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Obstacle Factors of Research Product Commercialization in Andalas University

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Abstract: In an increasingly competitive market landscape, companies must innovate by allocating a significant portion of product sales revenue, specifically at least 22%, towards research and development (R&D). Collaboration between companies and universities, which actively engage in R&D, is crucial in this context. At Andalas University, the Research and Community Service Institute (LPPM) oversees R&D initiatives and community services, including the management of the Science Techno Park. To achieve commercialization objectives, it is imperative to identify and address the factors that inhibit the commercialization of research products at Andalas University. The Fuzzy Analytical Hierarchy Process (FAHP) method has been employed to ascertain the primary factors impeding commercialization. The research findings indicate that the foremost factor inhibiting commercialization is resource availability, assigned a weight of 0.221. This is followed by intellectual property considerations, with a weight of 0.215, and marketing challenges, with a weight of 0.160. These insights provide a foundational basis for the development of strategies aimed at enhancing the commercialization of research products at Andalas University.

Keywords: Commercialization; Innovation; Research and development (R&D); Collaboration; Inhibiting factors; Intellectual property; Marketing

1. Introduction

The Introduction section should place the study briefly in a broad context, and clearly define its purpose and importance, including the specific hypotheses being tested. R&D constitutes a systematic approach employed to assess the effectiveness of products through structured procedures designed to conceive, develop, and evaluate programs, processes, and learning outcomes. These procedures are aligned with criteria for internal consistency and effectiveness (Syamsuddin & Fuady, 2020). The importance of R&D activities is supported by a study from the Thailand Development Research Institute (TDRI), which explains that companies or business entities in Thailand that have a great chance to dominate the market are those that are able to innovate and invest in R&D. Companies that are successful and well-known invest 22% of their annual product sales in R&D of their products (Karaveg et al., 2015). The study illustrates the importance of R&D activities. According to the Head of the Badan Riset dan Inovasi Nasional (BRIN), 90% of research in Indonesia is carried out by universities; the rest comes from research institutions (www.carapandang.com). This statement shows the active role of universities in R&D activities in Indonesia (Hendrix et al., 2021).

Andalas University is a legal entity state university in Indonesia that supports R&D activities. Currently, Andalas University has a Lembaga Penelitian dan Pengabdian Masyarakat (LPPM). LPPM is an institution that acts as a facilitator, reinforcer, empowerer and guardian of research and community service in a tertiary institution (Rahayu & Wahab, 2013). According to the structure of the Andalas University Research and Community Service Institute, several centers have different focuses, with one of the development centers focusing on innovation being

the Andalas University Science Techno Park (Asmara et al., 2018). As one of the Science and Kawasan Sains dan Teknologi (KST), the Science Techno Park is considered capable of supporting the achievement of downstream goals and commercialization of research and innovation products that have been developed by inventors at Andalas University. Research products of Andalas University focus on studies in the sectors of food, herbs, and drugs.

Science Techno Park continues to strive to improve R&D activities at Andalas University. Based on interviews conducted with the management of the Science Techno Park, Andalas University is currently very oriented towards commercializing research products, which enables research products to have the opportunity to be accepted by industry and obtain product copyrights (Odom et al., 2016). The university status of Andalas is PTN-BH, indicating that the university has a great opportunity to generate income from commercialized research products (YazdiMoghaddam et al., 2018). Andalas University has produced 148 research products covering the fields of food, herbs and medicines. However, not all products have reached the commercialization stage (Mujiyanto & Utami, 2018). Figure 1 shows a comparison of the percentage data of research products that have and have not been commercialized.

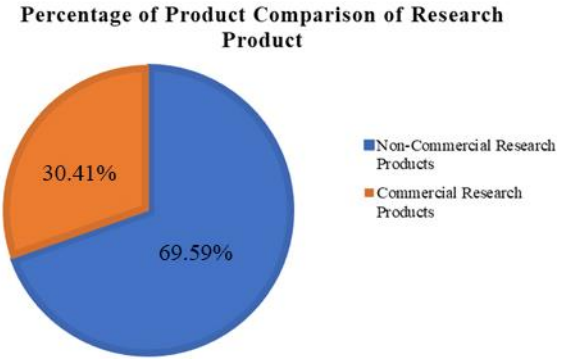

Figure 1. Percentage comparison of research product results
(Source: Science Techno Park Unand)

Based on the data in Figure 1, there are 148 research products in the fields of food, health and medicine. Only 30.41% of the research products have reached the commercialization stage, which means that only 45 research products are ready for commercialization (Ismail & Sidek, 2019). The research products that are ready for commercialization can be measured using the Tingkat Kesiapterapan Teknologi (TKT), which means the technology readiness level. The level of maturity or readiness of a particular research and technological development result can be measured in a systematic manner based on interrelated scales. Comparative data on the level of technological readiness of research products is shown in Figure 2. Products that can be commercialized are at the model demonstration level in a relevant environment or the sixth level of the TKT measuring instrument.

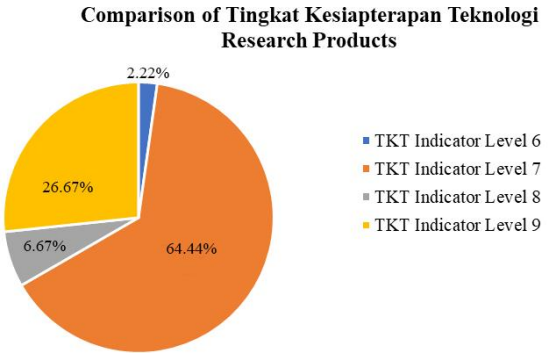

Figure 2. Comparison percentage of TKT
(Source: Science Techno Park Unand)

Based on the data in Figure 2, there are 45 research products that can be commercialized. The dominance of research products is at the seventh level of the TKT, which accounts for 64.44% with 45 products. It can be seen that the level includes the demonstration stage of the system prototype in the actual environment. Based on the acquisition of comparative data on the TKT, it can be seen that there are several things that hinder the process of commercializing research products at Andalas University so that research products do not yet have maximum absorption in the industry. The causes of these problems can be viewed from various aspects of the commercialization process. It is necessary to identify inhibitors based on factors or criteria that determine the

success of commercialization (Jaya et al., 2020). Likewise in Institut Teknologi Bandung (ITB), the commercialization rate of these innovation products towards the implementation of the entrepreneurial university concept is still very low (Sihotang et al., 2019). This is evidenced by the small amount of intellectual property of start-up businesses at the Bandung Institute of Technology based on the data from LPIK ITB (Astiti et al., 2020).

A solution has been found in overcoming the problem of product commercialization in previous studies. Chung & Hyun (2018) found six (6) factors were derived as the key success factors of technology commercialization: Marketing Capability, Strategic Planning, Manufacturing Capability, Internal Cooperation, External Cooperation, and Learning Capability. The other example, Karaveg et al. (2016) found that in overcoming the problem of product commercialization, it is necessary to have criteria to assess the commercialization of research products. These six criteria include technology, marketing, finance, intellectual property, resources, and non-financial impacts (Andrianto, 2016). The evaluation criteria for the commercialization of research products only focus on one point of view, so they only evaluate the industry and market demand for the commercialization of research products. However, it is necessary to add criteria concerning government to focus on non-commercial reviews because most R&D activities are funded by the government (Karaveg et al., 2016). Based on the six assessment criteria plus government criteria included in the assessment, readiness can be reviewed and the factors inhibiting the commercialization of research products at Andalas University can be obtained. It is necessary to review the level of commercialization readiness and analysis related to inhibiting factors for the commercialization of research products to recommend system improvements, thereby minimizing obstacles to the commercialization process. Then the industry can glance at the research products of Andalas University that support R&D, thereby maintaining its status as PTN-BH.

2. Methodology

This study was conducted at Andalas University, which is a state university with legal entity in Indonesia and supports R&D activities through the Institute for Research and Community Service (LPPM) Andalas University. LPPM acts as a facilitator, reinforcer, empowerer and guardian of research and community service. This study analyzes the inhibiting factors for the commercialization of research products at Andalas University. The data was collected through interviews and questionnaires. The questionnaires contain pairwise comparisons regarding the factors and sub-factors determining the commercialization of research products. A fuzzy scale was used to assess each factor and sub-factor.

Commercialization is a series of processes, which transforms science into products or services from an institution that has a competitive advantage, aiming to increase regional economic growth. In addition, commercialization will be successful if commercialization is carried out by universities (Jamil et al., 2015). Universities have developed as “entrepreneurial universities” that support the commercialization process of research and knowledge, which is sustainable and supported by a progressive ecosystem (Audretsch, 2014). If commercialization is carried out by universities, it has great potential because the transfer of knowledge to the community can be the third mission of universities besides R&D. The success of commercialization also depends on the involvement of government, academics, industry, and society (Jamil et al., 2015). Thus, the implementation of commercialization is related to academics, industry, government, and researchers, all of which must be well integrated.

Commercialization also depends on R&D from the faculty, who are the initiators of commercialization, and the result evaluation (Namugenyi et al., 2019). In addition, commercialization also requires patents in the context of the resulting innovation, and marketing channels related to licensing and spin-offs (Jamil et al., 2015). This study was conducted to identify the factors and sub-factors that most hinder the commercialization of research products at Andalas University. The factors and sub-factors were obtained based on how they determine the success of the commercialization of research products, aiming to identify those that most hinder the commercialization of research products at Andalas University (Anatan, 2008). The FAHP method was used for data processing to find out the priority factors that hinder the commercialization of research products at Andalas University.

The FAHP integrates the Analytical Hierarchy Process (AHP) with fuzzy logic to address the subjectivity inherent in criteria evaluation (Anshori, 2012; Gupta et al., 2023). By using fuzzy logic, FAHP enhances AHP’s ability to handle subjective measurements through linguistic variables represented as Triangular Fuzzy Numbers (TFNs) (Kamasak, 2017). The FAHP methodology includes several key steps: structuring the problem into a hierarchical framework, conducting pairwise comparisons to assess relative importance, converting linguistic variables into TFNs, calculating the geometric mean of these fuzzy numbers, and defuzzifying them into crisp values (Munthafa & Mubarok, 2017). Additionally, it involves determining local and global weights for criteria and testing consistency to ensure the reliability of the results (Santoso et al., 2016). The process ensures a comprehensive and structured approach to decision-making by accounting for the inherent subjectivity in evaluating criteria. The steps are as follows (Gayatri & Chetan, 2013):

Step 1: Pairwise comparison assessment

The pairwise comparison assessment begins when the expert questionnaire is designed (Kurnia & Hadiguna,

2016). The scale was determined using the TFN scale and was translated using linguistics on the questionnaire. The questionnaire comparison was carried out by comparing criteria and sub-criteria. The results of the pairwise comparison produced the priority order regarding the inhibiting factors that most affect the commercialization of research products.

Step 2: Transformation of the TFN scale into a single scale

The TFN scale was transformed into a single scale to calculate the consistency ratio.

Step 3: Calculation of the consistency ratio

The consistency ratio was calculated, or a consistency test was carried out to determine the level of consistency of the data acquisition. The consistency ratio was calculated with the normalization stage by calculating the weight sum factor, the consistency factor, and the consistency index, and determining the ratio index (Saaty, 1987). The obtained consistency value of the pairwise comparison data must be less than or equal to 0.1 to be declared consistent. If the consistency value is greater than 0.1, then it is declared inconsistent and the questionnaire must be filled out again.

Step 4: Conversion of data into fuzzy numbers

The paired comparison assessment data obtained was converted back into fuzzy numbers based on the lower limit value (l), the middle limit value (m), and the upper limit value (u).

Step 5: Calculation of the geometric mean of the expert assessment

The paired comparison assessment converted was then calculated as the geometric mean based on the lower, middle, and upper limit values.

Step 6: Calculation of weights

Weights were calculated to obtain the priority order of factors. The calculation includes several stages, namely the calculation of the fuzzy relative weight, the average relative weight, and the normal relative weight. The normal relative weight is a reference for obtaining the priority order.

Step 7: Data synthesis

Data synthesis was conducted by multiplying the normal relative weight of the criteria by the normal relative weight of the sub-criteria.

3. Results

This study was conducted for the commercialization of research products at Andalas University in the fields of food, herbs and medicines, thereby analyzing and formulating strategies for factors identified as obstacles to the commercialization.

The data collection phase involves gathering fundamental data for research, which is categorized into two types: primary and secondary data. Primary data was obtained directly from sources through interviews and questionnaires. Interviews were conducted with the management of the Science Techno Park at Andalas University to gather information on the commercialization process of research products, specifically the number of products reaching the commercialization stage. Questionnaires were designed based on expert needs and distributed to the management of the Research and Community Development Institute (LPPM) and the Science Techno Park. These questionnaires assess criteria such as technology (Wahyuningrum & Desrianti, 2018), marketing, finance, intellectual property, resources, non-financial impact, and government involvement (Behboudi et al., 2011; Karaveg et al., 2016). The results help prioritize barriers to the commercialization of research products at Andalas University. Secondary data was collected from existing sources without direct observation, including documents, reports, journals, data on research products, and previous studies (Sarwono, 2010). In data collection, the factors and sub-factors determining the commercialization of research products were identified, which would become the criteria and sub-criteria in the pairwise comparison assessment questionnaire based on the source (Sasongko et al., 2016). The identification of factors and sub-factors, which comes from the previous research, is shown in Table 1 and Table 2.

Table 1. Identification of influencing factors

No.	Factor	Source	
		Karaveg et al. (2016)	Behboudi et al. (2011)
1	Technology	√	
2	Marketing	√	
3	Financial	√	
4	Intellectual property	√	
5	Resource	√	
6	Non-financial impact	√	
7	Government		√

Table 2. Identification of influencing sub-factors

No.	Sub-Factor	Source			
		Karaveg et al. (2016)	Behboudi et al. (2011)	Hsu et al. (2015)	Mawaddah et al. (2020)
1	Preliminary studies	√			
2	Technology updates	√			
3	Comparative advantage	√			
4	Technology readiness	√			
5	Compatibility with available technology	√			
6	Standards and regulations	√			
7	Technological complexity		√		
8	Market analysis	√			
9	Competitor analysis	√			
10	Target market	√			
11	Market strategy	√			
12	Process development	√			
13	Product pricing	√			
14	Cost budgeting	√			
15	Financial analysis	√			
16	Benefit cost ratio	√			
17	Intellectual property reward	√			
18	Royalty fee	√			
19	Knowledge and experience	√			
20	Multidisciplinary capabilities	√		√	
21	Ability to cooperate and organize				√
22	Enthusiasm and ambition	√			
23	Understanding of product R&D	√			
24	Social impact	√			
25	Environmental impact	√			
26	Innovation capacity	√		√	
27	User satisfaction	√			
28	Government budgeting		√		
29	Development of a national innovation system		√		
30	Market creation		√		

Factors and sub-factors that determine the commercialization of research results were described as a hierarchical structure, consisting of several levels. The hierarchical structure is shown in Figure 3.

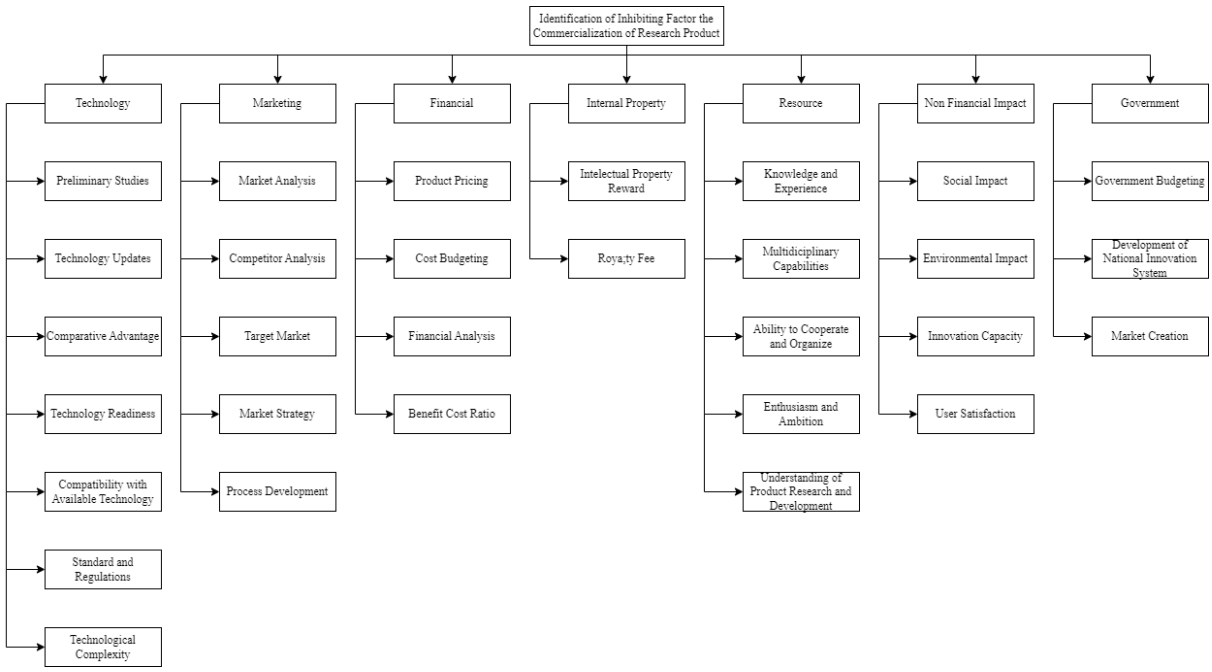

Figure 3. Research hierarchy structure

Furthermore, questionnaires were distributed and filled out by experts, who are managers of the Research and Community Service Institute (LPPM) and the Andalas University Science Techno Park. The determining criteria for the experts were adjusted to the length of service based on the field of each expert. The recapitulation of expert data from this research questionnaire can be seen in Table 3.

Table 3. Recapitulation of research questionnaires answered by experts

No.	Name	Sex	Age	Position	Year of Service
1	Berri Briliant Albar, SE. MM	Male	37	Business and Technology Incubation Center Coordinator/Science Techno Park Andalas University	Three years
2	Hanalde Andre, S.T., M.T	Male	35	Intellectual Property and Center Coordinator/Science Techno Park Andalas University	Five years
3	Dr. Eka Candra Lina, SP. M.Si	Female	46	Head of Science Techno Park Center/Science Techno Park Andalas University	Two years
4	Dr. Eng. Muhammad Makky, S. TP., M. Si	Male	43	Director of Cooperation and Research Downstreaming/Institute for Research and Community Service Andalas University	Three months
5	Daimon Syukri, S.Si, M.Si,Ph.D	Male	41	Head of Subdirectorate Collaboration and Research Downstreaming/Institute for Research and Community Service Andalas University	Three months

3.1 Data Processing

Data processing starts with the transformation of the fuzzy scale to a linguistic set. This transformation step refers to the half diagonal value at the top, which shows the results of pairwise comparisons by the experts. However, the value of the half diagonal at the bottom refers to the opposite value of the diagonal at the top (Solangi et al., 2019). The complete transformation can be seen in Table S1.

Furthermore, the consistency ratio was calculated by calculating the priority factor, the weight sum factor and the consistency factor to produce a lambda value. When calculating the consistency ratio value, the random index value was determined in advance, which depends on the matrix order value (Paulus Wardoyo, 2011). Normalization was previously carried out on the pairwise comparison values obtained. Table S2 shows the process of obtaining the normalization matrix and calculating the consistency ratio.

Based on the calculation of the consistency ratio, a value of 0.092 was obtained, which means that the pairwise comparison assessment is consistent. A consistency ratio can be said to be consistent if the value of the consistency ratio is or less than 0.1. The consistency ratio was also calculated for other factors and sub-factors. A recapitulation of the consistency ratio results was obtained based on the determining criteria in Table S3.

After testing the consistency ratio for each criterion and sub-criteria, the fuzzification was carried out by classifying the TFN pairwise comparison rating scale into three different values, consisting of the lower, middle, and upper limit values. The results of the matrix classified into three different values are based on the pairwise comparison assessments in Table S4. Then the pairwise comparison assessments of all experts must be averaged, as shown in Table S5.

After obtaining the average pairwise comparisons, the geometric mean of each criterion and sub-criteria was calculated based on the lower, middle, and upper limit values. When calculating the geometric mean, the value of the reverse, increasing order was also calculated. Table S6 presents the calculation of the geometric means.

Then the fuzzy relative weight was calculated by multiplying each geometric mean value of each criterion and sub-criteria with the increasing order value. Calculation of relative fuzzy weights can be seen in Table S7.

Based on the acquisition of fuzzy relative weight data, the average relative weight (*Mi*) and normal relative weight (*Ni*) were then calculated using the center of area method. The *Mi* value was calculated by averaging the sum of the $\tilde{w}i$ values at the *l*, *m*, and *u* levels. Followed by the calculation of *Ni*, each criterion value in the calculation of *Mi* was divided by the total value of *Mi*. Table 4 and Table 5 show the acquisition of *Mi* and *Ni* values.

Table 4. Acquired average relative weight criteria

Criteria Factor	M_i
Technology	0.110
Marketing	0.168
Financial	0.116
Intellectual property	0.227
Resource	0.232
Non-financial impact	0.084
Government	0.115
Total	1.052

Table 5. Acquired relative normal weight criteria

Criteria Factor	N_i
Technology	0.105
Marketing	0.160
Financial	0.110
Intellectual property	0.215
Resource	0.221
Non-financial impact	0.080
Government	0.109
Total	1.000

After obtaining the normal relative weights of the criteria and sub-criteria, it was found that the resource criteria have the highest normal relative weight among the other criteria. The weight of the resource criteria is 0.221. The non-financial impact criteria have the lowest normal relative weight of 0.080. The following is the overall relative normal weight obtained based on the criteria and sub-criteria, as shown in Table 6.

Table 6. Recapitulation of relative normal weight of criteria and sub-criteria

No.	Influencing Criteria Factor	Normal Relative Weight	Influencing Sub-Criteria Factor	Normal Relative Weight
1	Technology	0.105	Preliminary studies	0.124
			Technology updates	0.125
			Comparative advantage	0.171
			Technology readiness	0.205
			Compatibility with available technology	0.128
			Standards and regulations	0.114
			Technological complexity	0.133
2	Marketing	0.160	Market analysis	0.256
			Competitor analysis	0.166
			Target market	0.241
			Market strategy	0.158
3	Financial	0.110	Process development	0.179
			Product pricing	0.212
			Cost budgeting	0.222
			Financial analysis	0.288
			Benefit cost ratio	0.278
4	Intellectual Property	0.215	Intellectual property reward	0.537
			Royalty fee	0.463
5	Resource	0.221	Knowledge and experience	0.206
			Multidisciplinary capabilities	0.189
			Ability to cooperate and organize	0.282
			Enthusiasm and ambition	0.138
			Understanding of product R&D	0.185
6	Non-financial Impact	0.080	Social impact	0.283
			Environmental impact	0.163
			Innovation capacity	0.310
			User satisfaction	0.244
7	Government	0.109	Government budgeting	0.475
			Development of a national innovation system	0.270
			Market creation	0.255

Based on Table 7, there are relatively normal weights of the criteria and sub-criteria. There is a priority order of several sub-criteria that are not comparable to the priority order of the criteria. As can be seen in the criteria for resources and government, the sub-criteria for budgeting funds from the government contained in the government criteria have a relatively normal weight of 0.475. In contrast, the sub-criteria of ability to cooperate and organize have a weight of 0.282.

Thus, after calculating the relative normal weights, data synthesis calculations are needed in order to obtain optimal decision-making. Data synthesis was calculated by multiplying the normal relative weight of a criterion with the normal relative weight of each sub-criteria. Table 7 shows the summary results of data synthesis calculations based on the relatively normal weights of each criterion and sub-criteria.

After obtaining data synthesis, the weights were ranked based on sub-criteria. Thus, the sub-criteria with the highest weight becomes the most influential factor. Table 8 shows the recapitulation of the final synthesis results, which rank the factors based on the most influential sub-criteria.

Table 7. Recapitulation of data synthesis calculations based on criteria and sub-criteria

No.	Influencing Criteria Factor	Normal Relative Weight	Influencing Sub-Criteria Factor	Normal Relative Weight	Synthesis Result
1	Technology	0.105	Preliminary studies	0.124	0.0130
			Technology updates	0.125	0.0131
			Comparative advantage	0.171	0.0180
			Technology readiness	0.205	0.0215
			Compatibility with available technology	0.128	0.0134
			Standards and regulations	0.114	0.0120
			Technological complexity	0.133	0.0139
2	Marketing	0.160	Market analysis	0.256	0.0408
			Competitor analysis	0.166	0.0264
			Target market	0.241	0.0385
			Market strategy	0.158	0.0253
			Process development	0.179	0.0285
3	Financial	0.110	Product pricing	0.212	0.0233
			Cost budgeting	0.222	0.0244
			Financial analysis	0.288	0.0317
			Benefit cost ratio	0.278	0.0306
4	Intellectual Property	0.215	Intellectual property reward	0.537	0.1157
			Royalty fee	0.463	0.0996
5	Property	0.221	Knowledge and experience	0.206	0.0454
			Multidisciplinary capabilities	0.189	0.0417
			Ability to cooperate and organize	0.282	0.0622
			Enthusiasm and ambition	0.138	0.0305
			Understanding of product R&D	0.185	0.0409
6	Non-financial Impact	0.080	Social impact	0.283	0.0226
			Environmental impact	0.163	0.0131
			Innovation capacity	0.310	0.0248
			User satisfaction	0.244	0.0195
7	Government	0.109	Government budgeting	0.475	0.0520
			Development of a national innovation system	0.270	0.0295
			Market creation	0.255	0.0279

Table 8. Final synthesis recapitulation based on sub-criteria

Influencing Sub-Criteria Factor	Synthesis Results
Intellectual property reward	0.1157
Royalty fee	0.0996
Ability to cooperate and organize	0.0622
Government budgeting	0.0520
Knowledge and experience	0.0454
Multidisciplinary capabilities	0.0417
Understanding of product R&D	0.0409
Market analysis	0.0408
Target market	0.0385
Financial analysis	0.0317
Benefit cost ratio	0.0306
Enthusiasm and ambition	0.0305
Development of a national innovation system	0.0295
Process development	0.0285
Market creation	0.0279
Competitor analysis	0.0264
Market strategy	0.0253
Innovation capacity	0.0248
Cost budgeting	0.0244
Product pricing	0.0233
Social impact	0.0226
Technology readiness	0.0215
User satisfaction	0.0195
Comparative advantage	0.0180
Technological complexity	0.0139
Compatibility with available technology	0.0134
Technology updates	0.0131
Environmental impact	0.0131
Preliminary studies	0.0130
Standard and regulation	0.0120
Average	0.0333

After obtaining the data synthesis results, it was found that the results of the sub-criteria with the highest score were those with intellectual property rewards at the beginning with a weight of 0.1157. This is followed by royalty fees with a weight of 0.0996, and the ability to work together and organize with a weight of 0.0622. However, the standard and regulation sub-criteria have the lowest weight of 0.0120.

4. Conclusions

It was found in this study that there are three priority factors that hinder the commercialization of research products at Andalas University. The factor with the highest relative normal weight is the resource factor with a weight of 0.221, followed by the intellectual property factor with a relative normal weight of 0.215, and the marketing factor with a weight of 0.160. Therefore, it can be concluded that the factor that most hinders the commercialization of research products is the resource factor.

The limitations of this study lie in the criteria that may not have been discussed in this study. Therefore, it is necessary to add other criteria that may be an obstacle to the commercialization of research products. In addition, it is also necessary to adjust the criteria to the research location to achieve conformity with the original conditions of a problem. This study, being a case study of a single university, underscores the necessity for comparative analysis with other similar research institutions. Such comparisons would illuminate the disparities and commonalities in the challenges faced, thereby validating the criteria used and ensuring their broader applicability.

Commercializing research products from universities involves translating academic research into marketable products or services, which is a process with significant potential for economic and social benefits and numerous obstacles. Theoretical implications from various models highlight these challenges. The Resource-Based View (RBV) suggests that universities need to leverage their intellectual property and research capabilities for effective commercialization. However, they often lack the necessary business acumen and resources. Innovation diffusion theory underscores the importance of how well innovations are communicated and adopted. However, the triple helix model emphasizes the need for collaboration between universities, industry, and government, though aligning their objectives can be difficult. Practical challenges further complicate the commercialization process. Funding and financial constraints hinder the development and marketing of new products. Managing intellectual property rights, patents, and licensing agreements is complex and requires expertise that universities may lack. Cultural differences between the academic and commercial worlds present another hurdle, as their goals and success metrics often differ. Additionally, regulatory and legal barriers can be time-consuming and costly to navigate, and not all research products have clear market demand or commercial potential. Researchers and academics may also lack the entrepreneurial skills necessary for commercialization.

To overcome these obstacles, universities should build strong partnerships with industry and government to pool resources and expertise. It is crucial to enhance intellectual property management systems and secure diverse funding sources, including grants and venture capital. Providing researchers with training in entrepreneurship and business development can help bridge the skills gap. Creating supportive ecosystems, such as incubators, accelerators, and technology transfer offices, can further support the commercialization process. It is also essential to engage in policy advocacy to create favorable regulatory environments and support mechanisms. By addressing these theoretical and practical challenges, universities can enhance their capacity to commercialize research products, contributing to innovation and economic growth.

Data Availability

The data used to support the research findings are available from the corresponding author upon.

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Conflicts of Interest

The authors declare no conflict of interest.

References

Anatan, L. (2008). Kolaborasi universitas_industri: Tinjauan konseptual mekanisme transfer pengetahuan dari Universitas ke industri. *Jurnal Manajemen Maranatha*, *8*(1), 26-37. https://doi.org/10.28932/jmm.v8i1.197.

Andrianto, M. S. (2016). Strategi komersialisasi invensi perguruan tinggi. *Risalah Kebijakan Pertanian Dan Lingkungan Rumusan Kajian Strategis Bidang Pertanian Dan Lingkungan*, *3*(3), 216-227.

Anshori, Y. (2012). Pendekatan triangular fuzzy number dalam metode analytic hierarchy process. *Foristek*, *2*(1), 126-135. https://foristek.fatek.untad.ac.id/index.php/foristek/article/view/93/68

Asmara, A. Y., Oktaviyanti, D., Alamsyah, P., & Zulhamdani, M. (2018). *Science-Techno Park and Industrial Policy in Indonesia*. Saarbrücken, Germany, Scholars' Press.

Astiti, Y. M., Sakapurnama, E., & Huseini, M. (2020). The challenges in research commercialization lessons from Bandung institute of technology Indonesia. *Test Eng. Manage.*, *82*(1-2), 1535-1542.

Audretsch, D. B. (2014). From the entrepreneurial university to the university for the entrepreneurial society. *J. Technol. Transfer*, *39*, 313-321. https://doi.org/10.1007/s10961-012-9288-1.

Behboudi, M., Jalili, N., & Mousakhani, M. (2011). Examine the commercialization research outcomes in Iran: A structural equation model. *Int. J. Bus. Manage.*, *6*(7), 261-275.

Chung, B. & Hyun, B. H. (2018). Meta-analysis on the influencing factors of technology commercialization in Korea. *Global Bus. Finance Rev.*, *23*(2), 49-65. https://hdl.handle.net/10419/224401

Gayatri, V. & Chetan, M. (2013). Comparative study of different multi-criteria decision-making methods. *Int. J. Adv. Comput. Theor. Eng*., *2*(4), 9-12.

Gupta, S., Raj, S., Gupta, S., & Sharma, A. (2023). Prioritising crowdfunding benefits: A fuzzy-AHP approach. *Qual. Quantity*, *57*(1), 379-403. https://doi.org/10.1007/s11135-022-01359-z.

Hendrix, T., Nurhikmat, A., Hidayat, M., & Anggita, S. (2021). Canning technology in traditional food: Case study portrait of SMEs technology transfer product commercialization in Indonesia. In *IOP Conference Series: Earth and Environmental Science*. Bristol: IOP Publishing. p. 012055.

Hsu, D. W., Shen, Y. C., Yuan, B. J., & Chou, C. J. (2015). Toward successful commercialization of university technology: Performance drivers of university technology transfer in Taiwan. *Technol. Forecasting Social Change*, *92*, 25-39. https://doi.org/10.1016/j.techfore.2014.11.002.

Ismail, N. & Sidek, S. (2019). Determinant factors for commercialising research products in Malaysian Public Universities. *Int. J. Innovative Technol. Exploring Eng.*, *8*(6), 780-787.

Jamil, F., Ismail, K., & Mahmood, N. (2015). A review of commercialization tools: University incubators and technology parks. *Int. J. Econ. Financial Issues*, *5*(1), 223-228.

Jaya, R., Fitria, E., & Ardiansyah, R. (2020). Implementasi multi criteria decision making (MCDM) pada agroindustri: Suatu telaah literatur. *Jurnal Teknologi Industri Pertanian*, *30*(2), 234-343. https://doi.org/10.24961/j.tek.ind.pert.2020.30.2.234.

Kamasak, R. (2017). The contribution of tangible and intangible resources, and capabilities to a firm's profitability and market performance. *Eur. J. Manage. Bus. Econ.*, *26*(2), 252-275.

Karaveg, C., Thawesaengskulthai, N., & Chandrachai, A. (2015). A combined technique using SEM and TOPSIS for the commercialization capability of R&D project evaluation. *Decis. Sci. Lett.*, *4*(3), 379-396. https://doi.org/10.5267/j.dsl.2015.3.004.

Karaveg, C., Thawesaengskulthai, N., & Chandrachai, A. (2016). R&D commercialization capability criteria: Implications for project selection. *J. Manage. Dev.*, *35*(3), 304-325. https://doi.org/10.1108/JMD-01-2015-0005.

Kurnia, R. & Hadiguna, R. A. (2016). Penentuan prioritas risiko pada rancangan rantai pasok biodiesel dari minyak goreng bekas di Kota Padang. *Jurnal Rekayasa Sistem Industri*, *5*(1), 15-25. https://doi.org/10.26593/jrsi.v5i1.1909.15-25.

Mawaddah, P., Huang, B. N., & Chang, C. H. (2020). Analysis of the key success factors for commercializing innovation. *IPTEK J. Technol. Sci.*, *31*(2), 111-126. http://doi.org/10.12962/j20882033.v31i2.6330.

Mujiyanto, M. & Utami, E. (2018). Penerapan metode Me-MCDM untuk menentukan kelayakan komersialisasi produk. *Semnasteknomedia Online*, *6*(1), 2-8.

Munthafa, A. E. & Mubarok, H. (2017). Penerapan metode analytical hierarchy process dalam sistem pendukung keputusan penentuan mahasiswa berprestasi. *Jurnal Siliwangi Seri Sains dan Teknologi*, *3*(2). https://doi.org/10.37058/jssainstek.v3i2.355.

Namugenyi, C., Nimmagadda, S. L., & Reiners, T. (2019). Design of a SWOT analysis model and its evaluation in diverse digital business ecosystem contexts. *Procedia Comput. Sci.*, *159*, 1145-1154. https://doi.org/10.1016/j.procs.2019.09.283.

Odom, W., Wakkary, R., Lim, Y. K., Desjardins, A., Hengeveld, B., & Banks, R. (2016). From research prototype to research product. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. San Jose, United States. pp. 2549-2561.

Paulus Wardoyo, M. M. (2011). *Alat Analisis Manajemen*. Semarang, Indonesia, Semarang University Press.

Rahayu, S. & Wahab, A. A. (2013). Pengaruh penerapan prinsip-prinsip good university governance terhadap citra serta implikasinya pada keunggulan bersaing perguruan tinggi negeri pasca perubahan status menjadi BHMN. *Jurnal Administrasi Pendidikan*, *10*(1), 154-173. https://doi.org/10.17509/jap.v17i1.6441.

Saaty, R. W. (1987). The analytic hierarchy process—What it is and how it is used. *Math. Modell.*, *9*(3-5), 161-

176. https://doi.org/10.1016/0270-0255(87)90473-8.
Santoso, A., Rahmawati, R., & Sudarno, S. (2016). Aplikasi fuzzy analytical hierarchy process untuk menentukan prioritas pelanggan berkunjung ke galeri (Studi kasus di secondhand semarang). *Jurnal Gaussian*, *5*(2), 239-248. https://doi.org/10.14710/j.gauss.5.2.239-248.
Sarwono, J. (2010). Pengertian dasar structural equation modeling (SEM). *Jurnal Ilmiah Manajemen Bisnis Ukrida*, *10*(3), 98528.
Sasongko, E. N., Mustafid, M., & Rusgiyono, A. (2016). Penerapan metode structural equation modeling untuk analisis kepuasan pengguna sistem informasi akademik terhadap kualitas website (Studi Kasus Pada Website Sia. Undip. Ac. Id). *Jurnal Gaussian*, *5*(3), 395-404. https://doi.org/10.14710/j.gauss.5.3.395-404.
Sihotang, J. W., Hadian, M. S. D., & Muslim, D. (2019). A new perspective in Science and Technology Park Model (STPM) for eco-social development using penta-helix concept: Case study in Sumedang Regency. In *IOP Conference Series: Earth and Environmental Science*. Bandung, Indonesia. p. 012050.
Solangi, Y. A., Tan, Q., Mirjat, N. H., & Ali, S. (2019). Evaluating the strategies for sustainable energy planning in Pakistan: An integrated SWOT-AHP and Fuzzy-TOPSIS approach. *J. Cleaner Prod.*, *236*, 117655. https://doi.org/10.1016/j.jclepro.2019.117655.
Syamsuddin, R. & Fuady, M. I. N. (2020). Upaya penguatan badan penelitian dan pengembangan serta inovasi daerah di Kota Palopo. *Jurnal Wawasan Yuridika*, *4*(1), 63-79. https://doi.org/10.25072/jwy.v4i1.326.
Wahyuningrum, H. & Desrianti, O. (2018). Kajian evaluasi Tingkat Kesiapterapan Teknologi (TKT) penelitian di Batan. In *Seminar Nasional SDM & IPTEK Nuklir 2018*. Yogyakarta, Indonesia.
YazdiMoghaddam, J., Owlia, M. S., & Bandarian, R. (2018). Developing a fuzzy expert system to predict technology commercialization success. *J. Ind. Syst. Eng.*, *11*(2), 228-250.

Appendix

Table S1. Transformation of pairwise comparison matrix

Criteria Factor	Technology	Marketing	Financial	Intellectual Property	Resource	Non-Financial Impact	Government
Technology	**1.000**	0.333	0.333	1.000	0.333	1.000	3.000
Marketing	3.000	**1.000**	1.000	3.000	3.000	1.000	3.000
Financial	3.000	1.000	**1.000**	3.000	0.333	1.000	3.000
Intellectual property	1.000	0.333	0.333	**1.000**	0.333	1.000	3.000
Resource	3.000	0.333	3.000	3.000	**1.000**	3.000	3.000
Non-financial impact	1.000	1.000	1.000	1.000	0.333	**1.000**	1.000
Government	0.333	0.333	0.333	0.333	0.333	1.000	**1.000**
Amount	12.333	4.333	7.000	12.333	5.667	9.000	17.000

Table S2. Normalization of pairwise comparison matrix

Criteria Factor	Technology	Marketing	Financial	Intellectual Property	Resource	Non-Financial Impact	Government	Amount	Priority Factor	Weight Sum Factor	Consistency Factor
Technology	0.081	0.077	0.048	0.081	0.059	0.111	0.176	0.633	0.090	0.682	7.540
Marketing	0.243	0.231	0.143	0.243	0.529	0.111	0.176	1.677	0.240	1.958	8.171
Financial	0.243	0.231	0.143	0.243	0.059	0.111	0.176	1.207	0.172	1.318	7.649
Intellectual property	0.081	0.077	0.048	0.081	0.059	0.111	0.176	0.633	0.090	0.682	7.540
Resource	0.243	0.077	0.429	0.243	0.176	0.333	0.176	1.678	0.240	1.882	7.848
Non-financial impact	0.081	0.231	0.143	0.081	0.059	0.111	0.059	0.765	0.109	0.840	7.692
Government	0.027	0.077	0.048	0.027	0.059	0.111	0.059	0.407	0.058	0.445	7.646
Amount	1.000	1.000	1.000	1.000	1.000	1.000	1.000	7.000	**Lamda**		**7.727**
									CI		**0.121**
									RI		**1.320**
									CR		**0.092**

Table S3. Recapitulation of consistency ratio criteria for each expert

Criteria Factor	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Technology	0.068	0.093	0.087	0.080	0.085
Marketing	0.067	0.052	0.053	0.067	0.067
Financial	0.000	0.058	0.043	0.098	0.057
Intellectual property	0.000	0.000	0.000	0.000	0.000
Resource	0.000	0.051	0.098	0.084	0.067
Non-financial impact	0.000	0.043	0.043	0.097	0.057
Government	0.057	0.025	0.025	0.033	0.025

Table S4. Fuzzification of pairwise comparison criteria

Criteria Factor	Technology			Marketing			Financial			Intellectual Property			Resource			Non-Financial Impact			Government		
	l	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***
Technology	**1**	**1**	**1**	1/4	1/3	1/2	1/4	1/3	1/2	1	1	1	1/4	1/3	1/2	1	1	1	2	3	4
Marketing	2	3	4	**1**	**1**	**1**	1	1	1	2	3	4	2	3	4	1	1	1	2	3	4
Financial	2	3	4	1	1	1	**1**	**1**	**1**	2	3	4	1/4	1/3	1/2	1	1	1	2	3	4
Intellectual property	1	1	1	1/4	1/3	1/2	1/4	1/3	1/2	**1**	**1**	**1**	1/4	1/3	1/2	1	1	1	2	3	4
Resource	2	3	4	1/4	1/3	1/2	2	3	4	2	3	4	**1**	**1**	**1**	2	3	4	2	3	4
Non-financial impact	1	1	1	1	1	1	1	1	1	1	1	1	1/4	1/3	1/2	**1**	**1**	**1**	1	1	1
Government	1/4	1/3	1/2	1/4	1/3	1/2	1/4	1/3	1/2	1/4	1/3	1/2	1/4	1/3	1/2	1	1	1	**1**	**1**	**1**

Table S5. Mean criteria of pairwise comparison

Criteria Factor	Technology			Marketing			Financial			Intellectual Property			Resource			Non-financial Impact			Government		
	l	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***
Technology	**1**	**1**	**1**	3/4	1	11/3	11/9	11/2	2	3/4	1	11/4	1/2	4/7	2/3	6/7	7/8	8/9	11/5	12/5	13/5
Marketing	14/9	2	25/7	**1**	**1**	**1**	1	4/9	12/3	18/9	1	1	3/8	1	6/7	1	13/8	1	6/7	12/5	14/5	21/5	11/4	1	2/3	2
Financial	11/9	11/2	2	1	11/4	1	4/9	**1**	**1**	**1**	3/4	1	1	1/4	2/5	1/2	3/5	11/5	12/5	13/5	8/9	11/8	12/5
Intellectual property	16/7	21/2	31/9	12/3	21/3	3	16/7	21/2	31/9	**1**	**1**	**1**	11/2	2	22/5	2	23/5	31/5	13/5	21/5	24/5
Resource	2	23/5	31/5	1	2/3	2	1/3	3	14/5	23/5	32/5	1	11/2	2	**1**	**1**	**1**	21/5	3	34/5	14/5	23/5	32/5
Non-financial impact	11/5	12/5	13/5	2/3	3/4	4/5	6/7	6/7	8/9	1/2	4/7	2/3	3/8	4/9	5/9	**1**	**1**	**1**	2/3	5/7	3/4
Government	6/7	6/7	8/9	1	1/3	1/2	1	4/5	1	1/4	12/3	21/9	5/9	3/5	2/3	2/5	1/2	3/5	1	4/5	2	1/5	2	3/5	**1**	**1**	**1**

Table S6. Calculation results of the geometric mean criteria

Criteria Factor	$\tilde{r}_i$		
	l	***m***	***u***
Technology	0.853	1.005	1.172
Marketing	1.179	1.525	1.867
Financial	0.864	1.046	1.254
Intellectual property	1.609	2.059	2.506
Resource	1.595	2.109	2.609

Criteria Factor	$\tilde{r}_i$		
	l	***m***	***u***
Non-financial impact	0.719	0.769	0.845
Government	0.917	1.045	1.206
Total	7.737	9.558	11.460
Reverse	0.129	0.105	0.087
Increasing order	0.087	0.105	0.129

Table S7. Calculation results of the fuzzy criteria relative weight

Criteria factor	$\tilde{w}_i$		
	l	***m***	***u***
Technology	0.074	0.105	0.152
Marketing	0.103	0.160	0.241
Financial	0.075	0.109	0.162
Intellectual property	0.140	0.215	0.324
Resource	0.139	0.221	0.337
Non-financial impact	0.063	0.080	0.109
Government	0.080	0.109	0.156