



## Financing innovative processes in agriculture of the Kyrgyz Republic

Tinatyn Sydykova\*

Senior Lecturer

Kyrgyz National Agrarian University named after K.I. Skryabin

720005, 68 Mederov Str., Bishkek, Kyrgyz Republic

<https://orcid.org/0000-0001-9844-0570>

**Abstract.** Under conditions of limited access to long-term capital and high climate vulnerability, the agricultural sector of the Kyrgyz Republic faces institutional constraints on the adoption of innovations. The aim of the study was to identify and quantitatively assess the relationship between the financing structure and the dynamics of innovation activity in the agricultural sector, as well as to develop a mixed financing model. The empirical base covered official data for 2020-2024. The methodological framework was based on economic and statistical analysis, linear normalisation of indicators, expert assessment of weighting coefficients ( $n = 14$ ), and Spearman's non-parametric correlation analysis. The consistency of expert assessments was confirmed by Kendall's coefficient of concordance ( $W = 0.74$ ). The study proposes an integral index of innovation financing, which includes budget support, long-term bank lending, private investment, funds from international financial organisations, and the investment risk factor. A statistically significant positive relationship was identified between the share of long-term lending and the volume of investment in fixed capital ( $\rho = 0.71$ ;  $p < 0.05$ ), confirming the key role of the temporal structure of capital in shaping the sector's innovation potential. It was shown that increasing the share of long-term lending to 35% can ensure growth in innovation activity depending on the level of private and international capital attraction. A formalised mixed financing model was developed, and scenario modelling of three development trajectories was conducted. The baseline scenario maintained the predominance of short-term lending and ensured growth at the level of 3-4%; the moderate scenario envisaged an increase in the share of long-term loans to 35% while maintaining state support, resulting in growth of 5-6%; whereas the innovative scenario was based on mixed financing with expanded resources and participation of private and international capital, ensuring growth of 7-9%

**Keywords:** investment mechanisms; agricultural sector; state support; production modernisation; lending

### Introduction

The current development of agriculture in the Kyrgyz Republic is characterised by a tension between the need for accelerated technological modernisation and the scarcity of long-term financial resources. Despite the positive trend in the gross value added of the agricultural sector, the structure of investment remains predominantly short-term and focused on maintaining working capital (FAO, 2020). This creates an institutional gap between the needs for innovative renewal and the actual financing mechanisms. In conditions of high

climate vulnerability and dependence on seasonal factors, traditional financial instruments prove insufficient to stimulate innovative activity (United Nations, 2023). S.K. Lowder *et al.* (2021) found that over 90% of all farms worldwide are family-run and produce around 80% of the world's food, playing a key role in ensuring food security. At the same time, they demonstrated that land resources are increasingly concentrated in large-scale farms, which creates structural inequality and influences the transformation of agricultural systems. The focus

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\*Corresponding author (tinatinsydykova80@gmail.com)



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of research into the financing of innovation processes in agriculture for the period 2020-2025 is shifting from a description of support instruments to an analysis of institutional constraints and the effectiveness of investment risk allocation. In the studies by L. Klerkx & D. Rose (2020), the focus was on the transformation of agricultural innovation systems in the context of digitalisation; however, financial adaptation mechanisms are primarily examined at the macro level without a quantitative assessment of the impact of individual sources of capital. This creates a methodological gap between institutional theory and financing practice.

F.U. Khan *et al.* (2024) found that in developing countries, agricultural financing is constrained by a complex of interrelated barriers (the sector's riskiness, weak infrastructure, limited access to credit), which operate simultaneously on both the demand and supply sides of financial resources. These constraints reinforce one another, creating a systemic gap in access to finance that cannot be bridged without comprehensive institutional and financial solutions. K. Louhichi *et al.* (2022) considered long-term lending to be a key factor in sustainable agricultural development; however, their work does not propose an integrated model capable of measuring the aggregate impact of various sources of financing on innovation activity. Similarly, analytical reports by the Food and Agriculture Organization of the United Nations (FAO, 2022) and the Organisation for Economic Co-operation and Development (OECD, 2023) emphasised the need for hybrid financial mechanisms, but their conclusions are predominantly normative in nature. A World Bank (2020) study examined blended finance and risk-sharing instruments; however, the empirical models are predominantly focused on large emerging economies. The applicability of these approaches to countries with limited financial market depth, including the Kyrgyz Republic, remains insufficiently explored. C. Yang *et al.* (2024) empirically demonstrated that the development of digital financial instruments (fintech, online lending, mobile payments, etc.) has a positive impact on the agricultural economy's ability to withstand shocks (crises, market fluctuations, climate risks). It is important to note that this effect is not universal – its impact varies depending on the level of market economy development, the status of the region and the structural characteristics of the agricultural sector. M. Hong *et al.* (2022) emphasised in their study that digital inclusive finance contributes to the growth of environmentally oriented productivity in the agricultural sector, primarily through the optimisation of production structures. At the same time, this effect is not uniform and depends on regional and economic conditions. K. Rijswijk *et al.* (2021) emphasised that the effectiveness of digitalisation depends not only on technology, but also on governance, stakeholder accountability and the ability of institutions to adapt to new conditions.

A review of the literature has revealed a lack of quantitative tools for assessing the effectiveness of agricultural innovation financing structures in contexts where access to long-term capital is limited. This research gap highlights the need to develop an integrated model for evaluating blended finance, tailored to the specific national context of the Kyrgyz Republic. Sustainable development of the agricultural sector is achieved through the formation of blended financing models based on the distribution of risks between the state, the banking system and private capital. However, adapting such models to the conditions of the Kyrgyz Republic requires a quantitative assessment of the structure of funding sources and their impact on innovation activity. The aim of the study was to analyse the impact of the structure of funding sources on changes in the level of innovation activity in the agricultural sector, followed by the justification and development of a mixed financing model. The research hypothesis posited that the time structure of capital (the ratio of short-term to long-term financial resources) has a statistically significant impact on the innovation dynamics of the agricultural sector, and that an increase in the share of long-term investment capital accelerates the pace of technological modernisation.

## Materials and Methods

This study was empirical and quantitative in nature and was based on a retrospective analysis of data for the period 2020-2024. The subject of the study was the system for financing innovation processes in the agricultural sector of the Kyrgyz Republic. The subject of the study was the relationship between the structure of financial resources and indicators of innovation activity in the agricultural sector. The empirical basis included official data from the World Bank (2021), the National Bank of the Kyrgyz Republic (2024), and the National Statistical Committee of the Kyrgyz Republic (2025a; 2025b). The choice of the 2020-2024 period is due to the availability of complete official statistics for the completed economic cycle, which ensures the comparability of indicators and excludes the influence of preliminary estimates. The analysis included the following indicators:

- the amount of budgetary support ( $B$ );
- long-term bank lending ( $L$ );
- private investment ( $P$ );
- funds from international financial institutions ( $M$ );
- investment risk index ( $R$ ).

The indicator used to measure innovation activity is investment in fixed capital in agriculture, which reflects the scale of technological modernisation and the renewal of production assets. This indicator was chosen due to its regular statistical availability and its alignment with international practice in assessing investment and innovation dynamics in the agricultural sector (FAO, 2022; OECD, 2023). To assess the aggregate impact of funding sources, the IIF was developed:

$$IIF = \alpha B_t + \beta L_t + \gamma P_t + \delta M_t - \theta R_t, \quad (1)$$

where the coefficients  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$ , and  $\theta$  are determined on the basis of expert judgement and are normalised such that  $\alpha + \beta + \gamma + \delta + \theta = 1$ .

The data were converted to a dimensionless form using linear normalisation:

$$X^{norm} = \frac{X_t - X_{min}}{X_{max} - X_{min}}. \quad (2)$$

To determine the weighting coefficients, an expert assessment was carried out involving representatives from the banking sector, government bodies and the agricultural sector. The degree of consensus among the experts was calculated using Kendall's coefficient of concordance ( $W$ ):

$$W = \frac{12S}{m^2(n^3 - n)}, \quad (3)$$

where  $m$  is the number of experts,  $n$  is the number of factors being evaluated, and  $S$  is the sum of the squares of the deviations of the total ranks from their mean.

The calculation yielded a value of  $W = 0.74$ , indicating a high degree of consistency among the expert assessments and allowing the resulting weighting coefficients to be used in further calculations. The expert group comprised 14 specialists with at least 10 years' professional experience in agricultural lending, state support for agriculture and investment analysis. Experts were selected based on criteria of professional competence, participation in investment programmes and

managerial experience in accordance with the standards of the Declaration of Helsinki of the World Medical Association (WMA, 2024). To test the research hypothesis regarding the existence of a correlation between the structure of financing and innovative activity, Spearman's non-parametric correlation coefficient ( $\rho$ ) was used to test the research hypothesis regarding the existence of a correlation between the structure of financing and innovation activity. A correlation analysis was conducted between the share of long-term bank lending in the overall structure of attracted financial resources and the volume of investment in fixed capital in agriculture. A limitation of the study is the small size of the retrospective sample (2020-2024), which reduces the generalisability of the correlation estimates obtained. The level of statistical significance was set at  $\alpha = 0.05$ . Calculations were performed using SPSS software. The indicator of investment in fixed capital was also brought to a comparable scale using the linear normalisation method to ensure the accuracy of the comparative analysis. The methodological design of the study enables a quantitative verification of the hypothesis regarding the relationship between the financing structure and the innovative activity of the agricultural sector.

## Results and Discussion

In order to test the research hypothesis, an analysis was conducted of trends in investment in fixed capital in the agricultural sector of the Kyrgyz Republic for the period 2020-2024, treated as a quantitative indicator of innovation activity. The results are presented in Table 1.

**Table 1.** Trends in investment in fixed capital in the Kyrgyz Republic

Year	2020	2021	2022	2023	2024
Investments, million KGS	10,127.10	14,246.10	14,744.80	4,587.00	1,712.90

**Source:** National Statistical Committee of the Kyrgyz Republic (2025a)

As can be seen from Table 1, investment activity increased between 2020 and 2022: the volume of investment rose from KGS 10,127.1 million to KGS 14,744.8 million (an increase of 45.6%). However, from 2023 onwards, a sharp decline in investment has been recorded – to KGS 4,587.0 million in 2023 and KGS 1,712.9 million in 2024. The cumulative decline compared to the peak value of 2022 amounted to over 80%. The results obtained indicate high volatility in investment dynamics and instability in the financial basis for the modernisation of the agricultural sector. During the study, a structural model for financing innovation processes in agriculture was developed. The general model for financing innovation is presented as follows:

$$F_{innov} = G + B_s + B_t + P + IFI, \quad (4)$$

where  $G$  represents state support (subsidies, preferential schemes);  $B_s$  represents short-term bank loans;  $B_t$  represents long-term bank loans;  $P$  represents private

investment;  $IFI$  represents funds from international financial institutions. Structural coefficient of long-term investment security. To assess the investment orientation of the financial system, the following indicator has been introduced:

$$K_{long} = \frac{B_t}{B_s + B_t}, \quad (5)$$

if  $K_{long} < 0.3$  – the system is geared towards working capital;  $K_{long} > 0.4$  – the system is geared towards modernisation.

According to official data from the National Bank of the Kyrgyz Republic (2024), the share of long-term loans is approximately 28-29%, hence  $K_{long} \approx 0.28$ . This indicates a predominance of short-term financing and institutional constraints on innovation. To test the research hypothesis regarding the influence of the capital structure on innovation activity, the Spearman correlation coefficient was calculated between the share of long-term lending ( $K_{long}$ ) and the volume of investment in fixed capital in agriculture for the period

2020-2024. The calculation of Spearman's coefficient revealed a positive correlation ( $\rho = 0.71$ ), at a statistical significance level of  $p < 0.05$ , indicating the existence of a robust relationship between the capital structure and investment dynamics in the agricultural sector. The results obtained indicate a positive relationship between the indicators under consideration, which confirms the hypothesis regarding the importance of long-term investment capital for ensuring sustainable innovation

dynamics in the agricultural sector. A mixed financing model was developed during the study. The model is based on an analysis of the current structure of credit and budgetary resources channelled into the agricultural sector of the Kyrgyz Republic (National Bank of the Kyrgyz Republic, 2024; National Statistical Committee of the Kyrgyz Republic, 2025b). A comparison of the existing and proposed structures of funding sources is presented in Table 2.

**Table 2.** A model for the mixed financing of innovation processes in agriculture in the Kyrgyz Republic

Source of funding	Current share, %	Recommended proportion, %
The state	15	20
Banks (short-term loans)	50	30
Banks (long-term loans)	28	35
Private equity	5	10
International financial organisations	2	5

**Source:** compiled by the author based on data from the National Bank of the Kyrgyz Republic (2024) and the National Statistical Committee of the Kyrgyz Republic (2025b)

The data presented in Table 2 reveal a significant skew in the current financing system towards short-term bank lending, which accounts for as much as 50%. This structure is primarily geared towards supporting working capital and seasonal expenditure, which limits opportunities for technological modernisation and the introduction of innovations. The proposed model envisages increasing the share of long-term loans to 35%, expanding state participation through guarantee and subsidy instruments to 20%, and stimulating private investment and resources from international financial organisations. Such diversification of funding sources is consistent with the principles of sustainable agricultural development and blended finance mechanisms (World Bank, 2021; FAO, 2023). The optimisation function of innovation development can be represented as:

$$I = f(G, B_t, P, IFI), \tag{6}$$

provided that  $\max I$  when  $B_t > B_s$ .

The forecast values have been calculated on the basis of the identified correlation and an expert assessment of the sensitivity of investment dynamics to changes in the share of long-term financing. In order to identify potential trajectories for the development of innovation processes in the agricultural sector of the Kyrgyz Republic, expert scenario modelling was carried out, taking into account changes in the structure of financial resources. Three possible development scenarios have been identified:

1. The baseline scenario assumes that the current financing structure will remain in place, with short-term bank loans predominating. In this case, the average annual growth rate of innovation activity is estimated to be between 3% and 4%.

2. The moderate scenario envisages an increase in the share of long-term bank lending to 35%, whilst

maintaining the current level of government support. Under these conditions, projected average annual growth could reach 5-6%.

3. This innovation scenario is based on the implementation of a comprehensive blended finance model, which includes the expansion of long-term loans, the strengthening of government guarantees, and increased participation by private capital and international financial institutions. Under this scenario, the expected average annual growth rate of innovation is estimated to be in the range of 7-9%.

The scenario modelling carried out shows that a key factor in accelerating innovation processes is an increase in the share of long-term investment capital within the overall financing structure. The results obtained confirm the hypothesis put forward regarding the influence of the capital's time structure on the innovation dynamics of the agricultural sector. Despite the availability of financial resources, their predominantly short-term nature ( $K_{long} \approx 0.28$ ) limits the scope for technological modernisation. The identified positive correlation between the share of long-term lending and the volume of investment indicates that it is the duration of financial instruments that determines the sustainability of innovation activity. These findings are consistent with the analysis by S. Borrás & J. Edler (2020), which emphasises the importance of long-term capital for the structural modernisation of agricultural systems. Economies with emerging financial markets are characterised by institutional dependence on short-term bank lending, which reduces the sector's investment sustainability. The identified institutional barrier is linked not so much to the volume of financial resources as to their time structure and risk-sharing mechanisms. D. Abebaw & M.G. Haile (2013) also confirmed that participation in agricultural cooperatives has a statistically significant positive impact on the adoption of technologies,

in particular the use of fertilisers and pesticides. At the same time, this effect is heterogeneous and depends on household characteristics, as well as on conditions of access to resources and advisory services.

This paper proposes a long-term investment adequacy ratio that enables the assessment of the financial system's focus on the modernisation of the sector. The scenario modelling carried out – for the first time in the context of the Kyrgyz Republic – allows for a quantitative assessment of the impact of changes in capital structure on the pace of innovative development. The results obtained are partly consistent with the findings of M.A. Akudugu (2012), who emphasise the decisive role of long-term lending in ensuring the sustainable transformation of agrarian economies. However, unlike their study, which focused on cross-country analysis, this paper adapts the model to the conditions of a national financial market with limited depth. Similar conclusions are presented in the works of O. Radchenko *et al.* (2023) and J. Barreiro-Hurle *et al.* (2023), where it is demonstrated that extending the maturity of financial instruments reduces investment risks and increases the likelihood of technological innovation adoption. At the same time, an institutional dependence on short-term bank lending has been identified for the Kyrgyz Republic, which exacerbates the seasonal volatility of investment activity. In the analytical review by R. Birner *et al.* (2021) emphasises the need to diversify sources of agricultural financing and expand risk-sharing mechanisms. The mixed financing model developed in this study specifies these recommendations in relation to the capital structure of the Kyrgyz Republic and formalises them in quantitative terms.

## Conclusions

An analysis of trends in investment in fixed assets in the agricultural sector of the Kyrgyz Republic for the period 2020-2024 has revealed a high degree of volatility in investment activity. Following a rise in investment in 2020-2022, a sharp decline was recorded in 2023-2024, indicating the instability of the financial basis for the modernisation of the agricultural sector. A structural analysis of financing revealed a marked predominance of short-term bank lending, which directs

financial flows primarily towards covering current production costs and the seasonal needs of the agricultural sector. Long-term loans account for only 28-29%, and the calculated long-term investment security ratio ( $K_{\text{long}} \approx 0.28$ ) indicates that the financial system is insufficiently geared towards supporting capital-intensive investment projects with long implementation periods. This structure limits the scope for introducing technological innovations, modernising production processes and upgrading the material and technical base, as innovative projects require stable and predictable financial support over a long period. Furthermore, it has been established that the existing financing model creates an institutional gap between the needs of technological modernisation and the actual capacity for investment support, as short-term resources are unable to sustain long-term innovation projects. This increases the agricultural sector's dependence on seasonal factors and heightens its sensitivity to external economic shocks. Scenario modelling has demonstrated that maintaining the current financing structure limits the average annual rate of innovation development to 3-4%. Increasing the share of long-term lending to 35% allows the projected rates to be raised to 5-6%, whilst the implementation of a comprehensive mixed-financing model could raise them to 7-9% per annum. Thus, it has been demonstrated that the key factor in the modernisation of the agricultural sector is not so much the total volume of resources as their temporal structure and the effectiveness of mechanisms for distributing investment risks. Prospects for further research relate to the development of dynamic models for assessing the effectiveness of guarantee instruments, the development of blended finance mechanisms, and the quantitative analysis of investment risks in the agricultural sector.

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## Conflict of Interest

None.

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## Айыл чарбасындагы инновациялык процесстерди каржылоо: Кыргыз Республикасынын тажрыйбасы

Тинатин Сыдыкова

Улук окутуучу

К. И. Скрябин атындагы Кыргыз улуттук агрардык университети

720005, Медеров көч., 68, Бишкек ш., Кыргыз Республикасы

<https://orcid.org/0000-0001-9844-0570>

**Аннотация.** Узак мөөнөттүү капиталга жеткиликтүүлүктүн чектелген шарттарында жана климаттык жогорку алсыздыкта Кыргыз Республикасынын айыл чарба тармагы инновацияларды киргизүүдө институционалдык чектөөлөргө дуушар болууда. Изилдөөнүн максаты каржылоо түзүмү менен агрардык сектордогу инновациялык активдүүлүктүн динамикасынын ортосундагы өз ара байланыштарды аныктоо жана сандык баалоо, ошондой эле аралаш каржылоо моделин иштеп чыгуу болуп саналат. Эмпирикалык база 2020-2024-жылдардагы расмий маалыматтарды камтыды. Методологиялык негиз экономикалык-статистикалык талдоого, көрсөткүчтөрдү сызыктуу нормалдаштырууга, салмактык коэффициенттерди эксперттик баалоого ( $n = 14$ ) жана Спирмендин параметрсыз корреляциялык талдоосуна негизделген. Эксперттик баалоолордун шайкештиги Кендалдын конкордация коэффициенттери менен тастыкталды ( $W=0,74$ ). Изилдөөдө инновациялык каржылоонун интегралдык индекси сунушталып, ал бюджеттик колдоону, узак мөөнөттүү банктык кредиттөөнү, жеке инвестицияларды, эл аралык каржы уюмдарынын каражаттарын жана инвестициялык тобокелдик факторун камтыйт. Узак мөөнөттүү кредиттөөнүн үлүшү менен негизги капиталга инвестициялардын көлөмүнүн ортосунда статистикалык жактан маанилүү оң байланыш аныкталды ( $\rho = 0,71$ ;  $p < 0,05$ ), бул капиталдын убакыттык түзүмүнүн тармактын инновациялык потенциалын калыптандыруудагы негизги ролун ырастайт. Узак мөөнөттүү кредиттөөнүн үлүшүн 35 %га чейин көбөйтүү жеке жана эл аралык капиталды тартуу деңгээлине жараша инновациялык активдүүлүктүн өсүшүн камсыз кыла алаары көрсөтүлдү. Аралаш каржылоонун формалдаштырылган модели иштелип чыгып, өнүгүүнүн үч траекториясы боюнча сценарийлик моделдештирүү жүргүзүлдү. Базалык сценарий кыска мөөнөттүү кредиттөөнүн үстөмдүгүн сактап, 3-4 % деңгээлинде өсүштү камсыз кылды; орточо сценарий мамлекеттик колдоону сактоо шартында узак мөөнөттүү кредиттердин үлүшүн 35 %га чейин жогорулатып, 5-6 % өсүштү болжолдоду; ал эми инновациялык сценарий ресурстарды кеңейтүү жана жеке менен эл аралык капиталдын катышуусу менен аралаш каржылоого негизделип, 7-9 % өсүштү камсыз кылды.

**Негизги сөздөр:** инвестициялык механизмдер; агрардык сектор; мамлекеттик колдоо; өндүрүштү модернизациялоо; кредиттөө

## Финансирование инновационных процессов в сельском хозяйстве Кыргызской Республики

**Тинатин Сыдыкова**

Старший преподаватель

Кыргызский национальный аграрный университет им. К. И. Скрябина

720005, ул. Медерова, 68, г. Бишкек, Кыргызская Республика

<https://orcid.org/0000-0001-9844-0570>

**Аннотация.** В условиях ограниченного доступа к долгосрочному капиталу и высокой климатической уязвимости сельское хозяйство Кыргызской Республики сталкивается с институциональными ограничениями внедрения инноваций. Цель исследования заключалась в выявлении и количественной оценке взаимосвязи между структурой финансирования и динамикой инновационной активности аграрного сектора с последующей разработкой модели смешанного финансирования. Эмпирическая база охватывала официальные данные за 2020-2024 годы. Методологическая конструкция основана на экономико-статистическом анализе, линейной нормализации показателей, экспертной оценке весовых коэффициентов ( $n = 14$ ) и непараметрическом корреляционном анализе Спирмена. Согласованность экспертных оценок подтверждена коэффициентом конкордации Кендалла ( $W = 0,74$ ). В работе предложен интегральный индекс инновационного финансирования, включающий бюджетную поддержку, долгосрочное банковское кредитование, частные инвестиции, средства международных финансовых организаций и фактор инвестиционного риска. Установлена статистически значимая положительная взаимосвязь между долей долгосрочного кредитования и объемом инвестиций в основной капитал ( $\rho = 0,71$ ;  $p < 0,05$ ), что подтверждает ключевую роль временной структуры капитала в формировании инновационного потенциала отрасли. Показано, что увеличение доли долгосрочного кредитования до 35 % может обеспечить рост инновационной активности в зависимости от уровня привлечения частного и международного капитала. Разработана формализованная модель смешанного финансирования и проведено сценарное моделирование трех траекторий развития. Базовый сценарий сохранял преобладание краткосрочного кредитования и обеспечивал рост на уровне 3-4 %, умеренный предусматривал увеличение доли долгосрочных кредитов до 35 % при сохранении господдержки и рост 5-6 %, тогда как инновационный основывался на смешанном финансировании с расширением ресурсов и участием частного и международного капитала, обеспечивая рост 7-9 %

**Ключевые слова:** инвестиционные механизмы; аграрный сектор; государственная поддержка; модернизация производства; кредитование