THE PHARMACEUTICAL SECTOR IN SERBIA'S BIOECONOMY: EVIDENCE FROM THE AGRI-FOOD VALUE CHAIN

Miljan Adamović[1], Azra Hodžić[2], Radmila Kazanović[3], Sunita Delić-Ćustendil [4]

**Corresponding author E-mail: miljan.adamovic@ffbg.edu.rs*

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ABSTRACT

The aim of the paper is to analyse the pharmaceutical sector in the Republic of Serbia's agro-based production system through a comparative analysis with the food industry over the period 2016–2024. The analysis relies on aggregated sectoral financial data and uses various financial indicators. The findings show that the pharmaceutical sector consistently achieves higher value added, stronger export orientation, faster long-term growth dynamics, and more stable performance than the food industry. This confirms the existence of a pronounced structural gap within Serbia's bio-economy between traditional agro-industrial sectors and knowledge-intensive bio-based industries. The findings provide a quantitative basis for assessing the role of the pharmaceutical sector as a carrier of higher value-added stages in the agro-based production system.

Introduction

In modern development strategies, increasing attention has been paid to the concept of the bioeconomy and the role of agro-based sectors in creating sustainable economic growth (Rodrik, 2004). In order to respond to population growth, environmental challenges and the need for sustainability, development models are increasingly redirected toward renewable energy sources and biological resources. The food industry plays an important role in this process through the valorization of agricultural and food waste and by-products, generating not only food products, but also inputs for feed, cosmetics,

1 Miljan Adamović, Faculty of Medical Sciences, University of Kragujevac, 34000 Kragujevac, Serbia; Pharmacy Institution "Zdravlje lek", 11000 Belgrade, Serbia, E-mail: miljan.adamovic@ffbg.edu.rs, ORCID ID (https://orcid.org/0009-0009-9088-7576)

2 Azra Hodžić, Victoria International University, Faculty of Health Studies, 88000 Mostar, Bosnia and Herzegovina; Gorsen Ltd., 88000 Mostar, Bosnia and Herzegovina, E-mail: azrah_sa@yahoo.com, ORCID ID (https://orcid.org/0009-0004-6817-7272)

3 Radmila Kazanović, Naut Group doo, 7300 Bijeljina, Bosnia and Herzegovina E-mail: r.zelenovic@gmail.com, ORCID ID (https://orcid.org/0009-0009-7216-8084)

4 Sunita Delić-Ćustendil, Polyclinic for Blood Transfusion, University Clinical Center Tuzla,75000 Tuzla, Bosnia and Herzegovina, E-mail: sunitacustendil1970@gmail.com, ORCID ID (https://orcid.org/0009-0008-4713-1864)

pharmaceuticals, energy, and agronomy. Nevertheless, in most empirical analyses, the focus remains predominantly on primary agriculture and the food industry, while the role of knowledge- and technology-intensive sectors within bio-based value chains is still insufficiently explored, especially in developing and transition economies. At the same time, there is a lack of methodological standardization and limited integration of the environmental, economic, and social dimensions of sustainability (Vasić, Ristić, & Vasić Garić, 2025).

The existing literature largely points to the problem of the low degree of finalization of agricultural products and the limited ability of agro-food systems to generate high value-added products. In a broader perspective, this issue fits into the general debate on structural transformation and the transition from lower- to higher-productivity activities (Rodrik, 2004). However, empirical studies that quantitatively examine structural differences between classical agro-industrial sectors and technologically advanced bio-based industries remain relatively rare.

In this context, the pharmaceutical industry represents a particularly interesting case. Although it is commonly classified within the chemical or health industries, its production and technological profile is closely linked to the broader bio-based system and industrial biotechnology (Wydra, 2019). Despite this, its position within agro-based value chains has rarely been the subject of systematic empirical analysis, especially in direct comparison with the food industry.

In the case of the Republic of Serbia, this research gap gains additional importance. Despite a strong agricultural resource base and a long-standing reliance on the food industry, the economy remains largely oriented toward lower stages of processing and products with relatively modest added value. Increasing productivity therefore requires stronger investment in new technologies, modernization of existing capacities, and the development of activities that generate higher value added (Aničić et al., 2025). The food industry represents a significant segment of the Serbian economy (Božić & Nikolić, 2023), with exports dominated by primary and semi-processed agricultural and food products (Vapa Tankosić & Mirkov, 2025). Certain knowledge-intensive sectors, such as pharmaceuticals, exhibit significantly higher levels of productivity, export orientation, and technological complexity, yet their role within the broader bioeconomy framework has not been systematically and quantitatively assessed.

Starting from this problem, this paper conducts a comparative empirical analysis of the food sector (C10) and the pharmaceutical sector (C21) in Serbia over the period 2016–2024, in order to assess their relative positions within the agro-based value chain. Therefore, the aim is to analyse the pharmaceutical sector in Serbia as a structurally higher, knowledge- and technology-intensive segment of the agro-based value chain compared to the food sector, and to quantify the differences in their development patterns, levels of value added, and international competitiveness. The analysis is based on sectoral financial and performance indicators, including measures of value added, labor productivity, export intensity, growth dynamics, and performance stability.

Literature review

Bioeconomy represents a multidisciplinary framework for economic development based on renewable biological resources and their transformation through science- and technology-intensive processes (Wydra, 2019; Wang et al., 2022). It encompasses not only primary agriculture, but also a wide range of industrial activities in which biological inputs are used to produce food, materials, energy, and other bio-based products. In this sense, the bioeconomy is commonly defined as an economic system relying on research, innovation, and biological knowledge to generate economic activity and public benefit (The White House, 2012; OECD, 2009). Within the European Union, the Pharmaceutical Strategy for Europe further emphasizes the role of pharmaceuticals as a strategic and innovation-intensive segment of this broader bio-based system, aligned with the objectives of the European Green Deal and the New Industrial Strategy (European Commission, Pharmaceutical Strategy for Europe, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0761).

In the agro-bio context, the agri-food value chain links agricultural production, processing, distribution, and final consumption. Although modern trends increasingly emphasize sustainability and circularity (Tošović-Stevanović & Ristanović, 2024), the key development challenge within the bioeconomy is not the quantitative expansion of output, but the transition toward higher stages of product finalization and higher value added through the integration of knowledge and technology (Diakosavvas & Frezal, 2019). Numerous studies indicate that the performance of agro-based sectors depends not only on resource endowments, but also on organizational, managerial, and knowledge-intensive factors, as well as on the capacity for functional and structural upgrading (Cvijanović et al., 2015). During the COVID-19 period, these issues became even more closely linked to the broader concept of economic sustainability (Gyarmati, 2024).

The link between the bioeconomy and sustainable development is reflected in the emphasis on efficient resource use, waste reduction, and the integration of biological resources within circular economic processes (Georgescu-Roegen, 1971; Wydra, 2019). From this perspective, agro-bio systems should be viewed not as isolated production units, but as integrated value chains that enable the transition from low-value to high-value products (Wang et al., 2022).

While much of the literature focuses on primary production and the food industry, increasing attention is being paid to knowledge-intensive sectors such as pharmaceuticals and biotechnology, which transform biological resources into products with significantly higher economic value (Wydra, 2019; Diakosavvas & Frezal, 2019). The pharmaceutical sector is characterized by the intensive use of knowledge and technology, high regulatory standards, long development cycles, and a high level of value added embodied in final products (Wydra, 2019; Wang et al., 2022). For this reason, it can be interpreted as a higher segment of the bio-based value chain, in which scientific research, technological innovation, and global market orientation play a central role.

For countries with a strong agricultural base, such as Serbia, the integration of primary production with knowledge- and technology-intensive stages of processing represents a key mechanism for improving competitiveness and long-term growth (Diakosavvas & Frezal, 2019). However, the development of such linkages is constrained by institutional and structural weaknesses, including insufficient attention to sustainability reporting and value-added processing in agriculture (Stojić et al., 2024). At the same time, food industry by-products should be viewed not as waste, but as potential inputs for other production processes within the circular economy framework (Rajković et al., 2020).

Conceptually, this implies not only the modernization of traditional production capacities, but also the strengthening of linkages between agriculture, the food industry, and knowledge-intensive sectors such as pharmaceuticals. Similar evidence on the importance of organizational, managerial, and innovation-related factors for performance has been identified in other agro-based activities, such as beekeeping (Čavlin et al., 2023). In the Serbian context, stronger integration between the agri-food system and the pharmaceutical sector opens opportunities for the development of biopharmaceuticals, nutraceuticals, and herbal medicines, thereby strengthening value chains and competitiveness. At the same time, environmental challenges require pharmaceutical companies to adopt ambitious decarbonization strategies and advanced technological approaches, including green chemistry and AI-based modeling tools (Miralles-Quirós & Miralles-Quirós, 2022; Bratovčić, 2024).

Such a broader view of the bioeconomy as an integrated system supports the idea that research and technological innovation should not be viewed in isolation, but as key drivers of structural transformation toward higher value-added stages of production (Wang et al., 2022). In this sense, positioning the pharmaceutical sector within the agro-bio value chain provides a useful conceptual framework for understanding how biological resources can be utilized in a way that maximizes economic and social value while supporting sustainable development.

Materials and methods

This research is based on a combination of structural, descriptive and comparative analysis of sectoral data, with the aim of assessing the position of the pharmaceutical sector within the agro-food and bio-based value chain in Serbia over the period 2016–2024, which allows the simultaneous consideration of long-term trends and structural changes related to the COVID-19 pandemic.

The main data sources are aggregated financial reports from the Agency for Economic Registers (APR, 2025) and data from the Republic Institute of Statistics (SORS, 2025), based on the Classification of Activities fully aligned with NACE Rev.2. These sources enable consistent and methodologically comparable monitoring of sectoral trends over time.

The empirical analysis focuses on two processing industry sectors representing key segments of the bio-based production system: C10 – Production of food products and C21 – Production of basic pharmaceutical products and pharmaceutical preparations.

Agriculture is considered as a structural and conceptual component of the bioeconomy, but is not included in the direct quantitative analysis.

Due to the limited availability of sufficiently disaggregated national accounts data, the paper applies an accounting approach to the approximation of gross value added based on financial statements. Although such aggregated indicators have well-known limitations, they provide a consistent basis for comparative and structural sectoral analysis, as also noted in the literature (Čavlin, Pešić & Pešić, 2025). Gross value added (GVA) is calculated as the difference between total business income and intermediate consumption, including the costs of materials, energy, production services, intangible costs, and the purchase value of goods sold.

Based on the basic variables — gross value added (GVA), number of employees (EMP), total business income (REV) and export revenues (EXP) — several derived indicators are constructed: GVA per employee (GVA/EMP) as a measure of productivity, exports per employee (EXP/EMP) as an indicator of international competitiveness, and the share of exports in total revenues (EXP/REV) as a measure of sectoral internationalization.

The methodological framework combines several complementary approaches. First, a descriptive and dynamic analysis is applied using index numbers (2016 = 100). Second, a structural and comparative analysis is conducted by comparing average indicator values in two sub-periods (2016–2019 and 2020–2024) to assess the impact of the COVID-19 pandemic. Third, a cross-sectional comparison of sectors is performed for the final year (2024). In addition, long-term growth dynamics is evaluated using the compound annual growth rate (CAGR), while stability and typical performance levels are analyzed using the arithmetic mean, median, and coefficient of variation (CV) for GVA/EMP and EXP/EMP.

This methodological approach allows the position of the pharmaceutical sector to be assessed not only in terms of scale, but also in terms of productivity, growth quality, international orientation, and performance stability within the agro-based and bioeconomic value chain in Serbia.

Results and discussion

The empirical analysis of the food (C10) and pharmaceutical (C21) sectors within Serbia's agro-based value chain is preceded by a brief overview of their structural and institutional characteristics.

Structure of the pharmaceutical sector (C21)

The pharmaceutical sector in Serbia (C21) is relatively small in terms of the number of firms (128 companies in 2024), but highly concentrated in terms of capital, knowledge, and production capacities. Although micro and small enterprises dominate numerically, the sector has a significantly higher share of medium and large companies compared to most other processing industries, indicating the existence of a core group of technologically and organizationally strong firms that generate the dominant share of value added and exports.

The sector is predominantly organized in the form of limited liability and joint-stock companies and shows a pronounced spatial concentration, with almost half of all firms located in Belgrade. This reflects the strong dependence of pharmaceutical production on research infrastructure, highly qualified labor, and developed logistic and regulatory environments. Overall, despite its limited size in terms of the number of firms, the pharmaceutical sector represents a structurally mature, capital-intensive and knowledge-based industry with high technological and regulatory entry barriers.

Structure of the food sector (C10)

In contrast, the food sector (C10) comprises more than 37,000 firms in 2024. Its structure is characterized by extreme fragmentation, with micro and small enterprises accounting for the vast majority of firms, while medium and large companies represent only a marginal share. The sector is predominantly organized through entrepreneurial and small business forms and shows a much more even regional distribution across the country, reflecting its strong link to primary agricultural production and local markets. This organizational structure indicates a development model based primarily on extensive growth, limited capital intensity, and lower levels of technological complexity and product finalization.

These structural differences suggest that the pharmaceutical sector functions as a higher, final and knowledge-intensive segment of the agro-based and bioeconomy value chain, while the food sector remains largely anchored in a more extensive development model based on a large number of small producers and lower stages of product finalization.

Dynamics of key indicators by sectors

Table 1 shows the dynamics of the basic business indicators of the agri-food sector (C10) and the pharmaceutical sector (C21) in the period 2016–2024, using index numbers with the base year 2016 = 100. This approach enables a clear and comparable analysis of the development trends of added value, employment, exports and total business income in both sectors.

The findings indicate that both sectors achieved significant nominal growth in added value in the observed period. In 2024, the index of added value in the food sector amounts to 201.16%, while in the pharmaceutical sector it reaches 190.75%, which means that the added value in both sectors has approximately doubled compared to 2016. Although the food sector records a slightly higher cumulative growth rate of added value, the differences in growth dynamics between the two sectors are not large, which indicates a relatively similar long-term trend of nominal expansion of the volume of activity.

However, much clearer structural differences between sectors are observed when employment trends are observed. The number of employees in the food sector in 2024 is 128.17% index points, which means that employment has increased by about 28% compared to the base year. In contrast, the pharmaceutical sector recorded a significantly more moderate growth in employment, with an index of 103.18% in 2024,

which practically means that the level of employment remained almost unchanged compared to 2016. This growth pattern indicates that the increase in added value in the pharmaceutical sector is predominantly realized through productivity growth and technological intensification, and not through extensive employment which is consistent with the typical development pattern of knowledge and technology-intensive bio-based industries (Wydra, 2019; Diakosavvas & Frezal, 2019).

Table 1. Dynamics of Key Indicators by Sectors (2016 = 100)

Period	VA-C10	VA-C21	EMP-C10	EMP-C21	EXP-C10	EXP-C21	REV-C10	REV-C21
2024	201.16%	190.75%	128.17%	103.18%	182.75%	242.80%	170.17%	173.89%
2023	201.34%	206.11%	127.23%	100.20%	361.90%	226.82%	162.05%	163.49%
2022	172.07%	153.31%	127.38%	93.65%	353.70%	188.99%	163.63%	145.29%
2021	148.47%	159.77%	130.90%	87.95%	141.97%	152.66%	138.28%	124.18%
2020	131.61%	140.05%	130.80%	89.15%	110.35%	156.26%	114.96%	124.20%
2019	114.51%	125.48%	128.40%	91.93%	102.38%	139.61%	110.06%	122.66%
2018	101.20%	110.94%	124.39%	85.95%	99.41%	117.55%	102.23%	105.28%
2017	98.82%	100.35%	124.39%	96.19%	99.22%	116.63%	104.11%	122.48%
2016	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Note: C10 = Manufacture of food products; C21 = Manufacture of basic pharmaceutical products and pharmaceutical preparations, VA = Value Added; EMP = Employment; REV = Total Revenue; EXP = Exports; VA/EMP = Value Added per Employee;EXP/EMP = Exports per Employee; EXP/REV(%) = Export Share in Total Revenue.

Source: Authors' calculations

Differences in export dynamics are especially pronounced. In the food sector, exports in 2024 reach an index of 182.75%, while in the pharmaceutical sector it is as high as 242.80%, pointing to the growing international competitiveness of this activity in the observed period.

The movement of total business income additionally confirms the trend of stable growth in both sectors. In 2024, the total income index is 170.17% in the food sector and 173.89% in the pharmaceutical sector. This data additionally confirms that the growth of this sector is based above all on more intensive use of capital, technology and knowledge.

It is important to highlight the impact of the pandemic period, which is reflected in both sectors through temporary slowdowns or changes in the dynamics of certain indicators, especially in 2020 and 2021. Nevertheless, the overall trends indicate that the pharmaceutical sector showed relatively high resilience, especially in terms of export activity, while the food sector maintained stable growth in terms of production volume and employment.

Structural comparison of the sector before and after the COVID-19 pandemic

Table 2 shows a structural comparison of the food sector (C10) and the pharmaceutical sector (C21) based on the average values of key relative indicators in two sub-periods: 2016–2019 (the period before the pandemic) and 2020–2024 (the period of the pandemic and after it). The analysis is based on the indicators of added value per employee (BVD/EMP), exports per employee (EXP/EMP) and the share of exports in total revenues (EXP/REV), which together enable an overview of the level of productivity, international competitiveness and the degree of internationalization of the observed sectors.

Table 2. Structural Comparison of Sectors: Average Values by Subperiods

Sectors	Period	VA/EMP	EXP/EMP	EXP/REV (%)
Sector C10	2016-2019	1,567	2,064	21.87%
Sector C10	2020-2024	2,380	4,365	33.83%
Sector C21	2016-2019	3,336	4,755	40.82%
Sector C21	2020-2024	5,071	7,548	50.99%

Note: All monetary values are expressed in thousand RSD.

Source: Authors' calculations

The results clearly indicate pronounced and stable structural differences between the two sectors. Already in the period before the pandemic (2016–2019), the pharmaceutical sector achieves a significantly higher level of added value per employee compared to the food sector (3,336 versus 1,567), which means that labor productivity in the pharmaceutical industry was more than twice as high. This difference not only persists, but further deepens in the period 2020-2024, when the VA per employee in the pharmaceutical sector reaches an average value of 5,071, while in the food sector it is 2,380. This confirms that the pharmaceutical sector not only starts from a significantly higher level of added value, but also that in the post-pandemic period it further strengthens its relative structural position.

A similar pattern is observed in exports per employee, as an indicator of international competitiveness. In the period 2016–2019, the pharmaceutical sector achieves more than twice as many exports per employee compared to the food sector (4,755 versus 2,064). In the period 2020–2024, this difference increases further: exports per employee in the pharmaceutical sector grow to 7,548, while in the food sector it reaches 4,365. These data indicate that the pharmaceutical industry not only has a structurally higher level of international market orientation, but that in the period after the pandemic it additionally further strengthened its export position, which is fully consistent with the role of pharmaceuticals as one of the most internationally integrated segments of the bioeconomy (OECD, 2009; Wydra, 2019).

The results related to the share of exports in total revenues are particularly indicative. Already in the period before the pandemic, the pharmaceutical sector achieves a

significantly higher degree of internationalization, with an average export share of 40.82%, compared to only 21.87% in the food sector. In the period 2020–2024, this gap further deepens: the share of exports in total revenues increases to 50.99% in the pharmaceutical sector and to 33.83% in the food sector. This means that more than half of the total revenues of the pharmaceutical industry in the observed period were generated on foreign markets, which is a clear indicator of high international competitiveness and integration into global value chains.

Analysis of the agro-food and pharmaceutical sector in 2024

Table 3 shows the comparative indicators of the agro-food sector (C10) and the pharmaceutical sector (C21) in the final year of the observed period, 2024. This cross-sectional analysis enables an overview of their current structural position within the agri-food and bio-based value chain, through a combination of absolute and relative indicators of business performance.

Table 3. Comparative Indicators of the Agri-Food and Pharmaceutical Sectors in 2024

Sectors	VA	EMP	VA/EMP	EXP	EXP/EMP	REW	EXP/ REW(%)
Sector C10	239,861,670	85,316	2,811	295,833,342	3,468	1,214,144,708	24.37%
Sector C21	29,253,206	5,573	5,249	48,886,263	8,772	90,254,157	54.17%

Note: All monetary values are expressed in thousand RSD.

Source: Authors' calculations

Observed in absolute terms, the food sector represents a significantly larger part of the industrial base, with a total added value of 293,861.7 million RSD and 85,316 employees, while the pharmaceutical sector achieves an added value of 29,253.2 million RSD with 5,573 employees. These data confirm that the food industry is quantitatively significantly larger and more important in terms of production and employment. However, structural differences become clearly visible when looking at relative indicators. The added value per employee in the pharmaceutical sector is 5.3 million RSD, while in the food sector it is only 2.8 million RSD. This means that labor productivity in the pharmaceutical industry is almost twice as high as in the food industry, which indicates a significantly higher technological and knowledge-intensive nature of this activity.

Even more pronounced differences are observed in export activity. The total export of the food sector in 2024 amounts to 295,823.3 million RSD, while the pharmaceutical sector achieves exports of 48,886.3 million RSD. Although in absolute terms the export of the food sector is significantly higher, when looking at exports per employee, the picture changes completely: the pharmaceutical sector achieves 8.8 million RSD of exports per employee, while the food sector achieves 3.5 million RSD. In 2024, exports make up 54.71% of the total revenues of the pharmaceutical sector, while in the food sector this share is 24.37%, which is a clear indicator of the deep integration of the pharmaceutical sector into international value chains.

The joint observation of these indicators clearly confirms earlier findings from previous analyses: the food sector has a significantly larger volume and a wider employment base, but the pharmaceutical sector occupies a structurally higher position within the agro-based value chain, with higher added value per employee, greater exportability and a significantly higher degree of internationalization.

This structure indicates that the further development of the bioeconomy in Serbia cannot be based solely on the expansion of primary and secondary processing production, but requires stronger reliance on technology- and knowledge-intensive segments.

Analysis of average Annual Growth Rates (CAGR) in 2016–2024

Table 4 provides a synthetic measure of long-term growth dynamics and enables a clear and direct comparison of the development patterns of the observed sectors, independent of short-term oscillations and cyclical disturbances.

Table 4. Average Annual Growth Rates (CAGR) of Selected Indicators, 2016–2024

Sectors	VA	VA/EMP	EXP
Sector C10	9.13%	5.80%	7.83%
Sector C21	8.41%	7.98%	11.73%

Source: Authors' calculations

The results indicate that both sectors achieved positive and relatively high growth rates of added value in the observed period. The average annual growth rate of VA in the food sector is 9.13%, while in the pharmaceutical sector it is 8.41%.

However, when focusing on the growth of value added per employee, as an indicator of intensive growth and technological progress, the picture clearly shifts in favor of the pharmaceutical sector. The average annual growth rate of VA per employee in the food sector is 5.80%, while in the pharmaceutical sector it is 7.98%.

The average annual growth rate of exports in the food sector is 7.98%, while in the pharmaceutical sector it reaches as much as 11.73%. Such dynamics indicate that the pharmaceutical industry is not only strengthening its production base, but also rapidly increasing its international market presence, thereby further integrating into global value chains.

The combined observation of these indicators indicates the existence of two different but complementary development models. The food sector records a relatively strong growth in the total volume of activities, which is partly based on the growth of employment, while the pharmaceutical sector is developing through a particularly intensive growth in productivity and an even stronger export expansion. These results additionally confirm the thesis that the pharmaceutical sector represents a dynamic and developmentally promising segment of the agro-based industry, whose contribution to structural transformation and the shift towards products with more added value has long-term and strategic importance.

Analysis of stability and sector performance

The results in Table 5 clearly confirm that the pharmaceutical sector achieves a significantly higher typical level of added value per employee compared to the food sector. The arithmetic mean of VA/EMP in the food sector is 2.019 million dinars, while in the pharmaceutical sector it is 4.300 million dinars.

Table 5. Mean, Median and Coefficient of Variation (CV) of Value Added and Exports per Employee (2016–2024)

Sectors	VA/EMP-Mean	VA/EMP-Median	VA/EMP-CV	EXP/EMP-Mean	EXP/EMP-Median	EXP/EMP-CV
Sector C10	2,019	1,802	0.27	3,342	2,413	0.61
Sector C21	4,300	4,460	0.24	6,307	6,470	0.27

Note: All monetary values are expressed in thousand RSD.

Source: Authors' calculations

The average export per employee in the food sector amounts to 3.3 million RSD, while in the pharmaceutical sector it reaches 6.5 million RSD. The median additionally confirms this difference, which once again confirms the significantly higher typical level of export activity per employee in the pharmaceutical industry.

In addition to the level of indicators, the analysis of their stability is particularly important. The coefficient of variation of VA/EMP is 27% in the food sector, while it is 24% in the pharmaceutical sector. We can conclude that the pharmaceutical sector in Serbia not only achieves a significantly higher and structurally advanced level of performance in terms of added value and export activity per employee, but that performance is also characterized by greater stability and less exposure to oscillations over time.

These findings further strengthen previous findings and confirm the thesis that the pharmaceutical sector represents a higher, technologically and knowledge-intensive segment of the agro-based and bio-economic value chain, with an important role in the long-term structural transformation of the Serbian economy. The findings also consistently indicate that the pharmaceutical sector in Serbia occupies a structurally higher and more developmentally advanced position within the agro-based value chain compared to the food industry. Differences in value added per employee, export orientation, growth dynamics, and performance stability are not of a temporary nature, but reflect persistent differences between a knowledge-intensive and a predominantly extensive model of industrial development. The findings confirm that the pharmaceutical industry functions as a higher segment of the bioeconomy and the agro-based value chain, characterized by knowledge- and technology-intensive upgrading, which is fully consistent with the logic of value chain upgrading described in the global value chain literature (Gereffi, Humphrey, & Sturgeon, 2005; Wydra, 2019).

At the same time, the identified structural gap points to a significant but still underutilized potential for stronger integration within the broader agro-based production system, particularly through the development of functional food, supplements, phyto-pharmaceutical and biotechnological products. Although the analysis focuses on Serbia, the results have broader relevance for countries with similar economic structures in Central and Eastern Europe, where a comparable gap between traditional agro-industrial sectors and knowledge-intensive bio-based industries represents a common development pattern.

From a broader perspective, these results support the view that the development of the bioeconomy cannot be based solely on the expansion of primary production and low stages of processing, but requires the systematic strengthening of knowledge-intensive segments and higher positions within value chains, as emphasized in the European bioeconomy policy framework (European Commission, 2018) and the value chain upgrading literature (Gereffi et al., 2005).

Conclusion

The development of the bioeconomy does not depend solely on the volume of primary production and basic processing, but primarily on the ability to move toward knowledge- and technology-intensive stages of value creation. The findings consistently confirm that the pharmaceutical sector in Serbia occupies a structurally higher position within the agro-based value chain. Compared to the food industry, it achieves significantly higher value added per employee, higher exports per employee, a higher degree of internationalization, faster long-term growth of key relative indicators, and greater performance stability over time. These differences are not transient, but reflect the coexistence of two distinct development models: one based mainly on the expansion of production volume and employment, and the other driven by productivity growth, technological intensification, and knowledge. In this sense, the findings provide empirical confirmation that the pharmaceutical industry is not merely another processing branch based on biological resources, but represents a final, knowledge- and technology-intensive segment of the bioeconomy. More broadly, it illustrates how biological resources, scientific knowledge, and industrial organization can be integrated into products with high value added and strong export orientation.

This paper makes three interrelated contributions to the literature. First, from a theoretical perspective, it positions the pharmaceutical sector within the bioeconomy framework from the viewpoint of agro-based value chains and structural transformation. Second, from a methodological perspective, it demonstrates that aggregated sectoral financial statements can be used as an operational approximation for analyzing value added and for the comparative assessment of differences in the level and quality of sectoral growth. Third, from an empirical perspective, it provides quantitative evidence of a pronounced structural gap within Serbia's bioeconomy between traditional agro-industrial sectors and knowledge-intensive bio-based industries.

The study is subject to certain limitations. The analysis is based on aggregated sectoral data and does not include firm-level evidence or international comparisons, which points to promising directions for future research. Further studies could incorporate micro-level data and cross-country comparisons in order to more precisely identify the mechanisms enabling upgrading toward higher stages of the value chain. Although the analysis focuses on Serbia, the findings have broader relevance for countries with similar economic structures, particularly in Central and Eastern Europe, which face comparable challenges in shifting toward more knowledge- and technology-intensive segments of the bioeconomy. In this context, the pharmaceutical sector can be seen not only as a successful individual case, but also as a potential benchmark for a wider structural transformation toward a growth model based on knowledge, innovation, and high value added.

Conflict of interests

The authors declare no conflict of interest.

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