ASSESSING THE IMPACT OF DIFFERENCES IN PARTICIPANTS' TECHNOLOGICAL CAPABILITIES ON THE EFFECTIVENESS OF INNOVATION COOPERATION IN INDUSTRIAL CLUSTERS

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Annotatsiya

Tezisda sanoat klasteri ishtirokchilari o‘rtasidagi texnologik salohiyat tafovuti innovatsion hamkorlik samaradorligiga qanday ta’sir qilishi baholandi. Nazariy asos sifatida yutib olish salohiyati va optimal kognitiv masofa g‘oyalari olindi. Tafovut Jaffe burchak masofasi va salohiyat indekslari farqi orqali o‘lchandi, hamkorlik natijasi esa tafovutning kvadratik funksiyasi sifatida modellashtirildi. Milliy statistika qo‘mitasi ma’lumotlariga ko‘ra, 2024-yilda 1 835 ta korxona va tashkilot 5 521 ta innovatsiyani joriy etdi, jo‘natilgan innovatsion mahsulot hajmi 63,6 trln so‘mga yetdi. Jahon banki baholashicha, 2019-yilda klasterlar paxta hosildorligi klasterdan tashqaridagidan 0,53 t/ga yuqori bo‘ldi. Shartli (simulyatsiya qilingan) 240 juftlik misolida teskari U shaklidagi bog‘liqlik va 0,49 atrofidagi optimal tafovut ko‘rsatildi. Hamkorlarni moslashtirish, ustozlik, o‘qitish va uskunalarni birgalikda ishlatish bo‘yicha takliflar berildi.

Kalit so‘zlar: sanoat klasterlari, innovatsion hamkorlik, texnologik salohiyat, texnologik masofa, yutib olish salohiyati, teskari U shaklidagi bog‘liqlik, hamkorlarni moslashtirish.

Аннотация

В тезисе была оценена зависимость результативности инновационного сотрудничества в промышленном кластере от различий в технологическом потенциале его участников. Теоретической основой послужили концепции абсорбционной способности и оптимальной когнитивной дистанции. Разрыв был измерен угловой дистанцией Джаффе и разницей индексов потенциала, а результат сотрудничества смоделирован как квадратичная функция разрыва. По данным Национального комитета по статистике, в 2024 г. 1 835 предприятий и организаций внедрили 5 521 инновацию, а объём отгруженной инновационной продукции достиг 63,6 трлн сумов. По оценке Всемирного банка, урожайность хлопка в кластерах в 2019 г. была на 0,53 т/га выше, чем вне кластеров. На условном (смоделированном) примере из 240 пар была показана перевёрнутая U-образная зависимость с оптимальным разрывом около 0,49. Были предложены меры по подбору партнёров, наставничеству, обучению и совместному использованию оборудования.

Ключевые слова: промышленные кластеры, инновационное сотрудничество, технологический потенциал, технологическая дистанция, абсорбционная способность, перевёрнутая U-образная зависимость, подбор партнёров.

Abstract

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The thesis assessed how differences in technological capability between participants of an industrial cluster affect the effectiveness of their innovation cooperation. The theoretical basis combined absorptive capacity with the idea of an optimal cognitive distance between partners. The gap was measured with Jaffe's angular distance and with the difference between composite capability indices, and cooperation performance was modelled as a quadratic function of the gap. According to the National Statistics Committee, 1,835 enterprises and organizations introduced 5,521 innovations in 2024, and shipments of innovative products reached 63.6 trillion soums. The World Bank reported that cotton yields in clusters exceeded those outside clusters by 0.53 t/ha in 2019. A clearly labelled simulated example of 240 partner pairs illustrated an inverted U with an optimal gap of about 0.49. Recommendations were made on partner matching, mentoring, training and equipment sharing.

Keywords: industrial clusters, innovation cooperation, technological capability, technological distance, absorptive capacity, inverted U, partner matching.

INTRODUCTION

Two firms that know exactly the same things have little to teach each other, while two firms that share almost nothing may not understand each other at all. Between these extremes lies a range in which partners are different enough to bring something new and close enough to make use of it. This simple observation has large consequences for industrial clusters, where a lead processor works with dozens of farms, suppliers, service firms and research units whose equipment, skills and routines differ widely.

Uzbekistan has built such clusters at speed. In the cotton-textile sector, the number of clusters rose from 15 in 2018 to 75 in 2019, and in 2019 they already produced 73% of the country's cotton [1]. The government has since asked every cluster to run seed, soil and biological laboratories and provided more than 23 trillion soums of preferential resources over three years [2]. Similar models now operate in fruit and vegetable, grain, chemical and automotive value chains. These reforms create a dense web of partnerships, and the quality of learning inside each partnership now matters as much as the number of clusters.

The thesis asks one question: how does the gap in technological capability between cluster partners shape the effectiveness of their joint innovation, and at what size of gap is cooperation most productive? It contributes a measurement approach for the gap, a testable inverted-U specification with an explicit formula for the optimal gap, and practical rules for matching partners and narrowing gaps that are too wide.

LITERATURE REVIEW

W. M. Cohen and D. A. Levinthal defined absorptive capacity as the ability of a firm to recognise the value of external knowledge, assimilate it and apply it to commercial ends, and showed that this ability depends on prior related knowledge [3]. P. J. Lane and M. Lubatkin moved the concept to the level of the pair, arguing that a student firm learns best from a teacher firm whose knowledge base, organisational structure and commercial logic are similar to its own [4]. Learning is therefore a property of the relationship and not only of each partner.

The distance between partners became the central variable in later work. A. B. Jaffe measured technological position by the distribution of a firm's patents across technology classes and proposed the angular distance between two such vectors as a measure of technological proximity [5]. D. C. Mowery, J. E. Oxley and B. S. Silverman found that alliances raise the technological overlap of partners, which means that cooperation itself narrows the distance over time [6]. R. Boschma warned that too much proximity in

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any dimension produces lock-in, whereas too little prevents interaction, and called this the proximity paradox [7].

B. Nooteboom and co-authors joined these ideas in the theory of optimal cognitive distance. The novelty value of a partner rises with distance, while the ability to understand the partner falls, so the product of the two forms an inverted U; their panel of alliances confirmed the curvature and showed that the optimum shifts outward when absorptive capacity is higher [8]. V. Gilsing and colleagues obtained the same shape for exploration in technology networks [9]. In a cluster setting, E. Giuliani and M. Bell showed that firms with a stronger knowledge base occupy central positions in the local learning network, while weak firms remain cognitively isolated even when they are physically close [10]. Gaps that are too wide therefore leave some cluster members outside the flow of knowledge.

METHODOLOGY

Measuring the technological gap

Two measures of the gap are proposed, so that the method can be used both where patent or product data exist and where only enterprise surveys are available. The first follows Jaffe [5]. Each participant i is described by a vector of shares f_{ik} of its technological activity across K fields (for example spinning, weaving, dyeing, garment making, seed breeding, irrigation technology):

$$D_{ij}=1-\frac{\sum_{k=1}^{K} f_{ik}f_{jk}}{\sqrt{\sum_{k=1}^{K} f_{ik}^{2}\cdot\sum_{k=1}^{K} f_{jk}^{2}}} \quad (1)$$

where D_{ij} is the technological distance between partners i and j, ranging from 0 (identical profiles) to 1 (no common fields). Put simply, the formula compares what two firms work on: if their activities overlap fully the distance is zero, and if they work in entirely different fields it equals one.

The second measure captures the level of capability rather than its direction. A composite capability index is built for each participant from standardised indicators:

$$K_i=\sum_{m=1}^{M} w_m z_{im} \quad (2)$$

where K_i is the capability index of participant i, z_{im} is the score on indicator m rescaled to the 0–1 range (equipment vintage, share of engineers and agronomists, certification, digital process control, in-house testing), w_m are weights summing to one and M is the number of indicators. The normalised gap between two partners is then:

$$G_{ij}=\frac{|K_i-K_j|}{K_{max}} \quad (3)$$

where G_{ij} is the capability gap and K_{max} is the highest index observed in the cluster. In plain words, the index scores how well equipped and skilled each firm is, and the gap shows how far apart two partners stand on that scale, from 0 (equal) to 1 (the strongest firm paired with a firm that has none of the measured capabilities).

Linking the gap to cooperation performance

Following the optimal cognitive distance argument [8], the performance of cooperation between a lead firm i and a partner j is specified as:

$$P_{ij}=\alpha+\beta_1 G_{ij}-\beta_2 G_{ij}^{2}+\beta_3 A_j+\beta_4 G_{ij}A_j+\gamma X_{ij}+\varepsilon_{ij} \quad (4)$$

where P_{ij} is a 0–100 index of cooperation performance (jointly introduced product, process and agro-technological innovations, adjusted for their commercial result), A_j is the absorptive capacity of the weaker partner on a 0–1 scale, X_{ij} are controls such as the duration of the contract and the size of both firms, and ε_{ij} is the error term. An inverted U requires $\beta_1>0$ and $\beta_2>0$. Setting the first derivative to zero gives the optimal gap:

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$$G^* = \frac{\beta_1 + \beta_4 A_j}{2\beta_2} \quad (5)$$

where G^* is the gap at which cooperation performance peaks and a positive β_4 means that a partner with stronger absorptive capacity can benefit from a more distant teacher. In everyday terms, the formula finds the top of the hill: cooperation improves as the partner brings more new knowledge, until the difference becomes too large to absorb. Following J. T. Lind and H. Mehlum, the inverted U is accepted only if the slope is significantly positive at the lowest observed gap and significantly negative at the highest [11], and, as R. F. J. Haans, C. Pieters and Z.-L. He recommend, the turning point must lie well inside the data range [12].

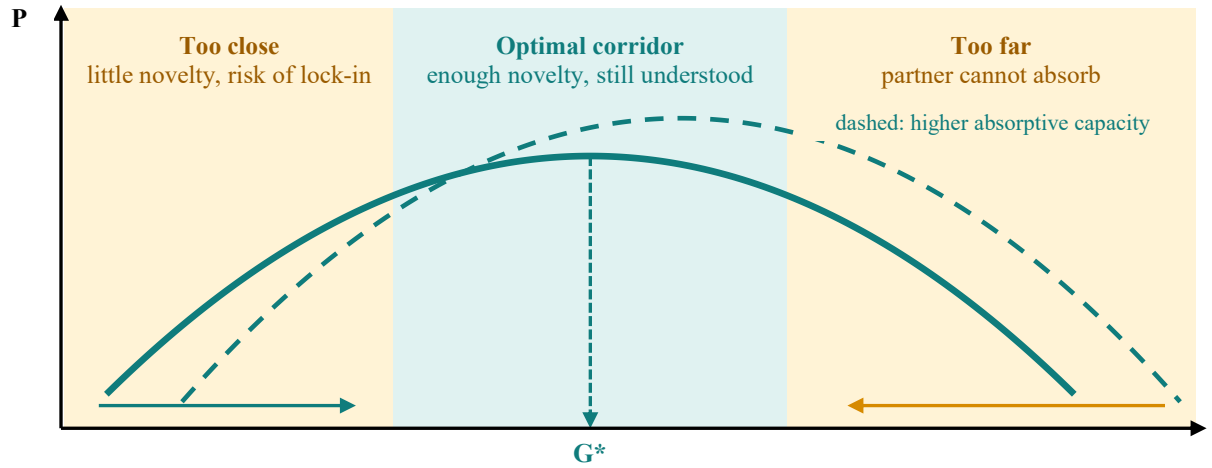


Figure 1. Capability gap and cooperation performance: the inverted U[1]

Figure 1 summarises the logic. On the left, partners with similar capabilities cooperate smoothly but generate little novelty. In the middle corridor, differences are large enough to create learning and small enough to be understood. On the right, the weaker partner cannot absorb what the lead firm offers, and joint projects stall. The dashed curve shows that investment in absorptive capacity lifts the whole curve and moves its peak to the right, while the instruments below the axis show how a cluster can move pairs out of the two weak zones.

ANALYSIS AND RESULTS

Innovation activity and capability gaps in Uzbek clusters

Table 1 sets out the national innovation statistics that frame cluster cooperation.

Table 1

Innovation activity indicators in Uzbekistan, 2020–2024[2]

[1] Source: Developed by the author based on [8]; [3]; [7].

[2] Source: Compiled by the author from [13]; [14]; [15]. Innovations per unit is the author's calculation. From 2022 the data include farms that implemented innovations.

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Year	Enterprises and organizations implementing innovations, units	Implemented innovations, units	Innovations per unit	Shipped innovative goods, works and services, bn soums
2020	1,217	4,290	3.53	31,142.8
2021	1,151	4,148	3.60	27,378.6
2022	1,323	3,792	2.87	40,451.6
2023	5,026	8,294	1.65	55,746.5
2024	1,835	5,521	3.01	63,604.4

Table 1 shows that shipments of innovative goods, works and services doubled between 2020 and 2024, an average annual growth of about 19.5%. The 2023 jump in the number of innovating units reflects the inclusion of farms in the statistics from 2022, so the drop in innovations per unit that year is a coverage effect rather than a decline in activity. In 2024, 4,889 of the 5,521 innovations were technological, and innovation expenditure amounted to 9,739.3 billion soums [15]. For cluster policy, the inclusion of farms is useful in itself: it makes the innovation behaviour of the weaker partners in agro-industrial clusters visible in official data for the first time.

The cotton-textile clusters offer the clearest evidence of a capability gap between lead firms and their partners. Table 2 summarises the indicators reported by the World Bank.

Table 2

Indicators of the technological gap in cotton-textile clusters[3]

Indicator	Value
Number of clusters, 2018 / 2019	15 / 75
Share of cotton area operated by clusters, 2018 / 2019	16% / 63%
Share of national cotton output produced by clusters, 2019	73%
Average cotton yield in clusters, 2019	2.9 t/ha
Yield advantage of clusters over non-cluster farms, 2019	0.53 t/ha
Fibre yield (ginning ratio): old gins / new investments	30–33% / up to 40%

Table 2 points to a wide but productive gap. Clusters operated on 63% of the cotton area in 2019 and obtained yields 0.53 t/ha above the rest of the sector, and the newest gins extracted up to 40% fibre against 30–33% at older plants [1]. The same report noted that many farmers lacked the capital and skills to mechanise on their own and that clusters were hiring local and foreign agronomists to transfer practices [1]. Put plainly, the lead firms already hold technology that their partners do not, and the pay-off from cooperation depends on how well that technology is passed on.

Illustrative estimation of the optimal gap

No public data set links partner-level capability gaps to cooperation outcomes in Uzbek clusters, so the estimation step is shown on an illustrative (hypothetical) data set. Python was used to simulate 240 lead firm and partner pairs with gaps drawn uniformly between 0.05 and 0.95 and absorptive capacity between 0 and 1. The assumed data-generating process was $P=20+50G-60G^2+8A+16GA$ with normally distributed

[3] Source: Compiled by the author from [1]. The yield outside clusters is implied by the reported difference of 0.53 t/ha.

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noise (standard deviation 5). Equation (4) was then estimated by ordinary least squares with heteroskedasticity-robust standard errors, with absorptive capacity centred at its sample mean.

Table 3

Estimated inverted-U model on simulated partner pairs (illustrative, hypothetical data)[4]

Parameter or statistic	Estimate
Constant	22.86*** (1.31)
Gap, β_1	64.09*** (5.68)
Gap squared, $-\beta_2$	−66.04*** (5.40)
Absorptive capacity (centred), β_3	7.82*** (2.94)
Gap × absorptive capacity, β_4	15.59*** (5.46)
R^2	0.571
Slope at lowest / highest gap (t)	57.3 (11.2) / −60.2 (−12.5)
Optimal gap G^* (95% CI)	0.485 (0.465–0.506)
G^* at A = 0.2 / A = 0.8	0.450 / 0.520
Pairs too close / optimal / too far, %	25.0 / 47.5 / 27.5

The simulated estimates in Table 3 recover the assumed shape. Both curvature conditions hold, the slope is clearly positive at the smallest gap and clearly negative at the largest, and the optimal gap of 0.485 lies in the middle of the observed range with a narrow confidence interval. The interaction term moves the optimum from 0.450 for partners with low absorptive capacity to 0.520 for partners with high capacity. Taking the corridor in which predicted performance is within 5% of the peak (gaps of 0.32–0.66), about a quarter of the simulated pairs fall in the too-close zone and slightly more than a quarter in the too-far zone. If the gap of each too-far pair is narrowed by 0.15 through mentoring, training and shared equipment, its predicted performance rises by 13.7%. These numbers describe the simulated example only; they show what the method delivers once real pair-level data are collected.

CONCLUSION AND RECOMMENDATIONS

The thesis linked the effectiveness of innovation cooperation in industrial clusters to the gap in technological capability between partners. Drawing on absorptive capacity and optimal cognitive distance, it proposed two gap measures, an inverted-U performance model with an explicit optimum and a test procedure, and showed on a clearly labelled simulated example how the optimum and the zones of under- and over-distance are identified. Official statistics confirm that innovation activity in Uzbekistan is growing quickly, and the record of cotton-textile clusters shows that lead firms already hold capabilities that partners can learn from.

Four recommendations follow. First, cluster organisers can compute a capability index for each partner at the start of every season and use it for matching, pairing weaker farms or suppliers with lead units that are ahead of them but not out of reach. Second, pairs in the too-far zone can be brought into the corridor through mentoring by agronomists and engineers, joint training and staff secondment, and shared access to laboratories, testing and machinery, which builds directly on the laboratories now required in each cotton-textile cluster [2]. Third, pairs in the too-close zone gain from a third, more distant partner such as a university department or a foreign technology supplier. Fourth, the statistical form on innovation

[4] Source: Author's calculation in Python (statsmodels) on 240 simulated pairs; assumptions are stated in the text. Robust standard errors in parentheses; *** p<0.01. Not real firm-level data.

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could add a short block on cooperation partners and their capability level, which would let the model be estimated on official micro data.

The next research step is empirical validation. A survey of lead firms and partners in textile, agro-industrial and chemical clusters, repeated over two or three seasons, would allow equation (4) to be estimated with real data, the optimal gap to be compared across sectors, and the effect of gap-narrowing programmes to be measured directly.

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