Cooperative Infrastructure Sharing for Food-Industry Efficiency

Abdibositova Muxlisaxon Latayibxonovna
Doctoral Researcher at Tashkent State University of Economics, Uzbekistan

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Abstract

This article designs and formalises a cooperative infrastructure-sharing mechanism for raising economic efficiency in food-manufacturing industries characterised by a fragmented, small-firm structure. The purpose of the study is to resolve three interlocking contradictions that prevent rising resource and investment inflows from translating into efficiency gains: a decreasing-returns-to-scale regime in which neither individual expansion nor continued fragmentation improves returns; a weak capital elasticity of output despite rapidly growing investment; and a declining technology-absorption rate despite accelerating equipment imports. Drawing on transaction-cost economics, the theory of institutions, hybrid governance forms, and cluster theory, the mechanism is built as a two-layer structure — a technological process chain and a governance layer of three prioritised blocks (technology absorption, shared cooperative infrastructure, and investment redirection) — closed by a monitoring–deviation–reallocation feedback loop. A minimum-membership condition for shared facilities, a loss-reduction valuation formula, an impact-weighted resource-allocation rule, and a target-achievement gain formula are derived to make the mechanism's blocks measurable and auditable rather than descriptive. Illustrative calibration shows that a cooperative cold-storage or testing facility becomes economical once the number of participating firms exceeds a threshold determined by the ratio of shared to standalone facility costs, and that closing the gap between current and best-practice efficiency levels can recover a substantial share of currently wasted resources without any net increase in resource inflow. The findings offer manufacturing-policy makers a practical, verifiable alternative to firm-level subsidy programmes that treat scale, technology, and investment problems in isolation.

Keywords: Food industry, organisational-economic mechanism, shared infrastructure, cluster cooperation, transaction costs, scale efficiency, technology absorption.

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1. Introduction

A recurring pattern in transition-economy food industries is that resource and investment inflows keep growing while measured efficiency does not follow. Three specific, empirically documented contradictions typically underlie this pattern. First, when the sector's aggregate production technology exhibits decreasing returns to scale, an individual firm's expansion lowers rather than raises its marginal return, yet the sector is simultaneously dominated by micro and small enterprises whose average capital base is too thin to justify firm-level modern infrastructure — so that neither growing nor staying small resolves the inefficiency. Second, investment inflows can rise by an order of magnitude while the estimated output elasticity of capital remains low and the return materialises almost entirely within the same year, with little carry-over to subsequent periods — indicating that capital is financing replacement and working-capital needs rather than genuinely new productive capacity. Third, the coefficient capturing how fully new equipment is actually absorbed into project-designed operating regimes can decline even as the share of externally financed, imported machinery rises sharply — machinery arrives, but the accompanying technological competence does not.

None of these three contradictions can be resolved by a single firm acting alone: an individual producer cannot change the sector's scale regime, cannot redirect the composition of aggregate investment flows, and cannot build a technical-service ecosystem by itself. Each therefore points to a coordination failure at the inter-firm level rather than a deficiency correctable through firm-level technical assistance alone, and each requires an organisational-economic mechanism operating above the level of the individual enterprise.

Institutional economics offers the relevant analytical tools for such inter-firm coordination. R.Coase's analysis of the boundary between markets and firms [1], O.Williamson's extension of that boundary problem to contractual governance [2], C.Menard's treatment of hybrid forms situated between market and hierarchy [4], and D.North's account of how institutions shape economic performance [3] together explain why a shared, contractually governed facility can outperform both fully independent firms and full vertical integration when transaction costs and asset specificity take intermediate values. M.Porter's cluster framework [5; 6] provides the complementary argument that geographic and sectoral proximity among otherwise independent firms can itself be a source of competitive advantage once shared infrastructure and institutions are in place.

The purpose of this article is to translate this institutional logic into an operational, three-block organisational-economic mechanism for food-manufacturing efficiency, to formalise the conditions under which its central instrument — shared cooperative infrastructure — becomes economically viable, and to specify measurable targets and a feedback procedure that make the mechanism auditable rather than declarative.

2. Methods

The mechanism is constructed as a two-layer architecture. The first layer represents the sector's technological process chain — the sequence of raw-material supply, processing, storage and logistics, market access, and financial outcome — each node of which is characterised by a measurable state variable inherited from prior empirical assessment (e.g., a seasonality coefficient, a technology-absorption level, a loss rate, an export-coverage ratio, a profitability rate). The second layer consists of governance blocks, each attached to a specific node of the process chain through a dedicated economic instrument and a dedicated outcome indicator, so that the effect of any instrument can, in principle, be traced and tested rather than assumed.

Three governing principles structure the mechanism. First, sequential dependency: the weakest node in the process chain constrains the sector-wide outcome, regardless of how well other nodes perform. Second, evidence-based prioritisation: resources are allocated across the three blocks in proportion to each factor's previously estimated statistical contribution to efficiency, not according to ex-ante administrative judgement. Third, mandatory feedback: measured outcomes are compared against targets at fixed intervals, and the resulting deviation reallocates resources among blocks for the subsequent period, closing an otherwise open-loop system.

The viability condition for shared infrastructure (Block II) is derived from a simple cost-comparison rule: cooperation is economical for a participating firm only if its share of the annual cost of a jointly used facility is lower than the cost of maintaining an equivalent standalone facility. This yields a minimum-membership threshold:

$$n_{min} = \left\lceil \frac{F_u}{c_y} \right\rceil \qquad (1)$$

where Fu denotes the annual cost of the shared facility (depreciation, energy, and operating staff) and cy denotes the annual cost a single firm would incur to provide the equivalent service independently; the ceiling operator reflects that membership is a discrete quantity. The economic value of loss reduction achieved through shared cold-storage, laboratory, and logistics facilities (Block II) is obtained by comparing the value of raw material lost at the baseline and target loss rates:

$$\Delta L = C \cdot m \cdot \left(\frac{\lambda_0}{1-\lambda_0} - \frac{\lambda_1}{1-\lambda_1}\right) \qquad (2)$$

where C is total operating cost, m is the material-cost share of that total, and λ0, λ1 are the baseline and target loss rates. Resources directed to the mechanism as a whole are allocated across the three blocks in proportion to their previously estimated marginal contribution to the sector's efficiency score:

$$\omega_i = \frac{h_i}{\sum_{j=1}^{3} h_j}, \quad R_i = \omega_i \cdot R \qquad (3)$$

where hi is the estimated contribution of block i and R is the total resource envelope available to the mechanism. The expected gain from raising the technology-absorption coefficient (Block I) toward its target level is obtained from the previously estimated marginal-effect relationship between that coefficient and the sector's efficiency score:

$$\Delta TE = \gamma \cdot \Phi \cdot (A^* - A_0) \cdot 100 \qquad (4)$$

where γ is the estimated marginal coefficient, Φ is the corresponding censoring (non-truncation) probability, and A0, A* are the current and target absorption levels. Finally, the aggregate economic gain from moving the sector from its current efficiency level to a target level is:

$$E_m = [(1 - TE_0) - (1 - TE^*)] \cdot (K + C) \cdot P_t \qquad (5)$$

where TE0 and TE* are the current and target technical-efficiency scores, K and C are input quantities at constant prices, and Pt is the price index required to restate the gain in current-price terms. Equations (1)–(5) were calibrated using stylised, order-of-magnitude parameter values consistent with the sector's previously estimated efficiency profile, so as to illustrate the mechanism's internal logic without reproducing any single firm-level or year-specific figure.

3. Results

The resulting mechanism comprises three prioritised blocks, each attached to a specific contradiction and to a specific, independently verifiable outcome indicator (Table 1).

Table 1

Three-block structure of the organisational-economic mechanism

Block	Contradiction addressed	Core instrument	Linked performance indicator
I. Technology absorption	Equipment inflow outpaces technology uptake	Regional technical-service network; subsidised certification	Technology absorption coefficient
II. Cooperation and shared infrastructure	Expansion and stagnation are both inefficient under decreasing returns to scale	Jointly used cold storage, testing lab, logistics pool	Scale efficiency; loss rate
III. Investment redirection	Rising investment volume without matching capital productivity	Priority financing for capacity utilisation over new capacity	Internal-funding share; capital payback lag

Source: author's elaboration.

Applying the minimum-membership rule in equation (1) to a representative shared cold-storage facility — with an illustrative annual operating cost several times larger than the cost a micro-enterprise would bear for an equivalent standalone cooling unit — shows that the facility becomes economical only once the number of participating firms exceeds a threshold in the region of six to eight; below that threshold, the shared facility is more expensive per participant than independent provision and cooperation loses its rationale. This threshold is not uniform across regions: applying it to the sector's actual spatial concentration indicates that the condition is comfortably met in the three most industrially dense regions, which together account for close to half of sectoral output, while it may not be met in the least concentrated regions, implying that Block II should be rolled out sequentially rather than simultaneously.

Applying the loss-reduction formula in equation (2) shows that lowering the sector's loss rate from its current level toward the ten-percent benchmark implied by international good-practice data on grain and legume post-harvest losses releases an amount of previously wasted material value equal to a low-double-digit share of total operating cost — a magnitude of the same order as the annual cost of establishing several regional shared-infrastructure facilities, indicating that Block II is broadly self-financing over a multi-year horizon.

The target trajectory implied by the mechanism's three blocks is summarised in Table 2.

Table 2

Target indicators of the organisational-economic mechanism

Indicator	Baseline	Target	Responsible block
Technology absorption coefficient	≈ 0.47	≥ 0.70	Block I
Scale efficiency score	≈ 0.73	≥ 0.85	Block II
Raw-material and product loss rate	≈ 14%	≤ 10%	Block II
Internal-funding share of investment	≈ 20%	≥ 35%	Block III

Source: author's elaboration, targets set relative to previously estimated sector best-practice levels.

Applying equation (5) to move the sector from its current efficiency level to the target level in Table 2 recovers roughly two-fifths of the resource-saving potential identified at the current inefficiency level, without requiring any net increase in the volume of resources employed — the gain is obtained purely through the reallocation of existing capital, materials, and organisational effort across the three blocks. Applying equation (4) to Block I indicates that most of this gain is attributable to closing the technology-absorption gap, consistent with that factor's dominant estimated contribution to the sector's efficiency score relative to the other two blocks.

4. Discussion

The three blocks resolve the three contradictions through the same underlying logic: none of them increases the volume of resources committed to the sector; each instead changes the organisational form in which existing resources are used. The scale contradiction is resolved not by firm expansion but by sharing the use of infrastructure while leaving individual production scale unchanged — the classic hybrid-governance solution described by Williamson [2] and Menard [4], and consistent with Porter's argument that clustered firms capture scale-like advantages without merging [5; 6]. The investment contradiction is resolved not by enlarging capital inflows but by redirecting them toward utilisation of existing capacity rather than construction of new capacity. The technology contradiction is resolved not by further equipment purchases but by building the technical-service and skills infrastructure that allows already-imported equipment to run at its designed operating regime.

A structural feature distinguishes this mechanism from conventional firm-level support schemes: every instrument in Table 1 is bound to a single, independently measurable outcome indicator. This binding is what makes the mechanism testable — if a subsidy for shared cold storage is granted and the loss rate does not fall, the failure is diagnosable as a design or implementation problem rather than absorbed into an unaccountable general support budget, which is the typical weakness of untargeted enterprise support identified in the food-industry investment literature.

The feedback loop adds a further safeguard against a common failure mode of infrastructure and cluster policies: treating a one-off facility grant as a permanent solution regardless of subsequent performance. By separating deviations attributable to external shocks (which should adjust the target rather than the block's resource allocation) from deviations attributable to insufficient block performance (which should trigger reallocation), the mechanism avoids both under-reacting to genuine external shocks and over-reacting to normal short-run volatility.

The mechanism's geographic sequencing implication — that shared-infrastructure blocks should be introduced first where firm density already satisfies the minimum-membership condition, and only later, if at all, where it does not — cautions against a uniform national rollout of cooperative facilities. A facility introduced below the viability threshold in equation (1) will operate at a persistent per-member cost disadvantage relative to standalone provision and is likely to be abandoned, discrediting the broader cooperative model even where it would otherwise be viable.

The main limitation of the present design is that its calibration relies on sector-level, time-series estimates rather than firm-level cross-sectional data; consequently the minimum-membership threshold and the block-level resource shares are best treated as first-order guides for pilot design rather than final operating parameters. Once firm-level data become available, the same three-block architecture can be recalibrated with firm rather than year as the unit of observation, sharpening both the viability threshold and the targeting of instruments to individual enterprises.

5. Conclusion

This study has designed a two-layer, three-block organisational-economic mechanism that addresses scale, investment, and technology-absorption contradictions in a fragmented food-manufacturing sector through the reorganisation of existing resources rather than their expansion. Grounded in transaction-cost economics, institutional theory, hybrid-governance analysis, and cluster theory, the mechanism attaches each governance block to a specific, independently verifiable outcome indicator and closes the system with a monitoring–deviation–reallocation feedback loop.

A minimum-membership condition was derived to determine when shared cooperative infrastructure is genuinely economical, together with formulas for valuing loss reduction, allocating resources across blocks in proportion to their estimated contribution, and quantifying the gain from closing the gap to best-practice efficiency. Illustrative calibration indicates that shared facilities become viable only above a firm-density threshold that is met in the most industrially concentrated regions but not uniformly across the sector, and that reaching the mechanism's target efficiency level can recover a substantial share of currently wasted resources without any net increase in resource inflow.

From a policy standpoint, the mechanism offers manufacturing authorities a verifiable alternative to undifferentiated firm-level subsidies: support is directed to specific, measurable bottlenecks, its effect is auditable against a bound indicator, and its geographic rollout is sequenced according to an explicit viability condition rather than applied uniformly. Future work should recalibrate the mechanism using firm-level panel data to refine the minimum-membership threshold and the block-level resource-allocation weights.

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