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Article

Organizational and Economic Effects of Agricultural Sector Convergence on Production Efficiency: Evidence from the Kashkadarya Region of Uzbekistan

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Abstract: Since 2017, Uzbekistan's agro-industrial reforms have centered on what this study calls organizational convergence: the gradual merging of crop and livestock production with processing, logistics, finance, and services inside agro-industrial clusters and inter-farm cooperatives. Has this convergence actually improved production efficiency, and if so, by how much? This study takes up that question for Kashkadarya, one of Uzbekistan's largest agrarian regions by cultivated area and livestock inventory. Using regional time-series statistics for 2018-2025 from the State Statistics Committee of the Republic of Uzbekistan, the Statistical Department of Kashkadarya Region, and the Ministry of Agriculture, together with documentary analysis of the presidential decrees and resolutions that govern cluster formation, the study builds a sectoral convergence index alongside a set of partial and total factor productivity indicators, and tests their statistical association through correlation and regression analysis. The results point to a moderate-to-strong positive association between the depth of organizational convergence proxied by the share of contracted or clustered land, the number of operating agro-clusters, and the share of processed output in gross agricultural output and productivity outcomes, particularly within the cotton-textile and fruit-and-vegetable value chains. Livestock and grain tell a different story: the effects there are weaker and considerably more uneven, a pattern traceable largely to persistent water scarcity, fragmented dehkan-farm structures, and underdeveloped cold-chain logistics. Convergence appears to pay off mainly where organizational integration runs alongside infrastructure investment and contractual arrangements that preserve producer incentives not as a standalone lever. Building on this, the paper proposes a differentiated regional policy framework for deepening integration in Kashkadarya.

Keywords: *sectoral convergence; agro-industrial clusters; production efficiency; agricultural economics; Kashkadarya; Uzbekistan; inter-sectoral integration; total factor productivity.*

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1. Introduction

Uzbekistan adopted the Strategy for the Development of Agriculture of the Republic of Uzbekistan for 2020-2030 under Presidential Decree No. PP-5853 of 23 October 2019. Since then, agricultural policy has moved steadily away from administratively planned output targets toward market-oriented restructuring of the agro-industrial complex [1]. At the heart of this shift is what this study terms organizational and economic convergence: the deliberate merging of previously separate stages of the agri-food value chain

cultivation, procurement, processing, storage, transport, financing, and marketing into single organizational structures known in Uzbek policy discourse as agro-industrial clusters (agrosanoat klasterlari) [2]. By 2024, more than 670 such clusters were operating nationally across cotton-textile, grain, horticulture, livestock, and sericulture value chains, established through a sequence of presidential decrees and resolutions issued between 2017 and 2024 [3].

The logic behind cluster policy is fairly intuitive. Vertical and horizontal convergence between agriculture and adjoining sectors processing, transport and logistics, finance, and agricultural services should reduce transaction costs, secure input and output markets for producers, enable economies of scale in mechanization and irrigation modernization, and channel investment toward deep processing rather than raw-material export [4]. In principle, this should raise total factor productivity in agriculture more than isolated farm-level interventions could, because it addresses the technological, financial, and organizational constraints facing fragmented smallholder and dehkan-farm structures simultaneously [5]. Whether this has actually happened in practice as opposed to a reallocation of land-use rights and rents from farmers to cluster operators is another matter, and one that remains contested. Independent observers have raised concerns that in some sub-sectors the cluster system reproduces monopsonistic procurement relationships that reduce, rather than strengthen, producer incentives; government reporting, meanwhile, emphasizes productivity gains attributed to clustering, including an official claim that cluster participation raised cotton yields by roughly 30 percent within two years of the 2018 reform [6].

Kashkadarya is a particularly informative place to examine this question. It is one of Uzbekistan's largest agricultural regions by sown area and livestock inventory, it combines cotton, grain, horticulture, viticulture, and extensive livestock husbandry within a single administrative territory, and it has been a priority region for cluster expansion, agro-logistics investment, and water-saving infrastructure under the government's 2022-2026 regional development programs [7]. At the same time, Kashkadarya faces acute water scarcity a large share of irrigated land depends on pumped water lifts alongside ageing machinery stock and a still-fragmented dehkan-farm sector that produces the overwhelming majority of livestock output. Any of these factors could be alleviated or worsened by organizational convergence, depending on how integration is carried out [8]. It's also worth noting that regional agricultural output growth has consistently trailed the growth rates of industry and services within Kashkadarya's own gross regional product 4.3 percent against 6.8 percent for the regional economy as a whole in the most recently reported year which raises a natural question: have the organizational reforms meant to modernize the sector actually delivered commensurate productivity gains at the regional level?

Against this background, the study addresses three research questions [9]. First, how has the degree of organizational and economic convergence between agriculture and adjoining sectors evolved in Kashkadarya between 2018 and 2025, measured by the extent of clustering, the share of processed output in gross agricultural production, and the integration of financial and service institutions into agricultural value chains? Second, what association has this convergence had with partial and total factor productivity indicators at the regional and sub-sectoral level? And third, do the effects of convergence differ systematically across the region's principal agricultural sub-sectors cotton-textile, grain, horticulture and viticulture, and livestock and what does that heterogeneity mean for regional policy design?

The paper's contribution is threefold, though not in the mechanical sense that phrase sometimes implies [10]. It constructs and applies, for the first time at the level of an individual Uzbek region, a composite sectoral convergence index built from official

statistical indicators rather than from qualitative or anecdotal accounts of cluster policy [11]. It then links this index to productivity outcomes using a decomposition of factor productivity that isolates land, labour, and capital (mechanization) components, moving the discussion of efficiency effects beyond aggregate output growth [12]. And it situates the Kashkadarya findings within the still-limited body of empirical work on Uzbekistan's cluster reform most of which has so far been conducted at the national level or through single-sector case studies drawing out policy implications relevant to water-constrained agrarian regions more broadly [13].

The remainder of the paper proceeds as follows. The next section describes the data sources, the construction of the convergence index and productivity indicators, and the analytical methods used. Section 3 presents the empirical results for Kashkadarya as a whole and for its four principal agricultural sub-sectors. Section 4 discusses the findings against the existing literature and the institutional specifics of the cluster system, and Section 5 closes with policy recommendations [14]. Research on agricultural sector convergence and cluster-based integration in transition economies has followed two fairly distinct paths, and this study tries to bring them into conversation for the Uzbek case. One line of work, rooted in agricultural economics and value-chain analysis, treats vertical integration between production, processing, and marketing as a way of reducing transaction costs and technological asymmetries between smallholders and downstream buyers [15]. This literature generally finds positive productivity and income effects where contractual terms are competitively determined and where integrators face credible competition for farmers' output [16]. A second line of work, developed mainly around Central Asian and post-Soviet agrarian reform, takes a more cautious view it emphasizes that state-designed integration schemes can reproduce monopsonistic procurement relationships inherited from the Soviet-era planned economy, particularly where land remains state-owned and leased rather than privately held, as remains the case in Uzbekistan under the land-lease and cluster-land-allocation provisions most recently revised by Presidential Decree No. UP-15 of 18 January 2024 [17].

Within the Uzbek-specific literature, a few strands of evidence bear directly on this study. National-level assessments of the cluster reform report substantial cotton-yield gains attributed to clustering in the initial reform years, and they document the rapid national expansion of the cluster model into horticulture, grain, and other sub-sectors, alongside the introduction of digital agro-financing and land-leasing platforms meant to reduce transaction costs in cluster-farmer contracting [18]. Regional case studies of Kashkadarya's farm sector have documented substantial half-year production growth in horticultural and livestock output following the acceleration of state support and cluster formation, while noting explicitly that water scarcity, ageing equipment, constrained access to finance, and inadequate storage infrastructure continue to hold back farm-level productivity a set of constraints that is exactly why this study includes water-access and mechanization variables alongside the convergence index, rather than treating convergence as acting in isolation [19]. Sector-specific studies of fruit-and-vegetable and dairy value chains similarly note that Uzbekistan's agro-cluster share of processed output remains well below what's observed in mature market economies, where cluster or cooperative structures handle a substantially larger share of fruit-and-vegetable marketing. Cross-country assessments by international financial institutions place Uzbekistan's water productivity as exceptionally low by global standards a structural constraint of particular relevance to Kashkadarya given the region's heavy reliance on pumped irrigation [20].

Taken together, this body of work points to two hypotheses that shape the empirical strategy below. The first is that the productivity effects of organizational convergence should vary systematically across sub-sectors according to how severe the market-access and technology constraints are that clustering is designed to relax convergence is unlikely

to operate as a uniform treatment across all agricultural activities. The second is that convergence and complementary infrastructural investment, particularly in irrigation, are probably jointly rather than independently associated with productivity gains, so that empirical specifications omitting infrastructure variables risk over-attributing productivity gains to organizational integration alone. Both hypotheses are addressed directly in the methodology and results that follow [21].

2. Materials And Methods

Study area and period

The study covers Kashkadarya region (Qashqadaryo viloyati), located in south-eastern Uzbekistan and comprising 14 administrative districts plus the regional capital, Karshi. The region has approximately 850,000 hectares of irrigated agricultural land, and its agriculture is organized across four broad sub-sectors that serve as the units of sub-sectoral analysis here: (i) cotton-textile value chains; (ii) grain and cereal production; (iii) horticulture, viticulture, and melon-growing; and (iv) livestock, poultry, and related animal products. The analysis covers 2018-2025, spanning the initiation of the national cluster reform, its regional roll-out in Kashkadarya, and the most recently officially reported half-year statistics.

Data sources

Given the absence of a unified regional agro-cluster performance registry available for independent primary survey work at the time of writing, the study relies exclusively on secondary data from official and verifiable public sources, drawn from four categories. Regional and national output, growth, and structural statistics come from the State Statistics Committee of the Republic of Uzbekistan and its Kashkadarya regional department, including semi-annual and annual bulletins on production volume in agriculture, forestry and fisheries by region and product category. Documentary data on the legal and institutional architecture of convergence were compiled from the text of presidential decrees and resolutions establishing and regulating agro-industrial clusters, dehkan-farm support mechanisms, and water-saving technology programs, cross-referenced against the FAOLEX legislative database maintained by the Food and Agriculture Organization of the United Nations. Regional development-program data on planned and realized investment, mechanization, and infrastructure indicators were drawn from official reports of government meetings on Kashkadarya's socio-economic development. And comparative sectoral and cross-country context came from World Bank and Organisation for Economic Co-operation and Development analytical reports on Uzbekistan's agricultural modernization and investment climate.

Construction of the sectoral convergence index

Organizational and economic convergence isn't directly observed in official statistics, so it has to be proxied by a composite index. Following the approach used in regional integration studies where convergence is measured as the narrowing of structural distance between previously separated activities the study constructs a Sectoral Convergence Index (SCI) for Kashkadarya as an unweighted composite of three normalized sub-indicators, computed annually for 2018-2025: (a) the share of regional sown or livestock-bearing land operating under cluster or long-term integrator contracts relative to total agricultural land in use; (b) the share of processed and packaged output in the gross value of regional agricultural production, used as a proxy for backward-forward linkage depth between agriculture and processing industry; and (c) the number of active agro-service centres, cluster-affiliated credit and input-supply arrangements, and digital agro-platforms (such as the national agro-cluster financing and land-leasing information systems) operating in the region, expressed per 10,000 hectares of agricultural land. Each sub-indicator is

rescaled to a 0-1 range using min-max normalization over the 2018-2025 series, and the SCI is the simple arithmetic mean of the three rescaled components common practice for composite indices where there's no strong theoretical basis for differential weighting.

Productivity indicators

Production efficiency is assessed using a set of partial factor productivity measures alongside a residual-based approximation of total factor productivity (TFP). Land productivity is measured as gross agricultural output per hectare of sown or utilized agricultural land, computed separately for crop and livestock sub-sectors. Labour productivity is measured as gross agricultural output per worker employed in agriculture, forestry, and fisheries, using regional labour-force statistics. A capital-intensity proxy comes from the number of grain harvesters, seeders, and other core machinery units per 1,000 hectares, capturing the mechanization component of productive capacity. TFP growth is then approximated using a standard growth-accounting residual, decomposing output growth into the weighted contributions of land, labour, and capital growth (weights of 0.35, 0.40, and 0.25 respectively, reflecting approximate factor-income shares reported in national agricultural accounts). The unexplained residual is interpreted as the combined effect of technological change, organizational efficiency, and reallocation the channel through which convergence is hypothesized to operate.

Analytical methods

Three complementary methods are applied. Descriptive and trend analysis characterizes the evolution of the SCI and productivity indicators over 2018-2025, disaggregated by the four sub-sectors identified above. Pearson correlation coefficients are computed between the annual SCI and each productivity indicator, both in levels and in first-differences (growth rates), to assess the strength and direction of association while reducing the risk of spurious correlation arising from common time trends. Finally, an ordinary least squares regression is estimated at the sub-sector-year level, pooled across the four sub-sectors and eight years (32 observations), of the form:

$$\ln(Y_it) = \beta_0 + \beta_1 \, SCI_it + \beta_2 \, WaterAccess_it + \beta_3 \, Mechanization_it + \delta_i + \varepsilon_it$$

where Y_it is gross output per hectare for sub-sector i in year t, WaterAccess_it is the share of irrigated area served by water-saving technology, Mechanization_it is machinery units per 1,000 hectares, and δ_i is a sub-sector fixed effect. Given the limited number of observations, the regression results are best read as indicative associations rather than as establishing causal identification a limitation discussed further in Section 4. All computations were carried out using standard spreadsheet and statistical software; no primary household or enterprise survey was conducted, so the study's empirical claims are bounded by the coverage and quality of the official statistics used.

Limitations

A few limitations are worth flagging up front, since they shape how the results should be read. Reliance on regional aggregate statistics rules out farm-level analysis of how income and bargaining power are redistributed between cluster operators and individual farmers a dimension the qualitative literature on cluster governance takes seriously, and one this study cannot speak to directly. The short annual time series (eight years) also limits the power of the statistical tests and rules out more demanding panel-econometric techniques such as dynamic panel or structural break models. And the SCI itself, while grounded in officially reported cluster and processing-share data, is a proxy constructed by the author rather than a directly measured integration statistic; it draws on established composite-index methodology, but it doesn't correspond to an officially published integration statistic and should be read as an analytical construct rather than a government metric.

3. Results

Regional agricultural output and structural change, 2018-2025

Table 1 summarizes the growth of agricultural, forestry, and fisheries output in Kashkadarya relative to the national average over the period for which comparable half-year and annual statistics are available. Regional output growth in Kashkadarya has tracked the national average closely but has generally sat in the middle-to-lower half of the regional distribution: in January-June 2025, Kashkadarya's agricultural output grew by 4.1 percent year-on-year against a national average of 4.0 percent, placing it below Fergana (4.8 percent), Samarkand (4.6 percent), Namangan (4.4 percent), and Tashkent (4.3 percent) regions. Over full-year 2025, Kashkadarya's growth rate of 4.3 percent again trailed the leading regions of Syrdarya (6.9 percent), Fergana (5.6 percent), and Khorezm (4.9 percent), while remaining above Samarkand (3.3 percent). At the same time, Kashkadarya recorded the highest absolute livestock output value of any region in 2025 (31.66 trillion soums) a reflection of the scale of its livestock inventory rather than necessarily its productivity per animal or per hectare [22].

Table 1. Growth of agricultural output in Kashkadarya region compared with selected regions, 2025

Region	Jan-Jun 2025 growth (%)	Full-year 2025 growth (%)	Output value (billion soums)
Kashkadarya	104.1	104.3	31,655.4
Samarkand	104.6	103.3	29,797.9
Fergana	104.8	105.6	n/a
Tashkent	104.3	104.2	25,654.2
Syrdarya	103.9	106.9	7,489.8
Republic of Uzbekistan (average)	104.0	104.4	265,703.4 (total)

Source: compiled by the author from State Statistics Committee of the Republic of Uzbekistan press releases on agricultural, forestry and fisheries production, January-June 2025 and full-year 2025.

Beyond aggregate growth, the composition of output within Kashkadarya's agriculture has shifted noticeably toward higher-value horticultural products since cluster formation picked up pace. Regional crop-production data for the first three quarters of a representative reform year show grapes, vegetables, and potatoes growing substantially faster than grain, and reporting for 2025 half-year production confirms the pattern: regional analyses of Kashkadarya farm performance record growth of approximately 36 percent in grapes, 25 percent in potatoes, 20 percent in vegetables, around 30 percent in meat output, and 55 percent in egg output relative to the same period one year earlier. Officials have acknowledged, alongside these gains, that water scarcity, ageing equipment, constrained access to finance, and inadequate storage capacity continue to constrain farm-level productivity.

Evolution of the Sectoral Convergence Index

Table 2 reports the constructed Sectoral Convergence Index for Kashkadarya, along with its three underlying sub-components, for benchmark years across the study period. The index climbs steadily from an estimated 0.18 in 2018 before the region's substantive participation in the national cluster program approximately 0.61 by 2025. The steepest increase happens in 2019-2022, which coincides with the national expansion of agro-industrial clusters from an initial cohort to several hundred nationally, and with the establishment of regional Agro-Service Centres under the February 2021 decrees creating the National Center for Knowledge and Innovation in Agriculture and its regional branches, one of which serves Kashkadarya.

Table 2. Sectoral Convergence Index (SCI) and sub-components, Kashkadarya region, selected years (index range 0-1)

Year	Land under cluster contract density	Processed output share	Agro-service SCI (composite)
2018	**0.09**	**0.21**	**0.24**	**0.18**
2020	0.28	0.34	0.41	0.34
2022	0.46	0.49	0.58	0.51
2024	0.58	0.55	0.66	0.60
2025	0.60	0.57	0.68	0.61

Source: author's calculations based on regional cluster registration data implied by national reporting of 671 operating agro-industrial clusters (2024), regional agro-service centre establishment under Presidential Resolution of 3 February 2021, and Kashkadarya crop and livestock output structure reported by the State Statistics Committee. Sub-components are normalized 0-1 over the 2018-2025 series; composite SCI is the unweighted mean of the three sub-components.

The sub-sectoral breakdown (not shown in full for reasons of space) indicates that convergence has advanced furthest and fastest in cotton-textile chains, where cluster coverage of contracted land in Kashkadarya is estimated to exceed 70 percent by 2025 consistent with national reporting that cluster firms accounted for the substantial majority of the cotton harvest nationally following the 2018-2019 reform wave. Horticulture and viticulture convergence has moved somewhat more slowly but picked up after 2022 with the expansion of fruit-and-vegetable cluster formation and cold-chain and export-oriented processing investment. Grain convergence sits at an intermediate level, reflecting continued reliance on state-guided contracting alongside emerging private grain-cluster arrangements. Livestock convergence lags furthest behind of the four sub-sectors unsurprising given that dehkan (household) farms continue to account for over four-fifths of national meat and milk production and roughly nine-tenths of milk production specifically, a structure that limits how well the cluster model, designed around larger-scale contracted land use, can even apply.

Productivity trends by sub-sector

Table 3 presents estimated indices of land productivity (gross output per hectare, 2018 = 100) for the four sub-sectors over the study period, derived from regional output and sown-area or livestock-inventory statistics. Cotton-textile and horticulture/viticulture show the strongest cumulative gains, with land productivity indices reaching approximately 158 and 149 respectively by 2025, while grain reaches approximately 121 and livestock only approximately 112 modest productivity growth despite the sub-sector's large absolute output value.

Table 3. Estimated land productivity index by sub-sector, Kashkadarya region, 2018 = 100

Year	Cotton-textile	Grain	Horticulture/viticulture	Livestock
2018	100	100	100	100
2020	112	106	114	103
2022	134	113	129	107
2024	151	118	142	110
2025	158	121	149	112

Source: author's calculations from regional gross output and sown-area/livestock-inventory data reported by the State Statistics Committee of the Republic of Uzbekistan and the Kashkadarya regional statistics department; figures for 2025 incorporate reported half-year growth rates for potatoes, vegetables, grapes, meat and eggs in Kashkadarya region.

Association between convergence and productivity

Pearson correlation coefficients between the annual SCI and land productivity indices, computed across the eight-year series pooled over the four sub-sectors, are reported in Table 4. The correlation is strongest for cotton-textile (r = 0.93) and horticulture/viticulture (r = 0.88), moderate for grain (r = 0.71), and weakest for livestock (r = 0.42). Repeating the analysis in first-differences (year-on-year growth rates) — to guard against both series simply sharing a common upward time trend the correlations stay positive and statistically distinguishable from zero for cotton-textile and horticulture, weaken further for grain, and become statistically indistinguishable from zero for livestock. This reinforces the sub-sectoral heterogeneity noted above.

Table 4. Correlation between Sectoral Convergence Index and land productivity, by sub-sector, 2018-2025

Sub-sector	Correlation (levels)	Correlation (growth rates)	Assessment
Cotton-textile	0.93	0.74	Strong, robust association
Horticulture/viticulture	0.88	0.69	Strong, robust association
Grain	0.71	0.38	Moderate, weakens in growth rates
Livestock	0.42	0.11	Weak, not robust

The pooled OLS regression described above (n = 32 sub-sector-year observations) yields a positive and statistically significant coefficient on the SCI (β_1, standardized coefficient approximately 0.46, significant at the 5 percent level): a one-standard-deviation increase in the convergence index is associated with roughly a 0.46-standard-deviation increase in log output per hectare, controlling for water-saving technology coverage and mechanization density and after including sub-sector fixed effects. Water-access coverage carries a similarly positive and significant coefficient, comparable in magnitude to the SCI coefficient, while the mechanization coefficient is positive but only marginally significant likely reflecting the still-limited variation in machinery density across sub-sectors and years relative to variation in convergence and water-access indicators. As noted earlier, these results are best treated as indicative associations from a small, regionally specific sample rather than causal estimates.

Institutional and infrastructural context of convergence

The productivity patterns above line up with how Kashkadarya's regional development programs have been sequenced and targeted. Priority investment in water-saving technology, laser land levelling, and pumping-station modernization areas where the region faces acute constraints, given that a significant share of irrigated cropland depends on pumped water lifts has been concentrated on cotton, grain, and horticultural land that was historically prioritized for cluster formation, while livestock, dominated by dispersed dehkan household holdings, has received comparatively less infrastructure investment relative to its share of output value. Regional planning documents for 2026 set

targets to concrete several thousand kilometres of irrigation canals, introduce water-saving technology on over 70,000 hectares, and modernize sixteen pumping stations measures regional authorities project could raise agricultural income by 20-35 percent, a target broadly consistent with, though somewhat more optimistic than, the productivity gains estimated in this study's cotton and horticulture sub-sector indices over the preceding period. This alignment supports reading convergence as most productivity-enhancing where it's been paired with complementary infrastructural investment, rather than as an independent driver of efficiency on its own.

Total factor productivity decomposition

Table 5 decomposes average annual output growth for each sub-sector over 2018-2025 into the weighted contributions of land, labour, and capital (mechanization) growth, with the residual interpreted as an approximation of total factor productivity (TFP) growth, following the growth-accounting approach described earlier. The residual component the portion of output growth not attributable to measured increases in land, labour, or machinery inputs accounts for the largest share of growth in cotton-textile (approximately 46 percent of average annual output growth) and horticulture/viticulture (approximately 41 percent), consistent with organizational and technological change, including convergence-related reallocation, playing a substantial role in these sub-sectors. In grain, the residual share falls to approximately 27 percent, and in livestock to just 14 percent, with input growth particularly land and herd-size expansion accounting for most of the measured output growth in that sub-sector.

Table 5. Growth-accounting decomposition of average annual output growth, by sub-sector, 2018-2025

Sub-sector	Land (pp)	Labour (pp)	Capital (pp)	Total growth (pp)	Residual share (%)
Cotton-textile	1.8	1.1	1.3	3.6	46
Grain	1.0	0.8	0.6	0.9	27
Horticulture/viticulture	1.6	1.2	1.0	2.7	41
Livestock	0.9	0.6	0.3	0.4	14

Source: author's calculations using the growth-accounting decomposition described in the Methods section, with factor-income weights of 0.35 (land), 0.40 (labour), and 0.25 (capital). Figures are average annual percentage-point (pp) contributions to output growth, 2018-2025.

It's worth noting that the TFP residual concentrates in exactly the two sub-sectors cotton-textile and horticulture/viticulture that showed the strongest SCI-productivity correlation above. That's consistent with, though it doesn't by itself prove, the idea that convergence has worked mainly through organizational and allocative efficiency channels in these sub-sectors rather than through simple input accumulation. In grain and especially livestock, output growth looks to have been driven predominantly by expansion of conventional inputs, suggesting the organizational reforms examined here have so far played a comparatively limited role in raising efficiency in those two sub-sectors.

4. Discussion

Convergence as a conditional, not unconditional, driver of efficiency

The Kashkadarya evidence supports a qualified version of the hypothesis that organizational and economic convergence raises production efficiency. The association is robust and economically meaningful in cotton-textile and horticulture/viticulture, where clustering has been most extensive and has coincided with parallel investment in

processing capacity, water-saving technology, and export logistics. It's considerably weaker in grain and essentially absent in livestock. This fits the theoretical expectation that convergence delivers efficiency gains chiefly by relaxing binding constraints market access, input finance, processing capacity that differ substantially across sub-sectors. Where these constraints were most binding before reform, as in cotton procurement and horticultural export logistics, convergence appears to have generated the largest measurable productivity response. Where the binding constraint lies elsewhere as in livestock, where the main limitations relate to fragmented household herd sizes, feed-base deficiencies, and veterinary service access rather than market integration per se organizational convergence modelled on the cluster template has so far had limited traction.

Distributional and governance considerations

None of this should be read as evidence that convergence has been costless for everyone in the value chain. The broader literature on Uzbekistan's cluster reform has documented concerns that, particularly in the early cotton-cluster rollout, contractual terms between cluster operators and farmers concentrated bargaining power with the cluster firm, and that in the absence of competitive procurement channels, this risked replacing a state monopsony with a private one. Regional aggregate productivity gains are, in principle, entirely compatible with a redistribution of income away from farmers toward cluster operators, if output prices paid to farmers don't track productivity gains. The data used here don't allow a farm-level assessment of this distributional channel, and that's a genuine gap: aggregate efficiency gains and farmer welfare outcomes are analytically distinct, and any policy evaluation of convergence should track both.

Methodological limitations and threats to inference

Three methodological caveats temper how far these conclusions can be pushed. The small sample size (32 pooled sub-sector-year observations) limits statistical power and the ability to include a fuller set of controls or test for non-linearities in the convergence-productivity relationship. The Sectoral Convergence Index, while grounded in officially reported cluster and processing-share data, is a constructed proxy rather than a directly measured integration statistic, and alternative weighting schemes or component choices could yield somewhat different index trajectories though sensitivity checks using alternative equal-weighting and principal-component weighting schemes (not reported in detail here) produced qualitatively similar sub-sectoral rankings. And the analysis can't fully rule out reverse causality or omitted common drivers: districts or sub-sectors that received priority infrastructure investment for reasons unrelated to convergence policy (proximity to export corridors, for instance) may have experienced both faster clustering and faster productivity growth for reasons the model doesn't capture. Future research combining farm-level survey data ideally through direct collaboration with regional agro-service centres and cluster operators with the aggregate approach used here would substantially strengthen causal inference.

Comparison with national and cross-country evidence

The sub-sectoral heterogeneity found here for Kashkadarya broadly matches national-level assessments of Uzbekistan's agricultural reform, which report substantial productivity and export gains in cotton, grain, and horticultural value chains alongside continued acknowledgement including by international financial institutions that water productivity remains exceptionally low by global standards, with Uzbekistan ranking among the lowest twenty countries worldwide on this metric in 2023. The World Bank-supported irrigation modernization programs approved in 2025, aimed at reducing water losses across several regions, target directly the infrastructural constraint that this study identifies as the most likely complementary condition for convergence to translate into efficiency gains in a water-scarce region like Kashkadarya. This suggests the marginal

return to further deepening organizational convergence in Kashkadarya's grain and livestock sub-sectors may depend more on the pace of water-infrastructure investment than on the intensity of cluster formation per se.

Policy implications for a water-constrained agrarian region

The Kashkadarya evidence carries implications beyond the region itself, for other water-constrained agrarian regions of Uzbekistan and Central Asia pursuing similar cluster-based reforms. Sequencing matters: convergence appears to have delivered the largest efficiency gains where it followed, or proceeded jointly with, investment in processing capacity and water-use efficiency, rather than preceding it. Regions or sub-sectors where irrigation infrastructure and processing capacity remain underdeveloped may see only limited productivity benefits from cluster formation alone which means regional investment planning, such as Kashkadarya's 2026 program to modernize pumping stations and expand water-saving technology across tens of thousands of hectares, should where possible be coordinated with, rather than trail behind, the pace of cluster expansion.

The pronounced weakness of the convergence-productivity association in livestock also points to the limits of applying a single organizational template across structurally different sub-sectors. Because the great majority of livestock output in Uzbekistan originates in dehkan household farms rather than the larger contracted landholdings the cluster model was designed around, policy instruments better suited to fragmented smallholder structures milk-collection cooperatives, veterinary and breeding service cooperatives, small-scale feed-base development programs may offer a more productive complement to, or partial substitute for, large-scale clustering in this sub-sector. Grain's intermediate position suggests it might benefit from a hybrid approach that preserves elements of state-guided contracting for food-security purposes while progressively expanding private grain-cluster participation, informed by the more clearly positive experience of cotton and horticultural clusters.

Finally, from a monitoring and evaluation standpoint, this analysis underscores the value of developing an official, publicly accessible regional cluster-performance registry disaggregated by sub-sector one that would let future assessments of convergence policy move beyond the composite proxy indices constructed here and incorporate farm-level income and welfare indicators alongside aggregate productivity measures.

5. Conclusions

This study examined the organizational and economic effects of agricultural sector convergence on production efficiency in Kashkadarya region over 2018-2025, using a constructed Sectoral Convergence Index linked to partial and total factor productivity indicators through correlation and regression analysis. Three conclusions follow. Convergence between agriculture and adjoining processing, financial, and service sectors has advanced substantially in Kashkadarya since 2018, but unevenly across sub-sectors proceeding furthest in cotton-textile and horticulture/viticulture chains and lagging in grain and, especially, livestock. The association between convergence and land productivity is strong and robust for cotton-textile and horticulture/viticulture, moderate for grain, and weak for livestock, which suggests organizational integration is a conditional rather than universal driver of efficiency, one whose effectiveness depends on the specific constraints binding in each sub-sector and on complementary infrastructural investment, particularly in irrigation and water-saving technology. And the regional evidence suggests that further deepening the cluster model in isolation is unlikely to close the productivity gap in livestock and, to a lesser extent, grain; targeted investment in feed-base development, veterinary and breeding services, and smallholder-compatible

cooperative mechanisms may offer a more productive complement to organizational convergence in these sub-sectors than continued expansion of the cotton-cluster template.

For regional policy, these findings support a differentiated approach: continued consolidation and quality upgrading of existing cotton-textile and horticultural clusters, including deeper processing and export-logistics investment; a recalibration of the livestock support model toward dehkan- and small-farm-compatible cooperative and service structures rather than large-scale clustering; and prioritization of irrigation and water-saving infrastructure investment as a complementary condition and in some sub-sectors possibly a precondition for organizational convergence to yield measurable efficiency gains. For research, the study points to the value of collecting farm-level survey data in Kashkadarya to complement the aggregate statistical approach used here, particularly to assess how convergence affects farmer incomes and bargaining power alongside its aggregate productivity effects.

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