having 'poor' resource availability (see also COMEC 2014). A more basic comparison is also informative. While Mozambique's most recent agricultural census was undertaken in 2009/10, the situation in Kenya in the same year appeared comparatively dire: 'the Census of Agriculture has not been conducted since the 1960s [and] has resulted in the declining quality of data on agriculture, a limited survey program, and increased use of desk-based or eye estimation approaches to fill gaps' (Braimoh et al. 2018).

As in other countries, the national statistics agency (*Instituto Nacional de Estatística*, INE) holds ultimate legal responsibility for and authority to collect and disseminate official information on the agricultural sector. However, this competency is delegated primarily to the relevant line ministry, the Ministry of Agriculture and Food Security (*Ministério da Agricultura e Segurança Alimentar*, MASA). Focusing henceforth on crop production statistics, the main sources of publicly available data are elaborated in Table 1.[4] These are the series of micro-surveys, administrative reports on crop production summarized in the government's annual *Balanço do Plano Económico e Social* (BdPES), INE statistical annuals including periodic sector-specific reports, and total production statistics by sector found in the national accounts, also published by INE.

Table 1: Sources of data on agricultural production and prices in Mozambique

		Coverage			
Dataset	Source(s)	Temporal	Population	Products	Vars.
TIA/IAI surveys	Micro-surveys	Periodic	Smallholders	All crops	A, Q, p
BdPES reports	Ministry estimates	Annual	All farmers	Selected crops	A, Q
Statistical annuals	INE	Annual	All farmers	Selected crops	A, Q
SIMA	Ministry estimates	Monthly	Markets	Food items	p^c
National accounts	INE	Annual	All farmers	All items	$V^*, \tilde{p}$
FAOSTAT	FAO	Annual	All farmers	All crop groups	A, Q, p^i
Bal. of payments	Central Bank	Annual	Formal sector	Traded goods	X, M

Note: variables in the final column are as per Equations (1) and (2); A is land area, Q is production quantity; $p, p^c, \tilde{p}$, and p^i respectively denote producer prices, consumer prices, an aggregate price index, and international prices; V is output values; X and M are exports and imports, respectively.

Source: authors' own elaboration.

Coverage of these different sources varies. Various limitations of the TIA/IAI surveys have been noted elsewhere (Donovan 2008; IGM 2024; Kiregyera et al. 2008). Most importantly, production quantities are generally only consistently available for major annual crops (staples), meaning that complete information needed to place a value on production (minimally, Q, p) is not available for many permanent crops and vegetables, as well as some cash crops for which coverage is patchy. The TIA/IAI series is also designed to capture activities of smallholder farmers, defined as those farming less than 5 hectares of land. A separate survey (effectively, a census) of large farms is undertaken alongside the TIA/IAI

[4] We focus on crop production to avoid the additional complexity of covering fisheries and livestock. In Mozambique, these latter two subsectors are not unimportant, but are much smaller relative to crop production—for example, according to the national accounts, in 2023 crop production accounted for 84% of the nominal value of the agriculture, livestock, forestry, and fishing sector.

surveys, but data from these exercises is not generally published, even at an aggregate level. Also, while the TIA/IAI samples are —in principle—drawn from the complete rural and urban sampling frame constructed from the most recent agricultural (and population) census, in practice the sample frame has not consistently covered major urban areas.[5]

The BdPES data pertains to administrative estimates collated by the agricultural ministry. These only cover selected major food crops and give information on two dimensions: total production quantities and farmed areas. The underlying methodology used to produce these estimates is not published and, thus, their coverage and reliability is unclear. However, it is widely understood that this data is sourced in a bottom-up fashion—district-level government officials (working with the *Serviço Distrital de Actividades Económicas*) report crop-level estimates of land allocated to different major crops, as well as estimates of yields (or total harvested outputs), typically based on visits to selected plots and other qualitative information. These estimates are then centrally aggregated.

The most granular statistical information published by INE on the sector is contained in their *Anuário Estatístico* (statistical annuals), as well as occasional reports containing agricultural production and food security indicators (e.g. '*Indicadores Básicos de Agricultura e Alimentação*'). Both outputs reply on primary data directly from the relevant line ministry, including the TIA/IAI series when available. The statistical annuals largely mirror the structure of the BdPES, presenting only farmed area and output quantities for selected major crops. To these, data on some major commercial crops are also added (e.g., cashew, tobacco, sugar cane). INE's occasional agricultural sector reports provide more detail. They include headline information regarding the number of so-called non-household 'statistical units' (e.g. commercial farms or associations) active in the agricultural sector. But these are tiny in absolute terms—as at 2020, this number was just 1,212 units versus 4,456,518 smallholders (INE 2022a). At the same time, production quantities and land-use data in these reports appears to be derived exclusively from the TIA/IAI series, which only covers the household sector. Additionally, while some price data is provided in these reports, it is taken from a separate source, namely the ministry's *Sistema de Informação de Mercados Agrícolas* (SIMA). This series reports data on the prices of agricultural food commodities in a range of primary urban markets and—as we return to below—reflects consumer rather than producer prices. Notably, no attempt in these reports is made to place a value on production either at the aggregate or crop level.

Theoretically, the national accounts data is the most complete of all official sources at an aggregate level. By definition, it should cover *all* economic activities within the scope of the agricultural sector in the country, including commercial farms, as well as both rural and urban smallholders. Nonetheless, this data is not disaggregated (e.g., by crops or farm size), nor does it indicate the gross value of production. Rather, the statistical sectoral aggregates typically published in the SNA capture 'value-added', defined as the gross value of the sector's outputs minus the value of intermediate goods (inputs) consumed in the production process, such as fertilizers or seeds.[6] As such, these figures should be interpreted as approximate lower-bound estimates of the value of agricultural output. However, as we discuss in Section 4.1, additional information reported to the United Nations Statistics Division allows adjustments to be made to estimate comparable gross output values for each sector.

The FAO provides an extensive compilation of data on total annual production, harvested area, and prices covering all crop groups.[7] As a general rule, data from official sources is employed to produce these

[5] Comprehensive methodological documents for all the TIA/IAI surveys are not in the public domain. Urban/rural identifying information is not available in the microdata. For present purposes, we use adjusted survey weights that are aligned to the most recent agricultural census for all statistics derived from these surveys—see IGM (2024: chapter 5) for further details.

[6] As already noted, in calculations of agricultural value-added, farm-gate prices should be applied in order to focus on the direct value of outputs from agriculture, rather than those of additional transport services or processing (AfDB 2017).

[7] Available in FAOSTAT in separate datasets on production quantities and values.

series, meaning they represent a curated version of all official production estimates. Prior to 2005, the BdPES estimates were mainly used for relevant crops; since then, the TIA/IAI results have been incorporated. Where official data is missing, estimates or imputations are applied to ensure complete coverage of each product in each year. But this only applies to estimates of production quantities and harvested areas, not prices. Specifically, in FAO's data for Mozambique, local currency prices are missing for a substantial number of crop–period combinations, implying consistent estimates of total production values cannot be generated on this basis. As an alternative, the FAO reports output in international dollar values, which reflect reference prices used primarily for purposes of real international comparisons (see Maddison and Rao 1996).

Finally, data provided by the central bank refers to the value of trade in agricultural and related products. Obviously, this provides a partial view of total domestic production, but this information is pertinent for (cash) crops that are primarily exported (without processing). The value of imported agricultural goods also is not directly informative, but as we show below, when combined with information on consumption and exports, it provides an indirect means to estimate total agricultural incomes.

4 Macro–micro comparison

4.1 Methods

Our primary analytical objective is to validate the macro-level estimates of agricultural output found in Mozambique's production-side national accounts series. Despite the variety of alternative data sources set out in Table 1, only the TIA/IAI surveys are sufficient for this purpose on a standalone basis, containing information on *both* production quantities and farm-gate prices for a reasonably complete range of crops and producers. Thus, based on the harmonized TIA/IAI dataset as described in IGM (2024), which incorporates 12 agricultural surveys collected over the period 2002–20, the task is to derive estimates for gross total sector output in both nominal and real terms.

To do so, we proceed in four steps. First, since many smallholders do not produce entirely for the market, transaction-level price data is not consistently available. Consequently, we use the approximation in Equation (1b) and calculate the production value of crop j in year t as the product of the total quantity produced and the median national price, applying appropriate sample weights to ensure estimates are nationally representative. Second, we make a simple upwards adjustment to account for cases where quantity data is missing despite the harvested area being non-zero. Specifically, for each crop we estimate the mean area for which production quantities are missing and rescale the total crop production value as: $V^1_{jt} = \bar{p}_{jt}Q_{jt}/(1-\bar{m}_{jt}) = V_{jt}/(1-\bar{m}_{jt})$, where $0 < \bar{m}_{jt} < 1$ is the average missing area. In practice, the average adjustment (per crop) is only around 4% of the original value.

In the third step we make an adjustment to reflect the exclusion of larger farms from the TIA/IAI series, such as commercial plantations, as well as other possible errors or omissions. For this, we calculate the (smoothed) ratio between the total cropped area estimated from the microdata and FAO's overall estimate for the same quantity, which is on average about 25% larger. Assuming (heroically) that the per hectare gross yield of this additional land is 1.5 times that of the average smallholder, the final estimate for total nominal production from the micro-surveys is thus:

$$V^2_t = V^1_t \times \left(1 + \frac{3}{2}\frac{A^{\text{FAO}}_t - A^{\text{TIA}}_t}{A^{\text{TIA}}_t}\right)$$

Roughly speaking, these two adjustment seek to make corrections for 'internal' and 'external' missing data, respectively.

The fourth step is to convert nominal into real values. Rather than using (fixed) base year prices for each product, we construct an elementary aggregate price index using a simplified version of the household product dummy model, as set out by Chakrabarty et al. (2018), which represents a micro-level version of the conventional country product dummy approach (e.g. Diewert 2005; Rao 2005). Effectively, this involves a hedonic regression of observed prices controlling for fixed product characteristics, location effects, as well as other relevant factors that may influence prices received by producers (e.g. affecting product quality). Namely, we run:

$$\ln p_{ijlt} = \pi_t + \delta_1 q_{ijt} + \delta_2 a_{ijt} + \delta_3 s_{it} + \lambda_{jk} + \mu_l + \varepsilon_{ijlt} \quad (3)$$

where l denotes provinces, k regions (North, Center, South), and s is a dummy variable denoting whether the household sold any produce on the market.[8] Other variables are as before, and parameters are (fixed) effects to be estimated. The estimated coefficients $\hat{\pi}_t$ are of primary interest and capture the average level of farm-gate prices faced by smallholders in a given year, based on a reference production basket.

Before proceeding, we previously noted that the main sector aggregates contained in the national accounts refer to value-added, which measure net as opposed to gross output values. As such, our micro-survey estimates are not directly comparable to the standard SNA aggregates. To address this, one option would be to calculate intermediate input costs from the micro-surveys and subtract these from the gross output value estimates. Unfortunately, insufficient information is available in the surveys to do so. As an alternative, we use supplementary data reported by national authorities to the UN Statistics Division, which provide a breakdown of gross output and intermediate inputs per sector.[9] Such data is available for Mozambique starting in 2002, but only for the agricultural sector as a whole, rather than for the crop production subsector. Thus, we calculate the ratio of total agricultural output to value-added, and apply this to the SNA estimates of income from crop production.[10] This final adjustment augments the raw value-added series by around 20% on average; however, as we show, our key results are not driven by this exercise.

With these components in hand, decomposition of the nominal gap between the macro- and micro-production series is informative.[11] Note that the nominal value can be expressed as the product of a real base level, a quantity (real production) index, and a price index:

$$V_t = \tilde{V}_0 \cdot \frac{\tilde{V}_t}{\tilde{V}_0} \cdot \frac{p_t}{p_0} \quad (4)$$

which implies that $\tilde{V}_t = V_t(p_0/p_t) = V_t/\tilde{p}_t$, namely being the real value of production derived by deflating with an aggregate price index. Using superscripts 'N' and 'T' to denote the macro- and micro-series, standard decomposition methods (e.g. Kitagawa 1955) allow us to identify the contributions due to

[8] Sample weights are used in these estimates, being the relevant household weights multiplied by the share of production undertaken by household i of crop j, meaning estimated coefficients reflect the structure of production as a whole.

[9] This detailed information is not always found in standard publications of national statistics authorities. For further references, see https://unstats.un.org/unsd/nationalaccount/madt.asp, especially tables 2.3 and 2.6.

[10] Annual production-side estimates of GDP provided by INE distinguish between 'agriculture', 'animal production', and 'forestry'. Here we focus on the first of these, which refer to the production food crops. In practice, since data on gross output is not available for all years, and the contribution of intermediates shows substantial volatility, we use the predicted linear trend in the output to value-added ratio to scale-up the crop value-added estimates.

[11] Data from the micro-surveys is not available in all years. Thus, to complete the time series of observations (2002–20), values are imputed using the mean of nearest-neighbour and piecewise cubic Hermite interpolation methods (available under the Stata command `mipolate`). Estimates are not sensitive to the interpolation algorithm used.

differences in the quantity and price indexes, respectively:

$$\Delta_q = (\tilde{V}_t^N / V_0^N - \tilde{V}_t^T / V_0^T) \frac{\tilde{V}_0^N + \tilde{V}_0^T}{2} \frac{\tilde{p}_t^N + \tilde{p}_t^T}{2} \tag{5a}$$

$$\Delta_p = (\tilde{p}_t^N - \tilde{p}_t^T) \frac{\tilde{V}_0^N + \tilde{V}_0^T}{2} \frac{(\tilde{V}_t^N / V_0^N + \tilde{V}_t^T / V_0^T)}{2} \tag{5b}$$

$$\Delta_b = (V_t^N - V_t^T) - \Delta_q - \Delta_p \tag{5c}$$

The final line is the residual difference, capturing the remaining contribution due to base levels (and interactions) and which naturally constitutes the entire gap in the base period itself.

4.2 Results

Figure 1 presents the headline comparison of the national accounts estimates of agricultural value-added, which excludes forestry, livestock, and fishery activities, and the micro-survey counterpart also only based on crop production, adjusted for potential under-reporting (see above). Panel (a) reports nominal values and panel (b) shows real values, where output from the national accounts is deflated by the implicit national accounts deflator for the sector, and we apply the elementary price index to the micro-survey estimates, as calculated from the same surveys. Appendix Figure A1 repeats the same figures using the raw national accounts value-added series rather than the estimate for output (i.e. ignoring the final adjustment factor).

Two main points merit note. First we observe a large and persistent gap between the two series—both the nominal and real micro-survey estimates are less than half the value of the corresponding national accounts aggregates on average. For instance, the mean nominal ratio is just 44% over the period, with a maximum of 61% in 2019; and even using the raw national accounts value-added series, the same ratio takes an average of 52%. Second, as shown in Figure A2, the ratios diverge over time. The nominal ratio of the micro-survey to the national accounts estimates slopes upward over time, implying some degree of convergence, while the real ratio falls. This hints at differences in their respective deflator series.

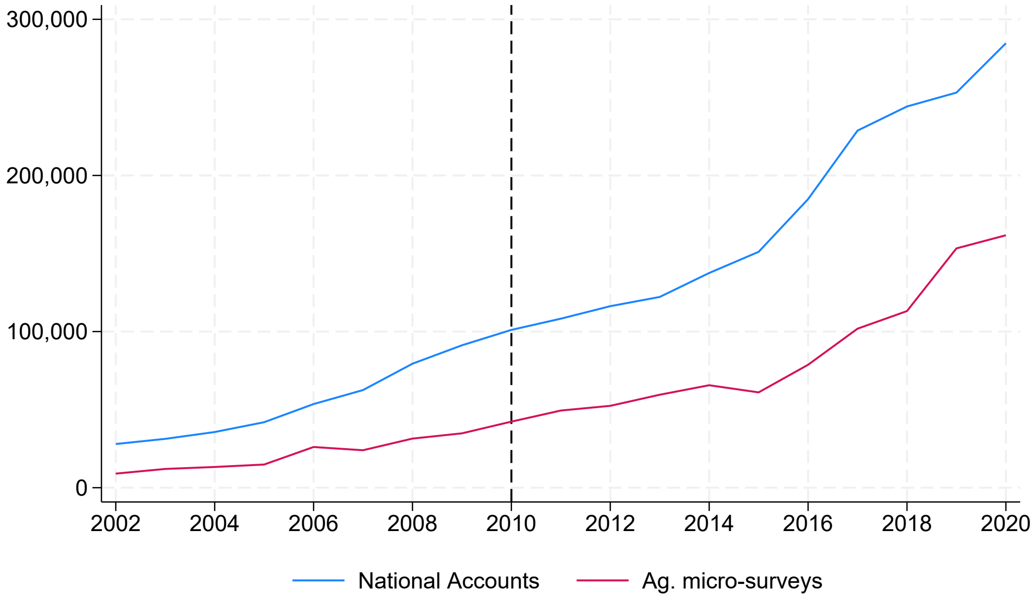
Building on the previous point, Figure 2 illustrates results from the three-way decomposition of the gap between the two nominal estimates, reported in relative terms—that is, the sum of the contributions of the base-level effect and quantity and prices indexes sum to 1 in each period. These two index effects are negligible in the base period (2008–12) by construction; thus, reflecting the large differences in levels noted above, the base-level component tends to dominate throughout. Nevertheless, as confirmed in Appendix Figure A3, the micro-survey producer price index shows a much steeper profile, contributing positively to the nominal gap in the early period but negatively in the later period. To put this in perspective, the approximate average rate of inflation implied by the national accounts deflator is 7.5% versus 12.2% from the micro-surveys.[12]

The quantity indexes also show notable differences—the national accounts shows smooth and steady growth, with few perturbations; the micro-survey estimates are much more volatile, but in doing so appear to reflect variability due to major climatic shocks, such as the 2014–16 Southern African drought. As such, although less material, the contribution of the quantity index tends to moderate the contribution of the price index, making a negative contribution to the nominal gap in the earlier period (associated with relatively higher growth in the micro-survey versus the national accounts) but positive contributions (in specific years) in the later period. Indeed, as can be seen visually in Figure 1(b), there is no evidence of sustained real growth since around 2012 according to the micro-surveys.

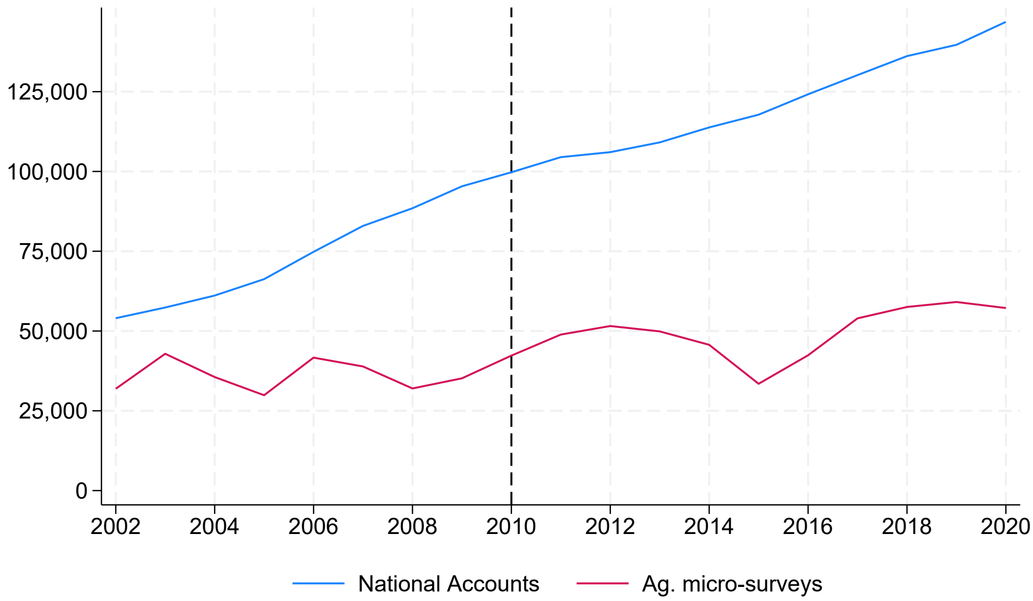
[12] These are log. linear growth rates (linear trends in the log. of the indexes).

Figure 1: Headline comparisons of estimates of agricultural production (MZN millions)

(a) Nominal values (current prices)



(b) Real values (constant 2008-12 prices)



Note: the figures plot national accounts and micro-survey estimates of total agricultural output; the national accounts series is adjusted from value-added; panels (a) and (b) give nominal and real aggregate output values; (nominal) national accounts values are deflated by the implicit sectoral price index in the same series; micro-survey values are deflated by a price index constructed from producer prices in the same surveys.

Source: authors' estimates.

Figure 2: Decomposition of nominal gap estimates of agricultural production (MZN millions)

Note: bars show the relative contribution to the total gap between the national accounts and micro-survey estimates of nominal agricultural production in each year; the components are as set out in Equation (5), capturing differences in: an index of production quantities, an index of prices, and residual base levels. The base period for all components is 2008–12, in which the price and quantity indexes are set to mean zero.

Source: authors' estimates.

5 Triangulation

The headline comparisons of data derived from national accounts and micro-surveys confirm persistent large differences in estimates of agricultural production values in Mozambique. Since neither estimate is necessarily 'better', it is valuable to assess their consistency with other sources of data on the sectoral output. To answer this, we now seek to triangulate our findings using a range of other sources of information on both prices and production values.

5.1 Methods

To triangulate trends in agricultural prices, we use the market data from the SIMA and apply the same product dummy hedonic regression approach to construct an elementary consumer food price index. Note that use of consumer prices *in lieu* of producer prices is permissible under the assumption that rates of inflation are common to both, such as when consumer price levels are a multiple (relative mark-up) of producer prices. However, to avoid contamination from imported or processed goods, in doing so we only rely on prices for basic food items that are typically sourced locally, such as white maize grain, groundnuts, and vegetables.[13]

Turning to production values, as noted previously, the FAO provides comprehensive estimates of national total production valued in international reference prices (stated in constant 2014–16 I$). Summing across crops, the challenge is how to convert the ensuing aggregate to *constant* local currency units. Two options merit consideration: the local currency to PPP conversion factor for the same base period; or

[13] Further details are available on request from the author.

the corresponding average market exchange rate. In Mozambique these diverge considerably, reflecting differences in the prices of non-tradeables (which include certain agricultural products, such as cassava), as well as short-run changes in market exchange rates. To balance these concerns, we use the geometric mean of the two rates.[14] This appears to be a sound choice—at the crop level, the quantity-weighted average ratio of these converted FAO prices to those found in the TIA/IAI surveys equals 99% in the reference period (see Appendix Figure A4). To obtain the corresponding nominal series, we then apply the aggregate price index derived from the SIMA data to this local currency constant price series.

A similar procedure can be used to estimate production values from MASA's administrative reports, given in the BdPES data. Namely, production quantities for major crops are valued at the same international reference prices (derived as unit values) employed by the FAO; the ensuing total is then converted as before, giving both real and nominal values in local currency units. In addition, to correct for the fact that the BdPES reports only cover selected crops, we adjust the estimated values upward by the ratio of the total FAO cropped land area to the total area reported in the BdPES data (a multiple of 1.25 on average).

As a third alternative we use consumption data from the series of household surveys (undertaken in 2002/03, 2008/09, 2014/15, and 2019/20) combined with annual balance of payments data to derive a back-of-the-envelope estimate for agricultural production. Based on these sources, a lower-bound nominal domestic production estimate is calculated as follows:

$$V_t^{H1} = \varphi_t \left(\sum_i c_{it} \gamma_{it} + (2/3) e_t X_t \right) \tag{6}$$

where c_{it} is total food consumption of household i, γ is the share of their food consumption that is own-produced (not purchased), e is the spot MZN:US$ exchange rate, and X_t is the US$ value of food and agricultural exports. Two adjustment factors are applied: first, since many agricultural exports are of semi-processed goods (e.g. sugar), we reduce their value by one-third; second, as both exports and consumption are valued at purchaser prices, which thereby include transport, storage, and trader margins, we apply a discount factor φ_t so as to approximate values at producer prices. Admittedly, the latter is difficult to estimate in the absence of comprehensive time series on farm-gate prices. Nonetheless, data used in earlier exercises can be leveraged to provide guidance. Specifically, we compare (national) median prices from the TIA/IAI and SIMA datasets for a range of products for which there is adequate coverage across periods and where direct comparison is possible.[15] For each product, we calculate the producer–consumer price ratio and estimate φ as their smoothed mean. On average, this gives a discount factor of 53%, with a slight trend increase over time, a value that closely accords with earlier estimates due to Arndt et al. (2000).

Rather than relying on estimates of own-produced food consumption, an option is to take total food consumption less food imports, plus exports. This broadly mirrors a type of food balance calculation, yielding an upper bound:

$$V_t^{H2} = \varphi_t \left(\sum_i c_{it} - e_t M_t + (2/3) e_t X_t \right) \tag{7}$$

Appendix Figure A5 plots the upper- and lower-bound estimates of the nominal value of agricultural production. As might be expected, they diverge somewhat (by around 40%), but they nonetheless show

[14] As discussed by Robertson (2022), averages of PPP and market exchange rates have been used elsewhere to account for the contributions of traded and non-traded goods in a given sector (see also Biesebroeck 2004; Vo and Vo 2023). The PPP conversion factor used here is taken from the World Bank Development Indicators: PA.NUS.PPP, which applies to total value-added. An alternative approach would be to apply prices from the TIA/IAI series to the production quantities in the FAO series. However, only a small number of crops can be (reliably) matched, meaning this would only provide incomplete coverage.

[15] Namely these are maize (grain), rice, cow pea, and peanuts.

broadly similar growth trends. Without additional information or assumptions, we thus use their mid-point (average) as the relevant household survey-based approximation in each period.

5.2 Results

Following the triangulation procedures outlined above, Figure 3(a) compares aggregate price indexes estimated from different datasets. All the indexes chart a similar pattern. Both the micro-survey (hedonic) and SIMA indexes are more volatile than the national accounts deflator—they capture sharper (average) price increases in 2009 and 2015/16, associated with global food price rises and a rapid exchange rate devaluation (and rise in consumer inflation), respectively. Overall, the SIMA index lies between the macro- and micro-deflators, suggesting food prices grew at an average annual rate of 10.1% over the period.

Turning to alternative sources of data on production values, Figure 3(b) plots the constant prices series for all five measures of agricultural production. These are the two headline series, plus those derived from the FAO, BdPES, and household survey (IOF) data. Recall that FAO and BdPES are valued first in constant international reference prices and converted to local currency units; the latter is estimated in nominal terms and then deflated using the SIMA price index. An immediate observation is that, despite some disagreement, the FAO, BdPES, and IOF series are generally in closer agreement with the micro-survey estimates in terms of *both* levels and trends; and the three series used for triangulation also show substantial volatility in production values, a feature that is similar to the micro-survey estimates but not apparent in the national accounts. While the trend growth rate in the BdPES is considerably more optimistic (see below), overall the FAO, BdPES, and IOF series differ by 43% in levels on average compared to the national accounts real production estimate; compared to the micro-survey production series, the same difference is only around 25%.[16] Corresponding estimates for nominal production are shown in Figure A6. They show similar patterns, with the national accounts aggregate dominating, but increasing divergence between the various estimates in the latest years.

Despite these findings, one cannot entirely discard the national accounts series. Thus, as a summary exercise we estimate an ensemble mean, which places the different estimates on an equal footing. To do so, we calculate the quartiles of the five nominal value series as well as the three price indexes in each period (see Figure 3). From these, we construct upper-, median, and lower-bound estimates for real production, where the upper bound is the third quartile nominal value (75th percentile) divided by the first quartile (25th percentile) of the price indexes, and so on. Figure 4 illustrates the results, confirming that the bulk of evidence places the real value of agricultural production considerably below that found in the national accounts. The average ratio of the ensemble medians to the national accounts value is 66%, falling to 61% in the final period. Figure A7 plots the ensemble prices and nominal values series in the same way. As expected, the latter also lends strong support to the micro-survey evidence.

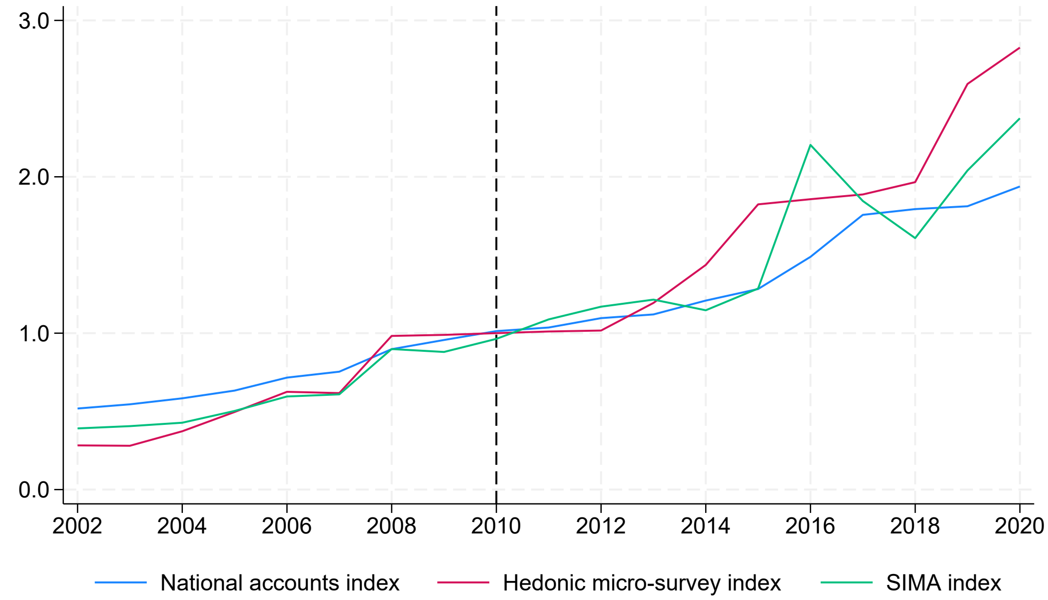
Finally, in addition to the stark gap in estimated production levels, what does this mean for estimates of productivity growth in the agricultural sector since the millennium? To see this, Table 2 calculates estimates of long-run real growth rates based on the full combination of nominal estimates (columns) and price indexes (rows), and where the final column and row refers to the ensemble means. As expected, the estimates are sensitive to the selected combination, ranging from a high of 8.0% to a low of -1.6%. Minimally, this indicates very substantial uncertainty as regards the evolution of agricultural productivity in the country over this period. Nonetheless, in general, we observe that estimates derived from application of the national accounts deflator produce comparatively higher growth rates (compare row 1 to others), while estimates based on the household survey nominal series are generally lowest (compare column 5 to the others). The overall ensemble growth estimate is 3.6%, which lies between

[16] Calculated as: $2 \mid V_1 - V_2 \mid / (V_1 + V_2)$, where V_1 and V_2 are the two series to be compared.

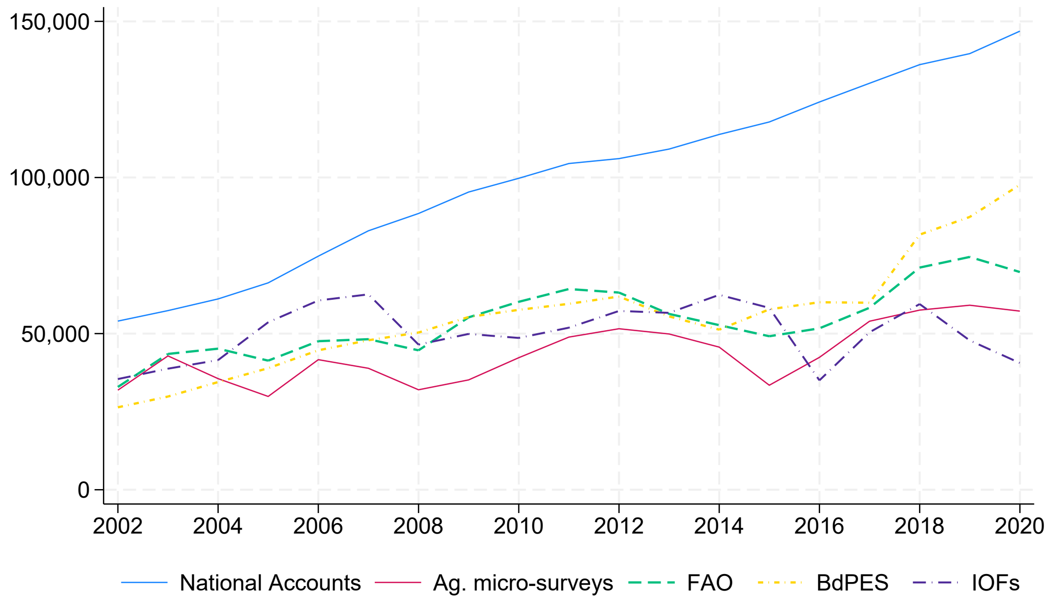
the macro and micro estimates (5.4% vs. 2.8%) and is only around 1 percentage point above average population growth for the same period.

Figure 3: Triangulation evidence on prices and real production

(a) Price indexes



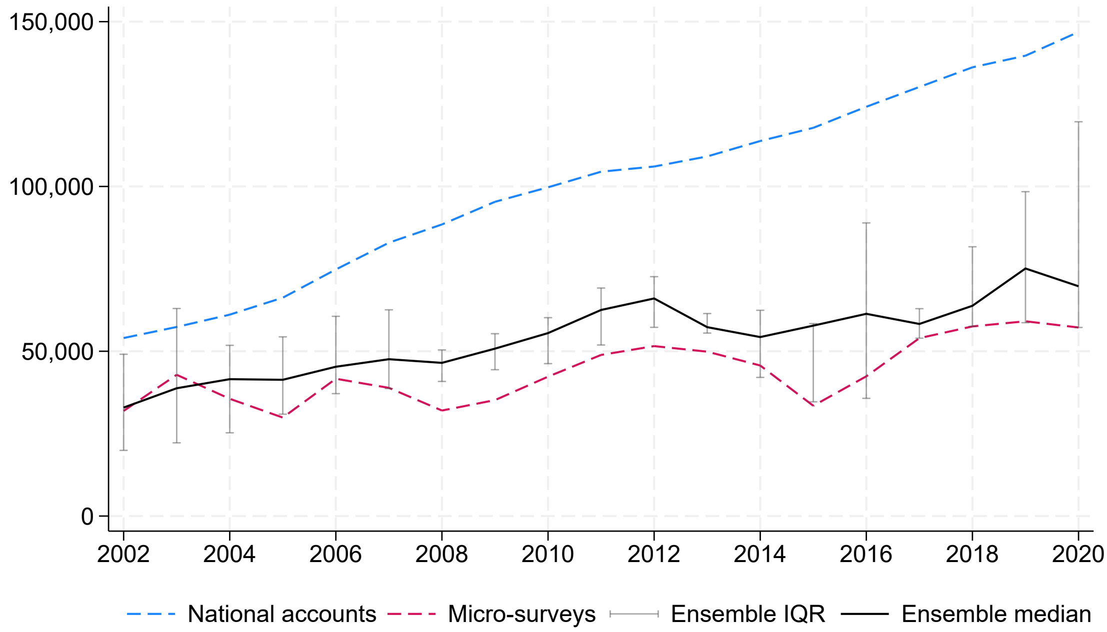
(b) Real values (constant 2008–12 prices)



Note: panel (a) plots alternative aggregate price indexes for the agricultural sector, based on national accounts, micro-surveys, and market price data; panel (b) updates Figure 1(b) with triangulated estimates of real production values from FAO, BdPES, and IOFs. In panel (b) the national accounts series is deflated by an implicit price index in the SNA, the micro-survey series is deflated by a hedonic index from the same surveys; all other series are deflated by a hedonic price index estimated from agricultural market price data (SIMA).

Source: authors' estimates.

Figure 4: Ensemble estimates of real agricultural production (MZN millions)



Note: the figure compares macro and micro estimates of agricultural production to an ensemble estimate spanning an additional three data sources; upper and lower bounds on the ensemble estimate represent the end points of the interquartile range (the 75th and 25th percentiles).

Source: authors' estimates.

Table 2: Estimates of long-run real productivity growth in agriculture (2002–20)

	Production values series (nominal)					
Deflator	SNA	TIAs	FAO	BdPES	IOFs	Ensemble
National accounts	5.4	7.6	5.6	8.1	3.2	6.1
TIAs	0.7	2.8	0.9	3.4	-1.6	1.3
SIMA	2.8	5.0	3.1	5.5	0.6	3.5
Ensemble	2.9	5.1	3.1	5.6	0.7	3.6

Note: each cell combines a series for nominal production values (in columns) with a deflator (in rows) to derive estimates of production values in constant prices; using these, the cells report long-run growth rates, defined as the slope of the linear trend in the natural logarithm of each series; SNA is the system of national accounts; all other abbreviations are as in the text.

Source: authors' estimates.

6 Cross-country comparisons

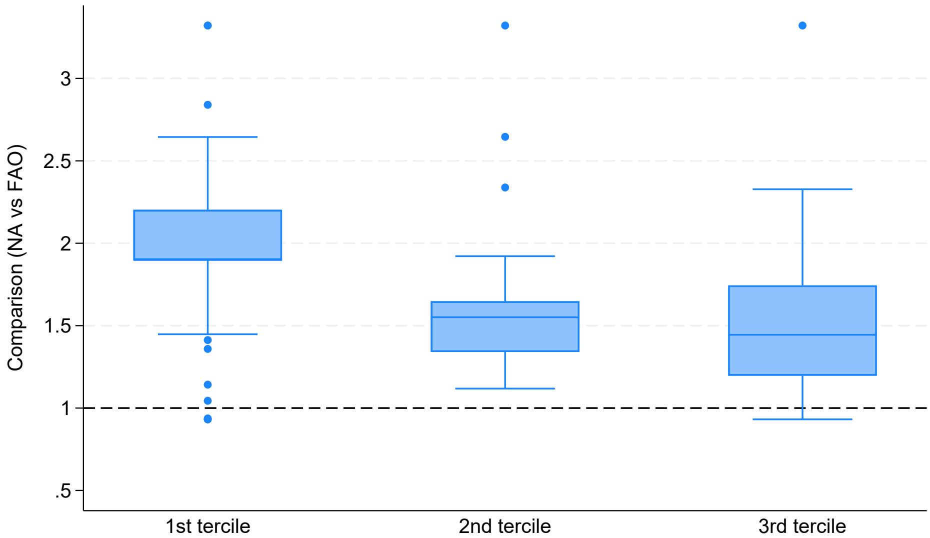
The previous sections focused on the case of Mozambique. The outstanding question is whether the data challenges found in that context are echoed elsewhere. To get a sense of this, we return to two of the earlier data sources that can provide a cross-country perspective. Specifically, we take data from the UN Statistics Division, which collates SNA estimates of output in basic prices for the 'Crop and animal production, hunting, and related service activities' subsector, representing the sum of this sector's value-added and intermediate consumption. We compare these aggregates against annual FAOSTAT data on the total value of agricultural output, which in this exercise spans the full range of crops, livestock, and non-food agricultural production.

As before, due to limitations on the coverage of local prices, our preferred comparison relies on the (constant price) international dollar FAO output valuations. To compare this against the SNA data, we first deflate the national accounts output aggregates by sector-specific implicit price deflators in the SNA for each country and then adjust by the geometric mean of the PPP and market exchange rates (all for the same base period). Effectively, this mirrors the procedure adopted in Section 5 and yields a total of around 1,300 observations, covering 70 countries.

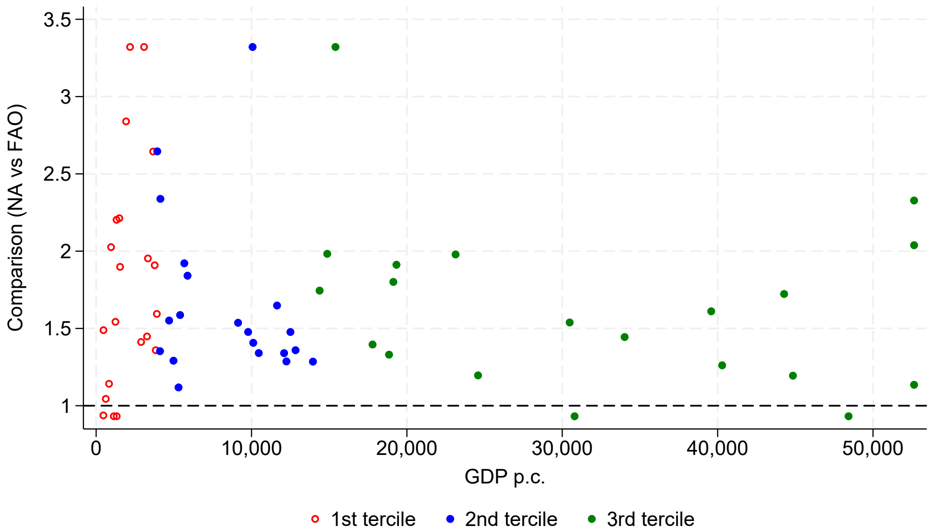
Figure 5 presents our main results, obtained by collapsing the data to the country level (one observation per country), showing the country-level average ratios of the SNA to FAOSTAT estimates against GDP per capita. Plot (a) is a summary box plot, where countries are split into income terciles (low to high); plot (b) is a scatter plot from the same data. The main insight is that positive differences between the SNA and FAOSTAT estimates are encountered across most countries, with the median SNA:FAOSTAT ratio being around 1.5. Nonetheless, larger deviations are generally found in lower-income contexts, supporting the interpretation that errors in measurement of agricultural production are generally more acute where this sector is highly informal.

Figure 5: Cross-country comparison of SNA and FAOSTAT agricultural production values

(a) Box plot



(b) Scatter plot



Note: panel (a) plots alternative aggregate price indexes for the agricultural sector, based on national accounts, micro-surveys, and market price data; panel (b) updates Figure 1(b) with triangulated estimates of real production values from FAO, BdPES, and IOF.

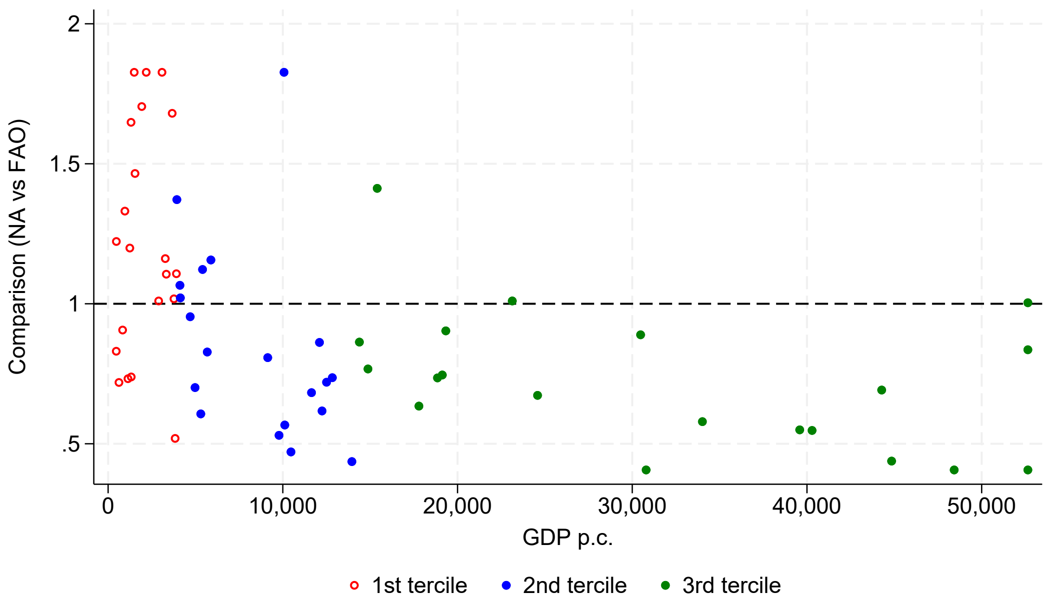
Source: authors' estimates.

As a complement to the preceding analysis, Appendix Figure A8(a) presents the same ratio of output aggregates now based on nominal local currency estimates from the two sources. These paint a similar picture—the median ratio is around 1.3 and greater variation is found at lower income levels. Finally, Figure A8(b) presents the absolute gap in mean real output growth rates—that is, showing the country-mean SNA growth rate minus the FAOSTAT growth rate. This also points to a more optimistic view from the SNA, with a mean deviation of around 0.3 percentage points.

The presence of systematic deviations in estimates of agricultural production between SNA and FAO sources, including in high-income countries where statistical capacity is strong and non-market production minimal, implies that factors beyond measurement errors may play a role. Among these are differences in the scope or coverage of output measured by the two sources. Indeed, a review of subclasses of the agricultural sector in the SNA indicate that in addition to activities associated with direct production (e.g. growing of crops), a range of agricultural support activities are also encompassed. These include (*inter alia*) seed propagation, land preparation, irrigation, and drainage, as well as certain post-harvest operations associated with preparing crops for primary markets (e.g. cleaning, drying).

It is reasonable to assume that such ancillary support activities can be material, particularly in industrialized farming systems. Nonetheless, they would typically represent intermediate inputs into final production. As a consequence, a lower-bound estimate of the deviation between the SNA and FAOSTAT estimates can be approximated from the ratio of the national accounts sectoral *value-added* versus the same FAOSTAT gross output values. These estimates are shown in Figure 6 and show an even clearer income gradient—the mean ratio among the first tercile of countries by per capita income is 1.2 but falls below unity in the two upper terciles. Although being far from definitive, this would support an interpretation that national accounts estimates of agricultural production may be more prone to being upward-biased in lower-income economies.

Figure 6: Cross-country comparison of lower-bound ratio of NAS and FAOSTAT agricultural production



Note: the figure plots the ratio of the SNA estimates of agricultural sector value-added versus FAOSTAT estimates of agricultural output, where the former represents a lower-bound estimate of the latter; colours reflect terciles of GDP per capita. Source: authors' estimates.

7 Conclusion

This study began by noting a contrast between aggregate indicators of success in Mozambique's agricultural sector over the period 2002–20 and a range of micro-economic evidence, including rising rates of consumption poverty. Echoing studies that compare national accounts to survey-based measures of consumption, we reviewed existing sources of (granular) data on crop production and constructed a counterpart of the national account estimate of gross value-added based on a harmonized series of nationally representative agricultural surveys.

The headline insight is that these macro and micro estimates of total crop production (by value) vary by a large margin, with the micro estimates averaging around half of those contained in the national accounts. A decomposition exercise revealed that while this is primarily due to a base-level effect, the price deflator applied in the national accounts is considerably more conservative than hedonic estimates derived from agricultural surveys, which appear to be the only publicly available data on farm-gate prices covering multiple crops and time periods. Consequently, estimates of real production and corresponding growth rates are considerably lower when original agricultural survey data is used.

To triangulate these findings, we derived an elementary price index based on market prices, as well as production aggregates based on FAO statistics and administrative reports, as well as occasional nationally representative household surveys of (own-)food consumption. Together, these external sources continue to support a less favourable perspective on the total level and growth rates in crop production. An ensemble of these estimates, which naively combines all available information, suggests that agricultural production may be one-third lower than the value stated in national accounts and long-run real growth rates in the sector have barely exceeded rural population growth. In other words, the weight of evidence suggests the sector remains distressed, a view that is consistent with recent trends in consumption poverty rates.

Pinpointing the exact source(s) of these statistical discrepancies is not possible. However, a strong candidate explanation concerns the absence of a reliable series of farm-gate prices upon which aggregate estimates of production, including national accounts, are valued. Comparing existing (albeit patchy) data on market and farm-gate prices, we estimated the former are typically double the latter—that is, transport and commercial margins constitute about half the consumer price. It is unlikely to be a pure coincidence that this is about the same as the spread between micro- and macro- production value estimates. Indeed, while retail prices may be used as a proxy for producer prices (Heston 1994), due adjustment must be made for transport and storage costs embedded in the former.

A cross-country comparison of estimates of agricultural output from official national accounts data and FAOSTAT revealed discrepancies are common, with a median ratio between the two sources of around 1.5. However, we found such gaps tend to be more pronounced in low-income countries, where informality in the agricultural sector is predominant and statistical systems face limitations. In higher-income contexts, the same ratio is closer to unity, suggesting greater alignment in the estimates. In part, these differences can be explained by differences in coverage of the two sources, particularly inclusion of auxiliary service activities in the SNA. Yet, since these activities are expected to be comparatively small in lower-income countries, reflecting the rudimentary nature of production, this merely underscores concerns regarding measurement errors in agricultural production statistics in such contexts.

It should be reiterated that this study does not take an absolute stand on which of the various estimates set out here is 'correct'. Nonetheless, the lack of consistency between national accounts and a range of alternative sources—in Mozambique and beyond—as well as the absence of a coherent set of explanations for their divergence, is concerning. As a minimum, it follows that greater methodological clarity is required as regards the coverage and compilation of agricultural sector accounts. This clarity should encompass the data sources used, how estimates are made for crops where primary data is missing, and how basic prices are obtained. Such an exercise is essential given the importance of agriculture in total GDP, as well as the reliance on estimates of trends and levels of GDP for a whole series of other macro-fiscal indicators (e.g. debt-to-GDP ratios and public finance indicators). Moreover, greater transparency would help identify exactly *where* improvements are required.

In addition, further investment in primary agricultural statistics is needed, including realization of a new agricultural census to provide updated benchmarks for cropping patterns and the overall scope of agricultural activity, both urban and rural. However, it must be recognized that funding required to undertake *annual* large-scale household-based agricultural surveys is not regularly available, and—even if it were—these surveys are not suited to provide time-sensitive data that can feed into national accounts (and other official documents). To overcome these limitations, a low-cost yet reliable high-frequency crop monitoring system should be considered. This might involve combining small-scale crop-cut surveys with expert input and remote-sensing of major crops, all of which can be benchmarked against rigorous data from the agricultural census. In short, in light of concerns regarding the quality of data, a systematic review of the agricultural statistical system is needed to provide more reliable as well as higher-frequency production estimates.

Summing up, it merits emphasis that Mozambique is not a unique case. This paper outlined methods to derive comparable nominal and real production aggregates from micro-survey data, as well as approaches to triangulate such estimates from other sources, including FAOSTAT. In particular, we showed how household consumption survey and balance of payments data can be combined to back-out a measure of domestic crop production. Application of such methods in other contexts, and perhaps even to other sectors, may provide valuable evidence on debates concerning the accuracy of sectoral production statistics incorporated in the national accounts, as well as provide impetus to adopt new estimation approaches. In addition, there is a critical need for robust producer price data so as to accurately estimate producers' incomes.

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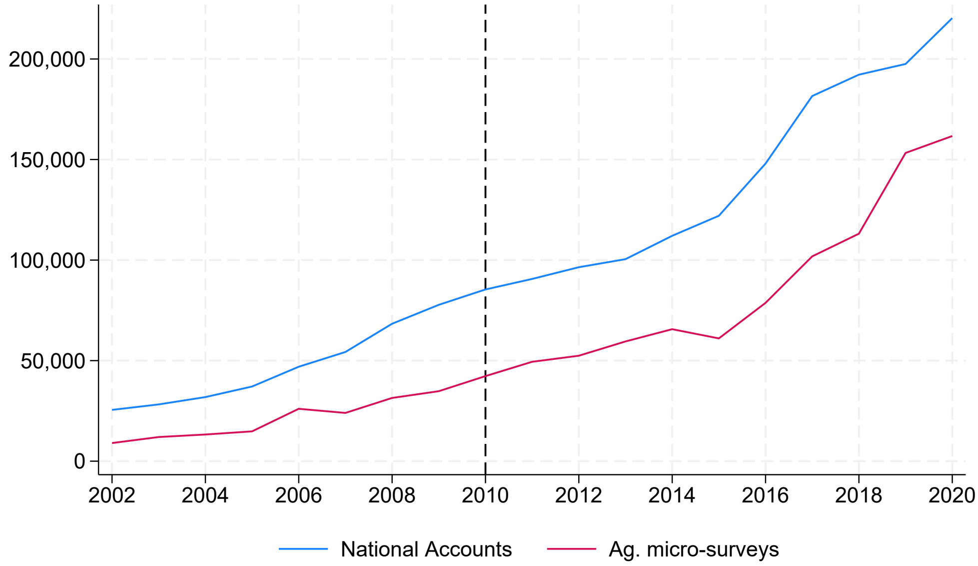
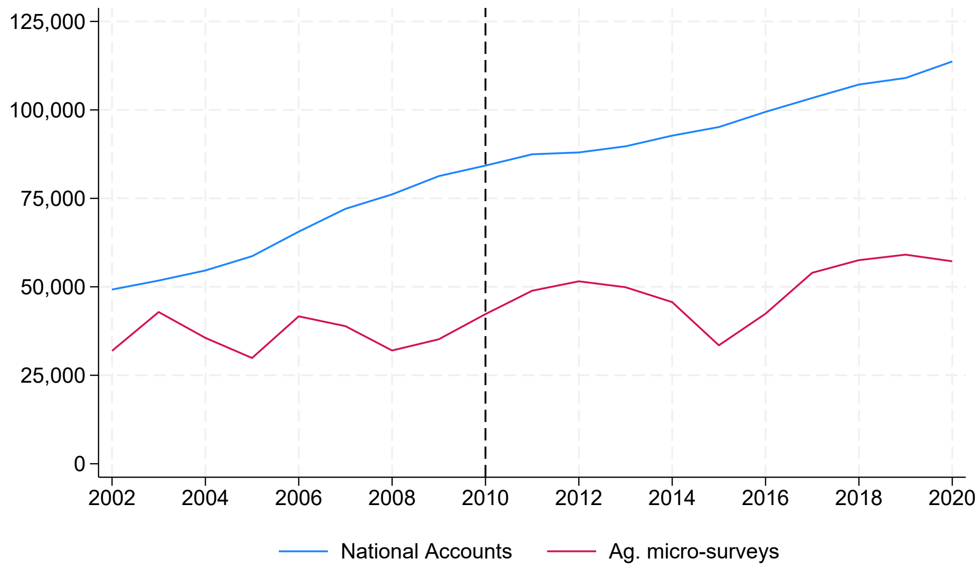
Appendix A: additional figures

Figure A1: Headline comparisons of estimates of agricultural production (MZN millions)

(a) Nominal values (current prices)



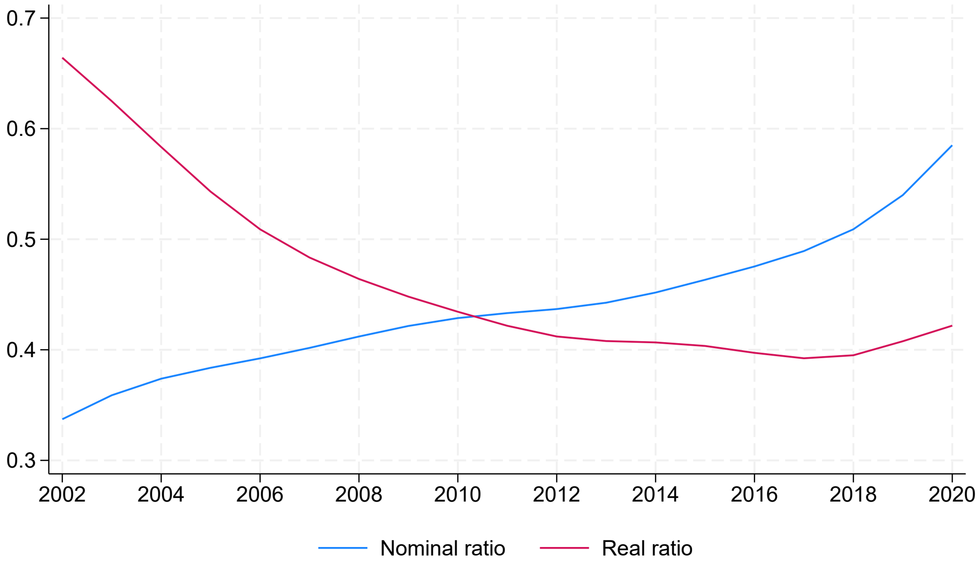
(b) Real values (constant 2008–12 prices)



Note: the figures plot national accounts and micro-survey estimates of total agricultural production; national accounts is raw (unadjusted) value-added. Panels (a) and (b) show nominal and real aggregate values, respectively.

Source: authors' estimates.

Figure A2: Smoothed ratios of nominal and real agricultural production (micro-surveys to national accounts estimates)

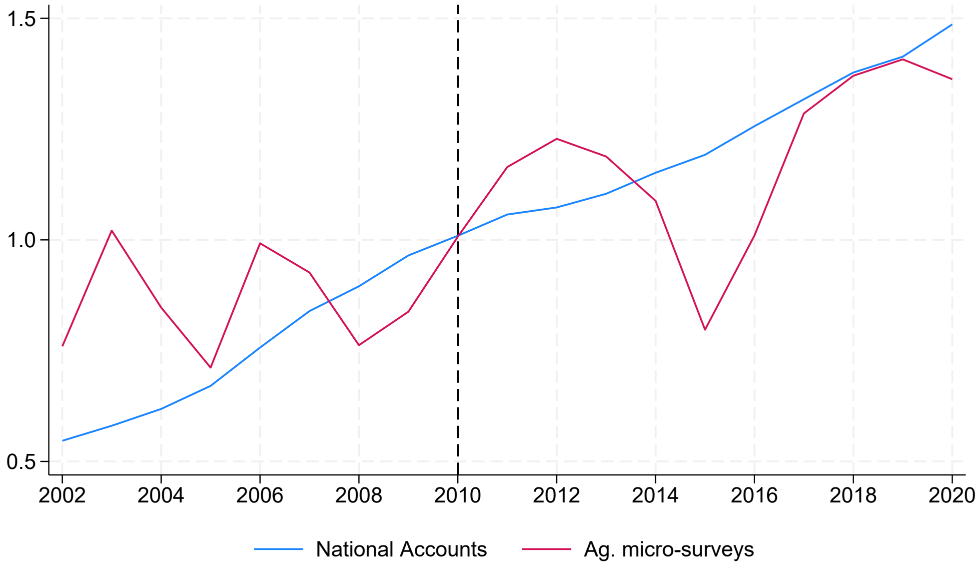


Note: the figure plots ratios of micro-survey estimates of agricultural production to national accounts estimates of value-added in the sector; lines are Lowess-smoothed.

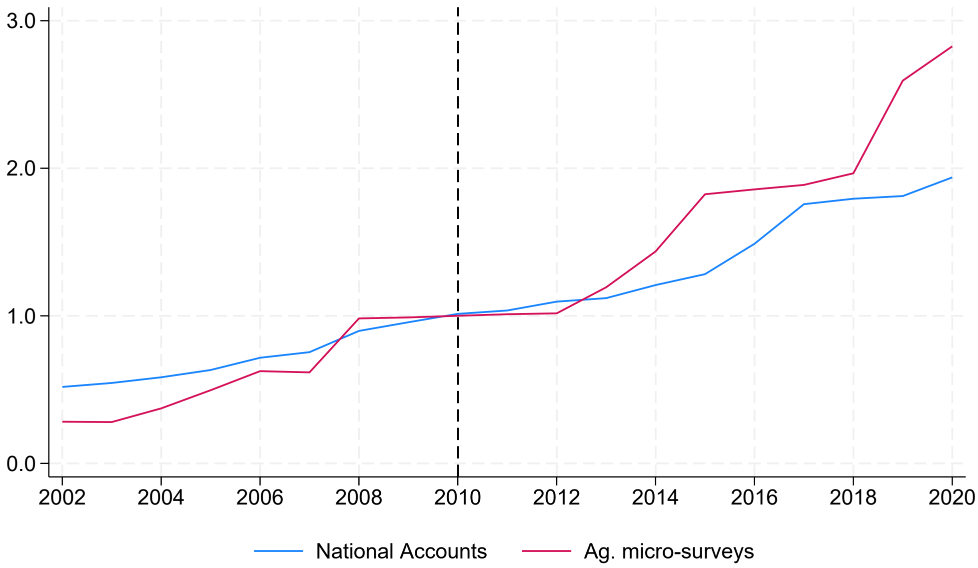
Source: authors' estimates.

Figure A3: Headline comparisons of agricultural quantity and price indexes

(a) Quantity index (2008–12 = 1)



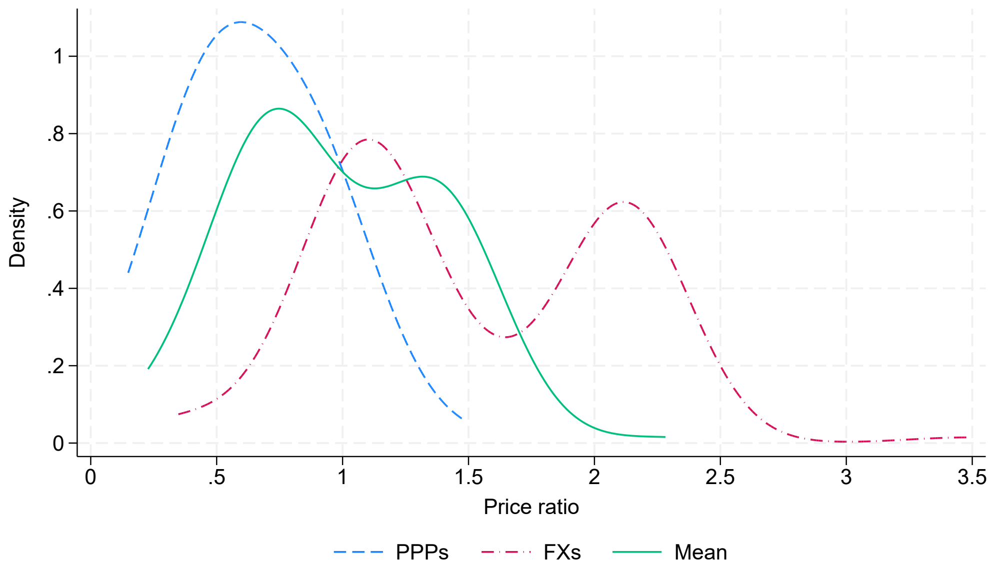
(b) Price index (2008–12 = 1)



Note: the figures plot the estimated quantity and price indexes that are employed as inputs in the decomposition exercise, as illustrated in Figure 2.

Source: authors' estimates.

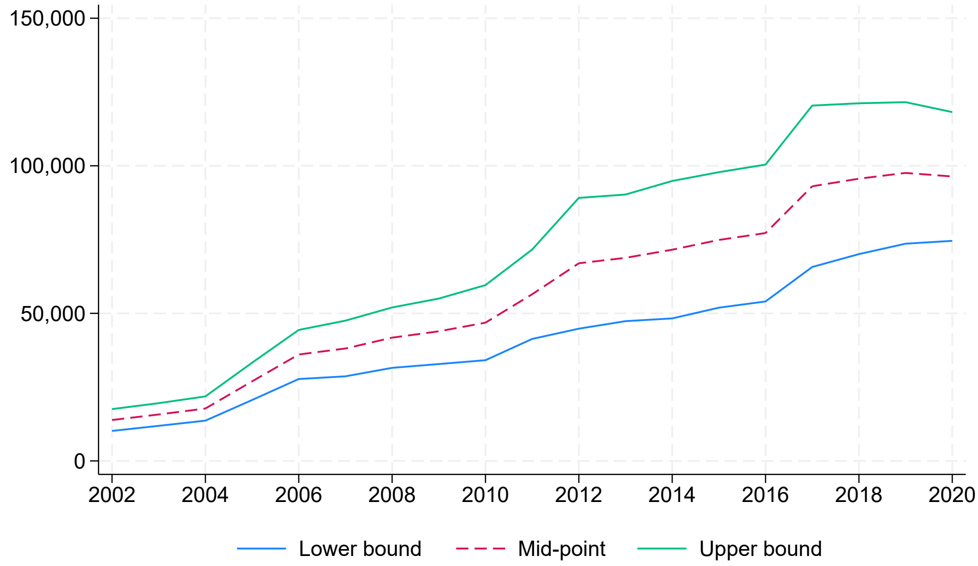
Figure A4: Comparison of the ratio of FAO and TIA/IAI producer prices, applying alternative currency conversion factors



Note: the figure depicts density distributions of the ratios of FAO reference prices to TIA/IAI prices for a range of (matched) productions applying alternative conversion factors to transform international US$ to local currency values in the reference period (2014–16); the factors are the PPP exchange rate, the official market exchange rate (FXs), and their geometric mean.

Source: authors' estimates.

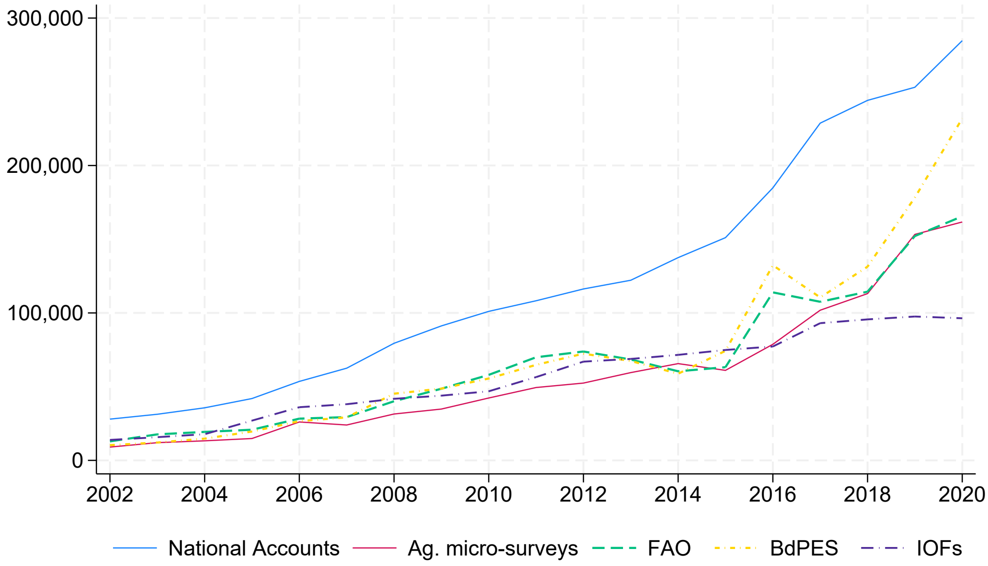
Figure A5: Upper-bound, mid-point, and lower-bound agricultural production estimates derived from household consumption surveys and balance of payments data



Note: the figure plots upper, lower, and mean estimates of nominal agricultural production derived from household survey and balance of payments data.

Source: authors' estimates.

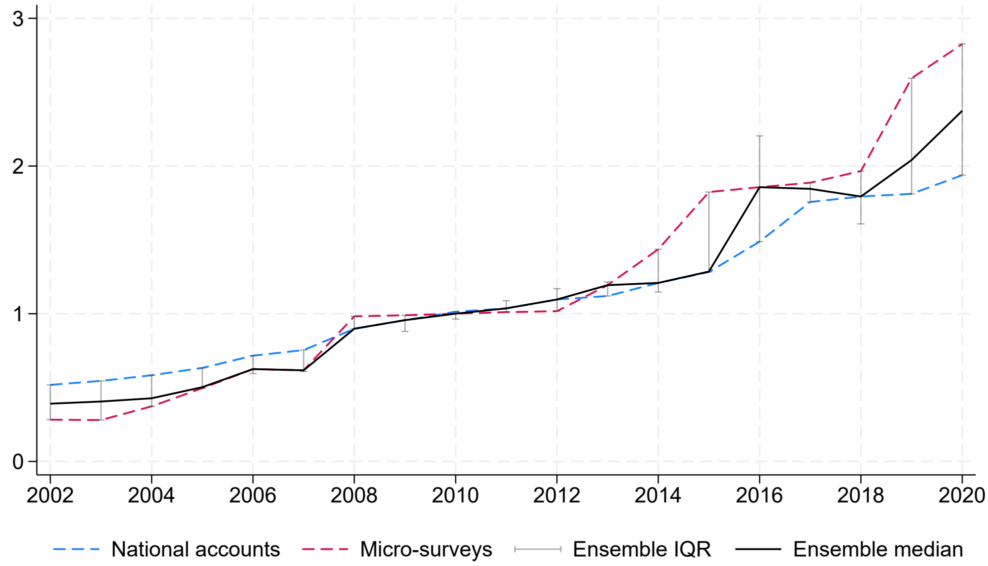
Figure A6: Triangulation evidence on nominal production



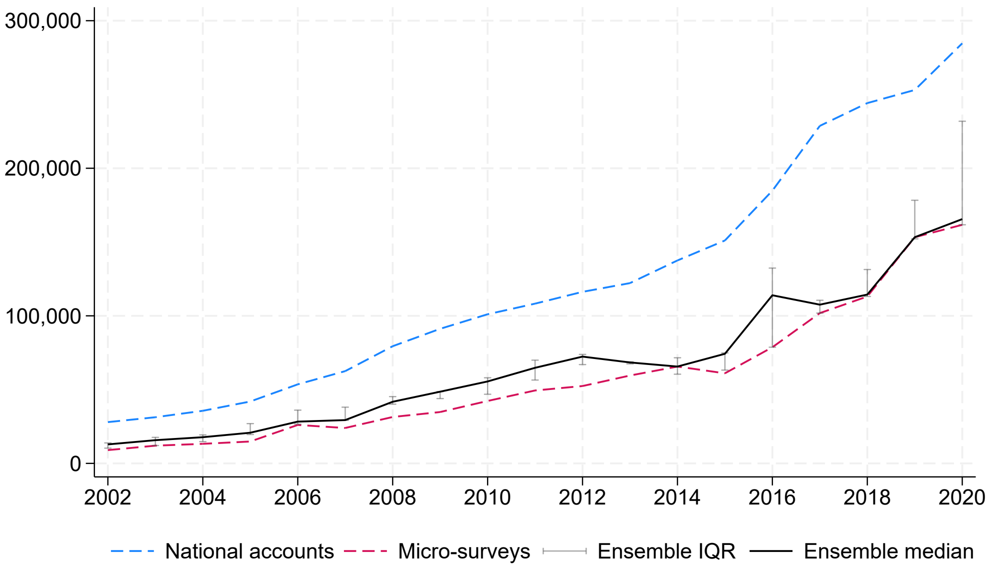
Note: this figure is the counterpart to Figure 3(b), showing all five nominal estimates of agricultural production.
Source: authors' estimates.

Figure A7: Ensemble prices and nominal production estimates

(a) Price indexes



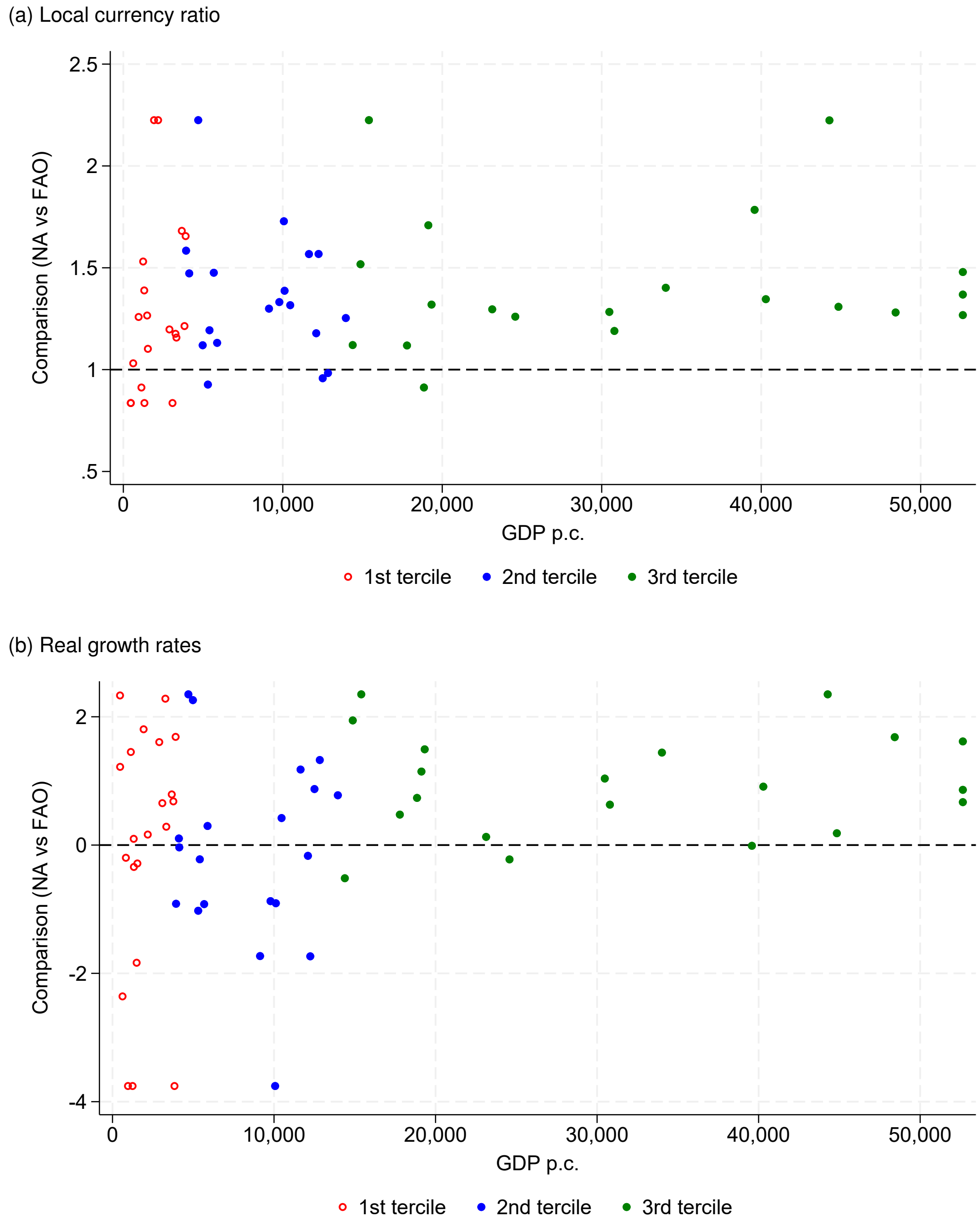
(b) Nominal values



Note: this figure is the counterpart to Figure 4, showing ensemble estimates for the producer price index and nominal agricultural production values.

Source: authors' estimates.

Figure A8: Cross-country comparison of NAS and FAOSTAT agricultural production values



Note: panel (a) plots the alternative aggregate price index for the agricultural sector, based on national accounts, micro-surveys, and market price data; panel (b) updates Figure 1(b) with triangulated estimates of real production values from FAO, BdPES, and IOF.

Source: authors' estimates.