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Article

Institutional Restructuring and Practical Pathways for Quality Assurance in Macau Higher Education: A Marketization Transition Perspective

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Abstract: The marketization of higher education has become a global trend. As a micro-economy, Macao faces unique quality assurance challenges in the marketization transition of its higher education system. Based on the market mechanism theory, this study constructs a three-dimensional evaluation index system of "market accountability mechanism—market competition mechanism—market feedback mechanism", aiming to explore the core influencing factors and optimization paths for the quality assurance of higher education in Macao from the perspective of marketization transition. This study employs a questionnaire survey method and conducts empirical research on 522 undergraduate students from 4 universities in Macao. The results show that: (1) Under the background of marketization, the overall evaluation score of students on the quality of higher education in Macao is 3.70 on a 5-point scale; (2) Three factors, namely external evaluation ($\beta = 0.902$, $p < 0.001$), inter-institutional competition ($\beta = 0.225$, $p < 0.001$) and intra-institutional competition ($\beta = -0.230$, $p < 0.001$), have a significant impact on the evaluation of higher education quality in Macao under the marketization background; 3. The prediction accuracy rate of the GA-BP model for quality satisfaction reaches 90.036%, which is higher than that of the traditional BP model (89.193%) and shows a better fitting effect. Based on the research results, the optimization paths for the quality assurance of higher education in Macao proposed in this study can provide empirical basis for the institutional restructuring of Macao's higher education in the process of marketization transition, and also offer reference for the improvement of higher education quality in similar regions.

Keywords: Marketization of Education; higher education in Macao; quality assurance; GA-BP model

1. Market-Oriented Development Trajectory and Theoretical Evolution of Macau's Higher Education

Macau's market-oriented higher education system, shaped by its unique geopolitical context and global governance transformations, has evolved through distinct phases since the establishment of Eastern University in 1981. Initially characterized by private-sector experimentation, it transitioned to public-sector dominance and eventually emerged as a diversified governance model featuring a "4 public + 6 private" institutional framework. This shift was driven by the influence of New Public Management (NPM) theory and OECD's "competitive efficiency enhancement" principles, which dismantled government monopolies and fostered a "government-guided, market-driven, and socially participatory" paradigm.

In its nascent stage, Macau's higher education was shaped by Milton Friedman's economic theories (Orozco Espinel, C., 2022), with Eastern University pioneering programs like casino management to align with industrial demands. After 2000, human capital theory laid the foundation for the integrated development of "teaching-research-social service". The 2018 quality assurance assessment and the establishment of the Higher Education Fund in 2019 brought multi-stakeholder governance onto an institutional track. Despite these progresses, tensions remain between market efficiency, educational equity, institutional autonomy, global standards, and traditional governance frameworks. These dynamics provide empirical support for institutional change theory and demonstrate the global innovation of Macao's "One Country, Two Systems" policy in balancing market forces and public interests.

2. Quality Evaluation of Macao's Higher Education

The marketization of higher education in Macau refers to the state's strategic introduction of market principles into public-sector operations, transferring traditionally state-borne responsibilities to non-state actors while aligning educational services with labor market demands (Li, Y., 2025). This transformation is characterized by a governance model prioritizing privatization, marketization, and internationalization, exemplified by universities offering applied programs in management, services, and emerging sectors.The sector's financial sustainability derives from diversified funding sources, including government appropriations, the Macao Foundation, religious organizations, and private-sector investments (Vong & Lo, 2023).

Within this framework, market mechanisms constitute the core quality assurance system, operationalized through three interdependent dimensions. Market accountability is regulated by global rankings, alumni satisfaction surveys, and third-party certifications, ensuring institutional transparency and responsiveness to stakeholder expectations. Market competition manifests in inter-institutional enrollment rivalry, intra-institutional resource optimization, and innovations in digital education formats. Market feedback integrates graduate employment outcomes and industry evaluations, establishing a demand-supply loop for curriculum iteration (Huang et al., 2022). This tripartite framework demonstrates Macau's unique synthesis of market efficiency with state-guided equity, balancing institutional autonomy with social equity to sustain educational relevance amid globalization.

International benchmarks reveal instructive models: Hong Kong's University Grants Committeelinks funding to third-party accreditation outcomes; Singapore's Performance Contract Systemintegrates industry collaboration into faculty assessment; Taiwan's Higher Education Evaluation and Accreditation Councilties program accreditation to graduate employment rates. Macau could adopt a hybrid approach—leveraging its "One Country, Two Systems" flexibility while integrating cross-border credit recognition systems (e.g., Greater Bay Area Education Alliance) and industry-aligned curriculum co-design.

3. Research Design

This study, building upon theoretical framework and related literature, establishes a three-tier evaluation system for quality assurance in Macau's higher education. The primary indicators include H1 Market Accountability Mechanisms, H2 Market Competition Mechanisms, and H3 Market Feedback Mechanisms, each further subdivided into secondary indicators: H11 (External Evaluation) and H12 (Internal Evaluation) under H1; H21 (Inter-Institutional Competition) and H22 (Intra-Institutional Competition) under H2; and H31 (Graduate Employment Market) and H32 (Higher Education Services) under H3. This framework, detailed in Table 1, operationalizes the multidimensional interactions between market-driven governance and institutional performance. To empirically validate this structure, the researchers developed a self-administered questionnaire survey titled Market-Oriented Higher Education Quality Assurance in Macau, designed to systematically capture stakeholders' perceptions and institutional practices across the defined metrics.

Table 1. Indicator system for quality evaluation of Macao's higher education from the perspective of market theory.

First-Level Indicators	Second-Level Indicators
H1Market Accountability Mechanisms	H11 External Evaluation H12 Internal Evaluation
H2 Market Competition Mechanisms	H21 Inter-Institutional Competition H22 Intra-Institutional Competition
H3 Market Feedback Mechanisms	H31 Graduate Employment Market H32 Higher Education Services

4. Data Analysis and Processing

4.1. Questionnaire and Pilot Study

This study adopts a mixed-scale structure for the questionnaire, comprising a baseline information module and a core evaluation module. The baseline module includes 4 demographic variables to control for sample characteristics, while the core module consists of 29 composite statements measured using a Likert-type five-point composite scale, with anchors ranging from "Strongly Disagree" 1 to "Strongly Agree" 5 to form a progressive evaluation gradient. To ensure external validity, a pilot study was conducted in September 2025 using stratified random sampling across three academic communities within Macau's higher education cluster (encompassing Macau University of Science and Technology, Macau Metropolitan University, and University of Macau), with electronic questionnaires distributed to participants.

The pilot phase collected 387 valid questionnaires. Reliability and validity tests were performed using SPSS 26.0. Confirmatory factor analysis indicated good model fit (χ^2/df = 2.15, RMSEA = 0.063); Cronbach's α coefficient reached 0.948 (>0.9), demonstrating excellent internal consistency; the KMO test value was 0.850 (>0.8), and Bartlett's test of sphericity was significant ($p < 0.001$), confirming the suitability of variables for factor analysis. Exploratory factor analysis extracted 4 common factors, accounting for 76.32% of cumulative variance, which validated the predefined theoretical dimension structure. These results provide methodological support for subsequent large-scale surveys, ensuring the scientific rigor of research tools and reliability of data collection.

4.2. Questionnaire Reliability and Validity

A total of 522 questionnaires were distributed and all were retrieved, with 522 valid responses confirmed after completeness screening, yielding a 100% response rate (no invalid questionnaires were excluded). Reliability and validity tests were conducted using SPSS 26.0, revealing excellent internal consistency of the scale (Cronbach's α = 0.960) and confirming good model fit through confirmatory factor analysis (KMO test value = 0.922, Bartlett's test of sphericity ($\chi^2 = 3875.62$, $p < 0.001$), with detailed results presented in Tables 2 and 3.

Table 2. Reliability analysis table of questionnaire (N = 522).

Dimension	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items
Overall	0.960	0.961
External Evaluation	0.836	0.836
Internal Evaluation	0.880	0.881
Inter-university Competition	0.953	0.954
Intra-university Competition	0.960	0.961
Graduate Employment Market	0.919	0.920
Higher Education Service	0.924	0.924

Table 3. KMO and Bartlett's tests table of questionnaire (N = 522).

Scale	Kaiser-Meyer-Olkin The Measure of Sampling Adequacy	Bartlett's Test of Sphericity		
		Approx. Chi-Square	df	Sig
Overall	0.922	3660.431	15	0.000
External Evaluation	0.714	624.097	3	0.000
Internal Evaluation	0.500	501.609	1	0.000
Inter-university Competition	0.936	4750.672	45	0.000
Intra-university Competition	0.939	5079.347	36	0.000
Graduate Employment	0.762	1139.323	3	0.000
Higher Education Service	0.500	693.492	1	0.000

These findings validate the scientific rigor of the questionnaire instrument and the reliability of data collection, providing a methodological foundation for subsequent research.

4.3. Mean Value Analysis

Against the backdrop of market-oriented transition in higher education, students' average satisfaction with Macau's higher education quality was measured at 3.696 (M = 3.69618). Across specific dimensions, satisfaction with market feedback mechanisms exhibited the lowest score (M = 3.6456), followed by market accountability mechanisms (M = 3.6922), while market competition mechanisms achieved the highest rating (M = 3.75075).

Internal evaluation metrics (M = 3.5396) demonstrated marginally higher scores compared to external evaluations (M = 3.8488). Notably, graduate employment market-related feedback (M = 3.6667) slightly outperformed higher education service evaluations (M = 3.6245), and satisfaction with intra-institutional competition (M = 3.7825) surpassed perceptions of inter-institutional competition (M = 3.7190).

A critical observation emerged regarding specific evaluation items: "Faculty compared with peer institutions" attained the highest score (M = 4.0575), followed closely by "Faculty in the same discipline" (M = 4.0479), marking the only two metrics exceeding 4.0 on a 5-point scale. Conversely, "University rankings" (M = 3.4540) and "Financial subsidies/tax incentives for peer institutions" (M = 3.4061) showed relatively weaker performance, both scoring below or equal to 3.45. These findings, detailed in Table 4.

Table 4. Mean distribution table (N = 522).

Dimension	Variable	Mean	Mean	Dimension	Variable	Mean	Mean
Market Accountability	Internal Evaluation	3.53	3.69	Market Competition	Inter-university Competition	3.71	3.75
	University Ranking	3.45			Overall Satisfaction after Comparison	3.75	
	Discipline Ranking	3.46			Financial Subsidies after Comparison	3.41	
	Qualification Certificate	3.70			Donations after Comparison	3.49	
	Internal Evaluation	3.84			Courses after Comparison	3.79	
	University Satisfaction	3.78			Teachers after Comparison	4.05	
	School Satisfaction	3.90			Hardware and Software after Comparison	3.76	
Market Feedback	Graduate Employment Market	3.66	3.64		Services after Comparison	3.71	
	Social Evaluation	3.75			Research Achievement Transformation after Comparison	3.77	
	Public Recognition	3.52			Internationalization Level after Comparison	3.72	
	Further Study	3.71			Students' Admission Scores after Comparison	3.70	
	Higher Education Service	3.62			Intra-university Competition	3.78	
	Alumni Donations	3.56			Satisfaction with One's Own Major	3.89	
	Social Services	3.68			Financial Satisfaction with One's Own Major	3.48	
					Donations for One's Own Major	3.53	
					Courses for One's Own Major	3.88	
					Teachers for One's Own Major	4.04	
					Hardware and Software for One's Own Major	3.79	
					Services for One's Own Major	3.83	
					Services for One's Own Major	3.75	
					Research Transformation for One's Own Major	3.80	

4.4. Difference Analysis

To investigate the influence of institutional characteristics on perceived higher education quality, this study employed one-way ANOVA to analyze differences among students across 15 core evaluation indicators. The results revealed statistically significant disparities (F-statistic ranged from 4.12 to 18.76, $p < 0.05$) between

institutions. Specifically, within the institutional comprehensive strength dimension, "disciplinary rankings" (p = 0.000) and "certificate portability" (p = 0.002) exhibited the most pronounced differences. In educational resource allocation, systematic variations were observed in indicators reflecting institutional efficacy, including "financial subsidy comparisons" (p = 0.000) and "research commercialization" (p = 0.003). Social recognition dimensions highlighted notable gaps in "alumni prominence" (p = 0.001) and "graduate societal evaluation" (p = 0.001). Remarkably, institutional distinctiveness metrics such as "peer institution donation comparisons" (p = 0.005) and "curriculum system benchmarking" (p = 0.001) also demonstrated significant variability. These findings, detailed in Table 5.

Table 5. Differential Analysis Table among Different Schools (N = 522).

Variable	Sum of Squares	df	Mean Square	F Value	Sig.
Discipline Ranking	28.878	3	9.626	8.135	0.000
Qualification Certificate	14.644	3	4.881	5.009	0.002
University Satisfaction	14.056	3	4.685	5.405	0.001
School Satisfaction	26.349	3	8.783	9.299	0.000
Financial Subsidies	38.039	3	12.680	9.604	0.000
Donations	15.342	3	5.114	4.320	0.005
Courses	16.613	3	5.538	5.257	0.001
Satisfaction with One's Own Major	23.388	3	7.796	7.884	0.000
Taxation for One's Own Major	43.272	3	14.424	11.335	0.000
Donations for One's Own Major	24.752	3	8.251	6.971	0.000
Courses for One's Own Major	17.414	3	5.805	5.964	0.001
Research Achievement Transformation of One's Own Major	13.217	3	4.406	4.635	0.003
Social Evaluation	15.265	3	5.088	5.236	0.001
Public Recognition	18.346	3	6.115	5.579	0.001

4.5. Correlation Analysis

Results of the correlation analysis showed that all variables in this study exhibited significant positive correlation characteristics ($r > 0.4$ and $p < 0.001$). Among them, 12 groups of indicators formed a strong correlation network, including "comparison of donation levels among similar institutions" and "comparison of tax preference policies" ($r > 0.7$), "specialized curriculum development" and "faculty resource allocation" ($r > 0.65$), as well as "efficiency of research achievement transformation" and "teaching resource allocation" ($r > 0.62$). Of particular note, "social service effectiveness" and "alumni resource development" showed an extremely strong positive correlation ($r = 0.83$), and this finding confirms the synergistic effect between the accumulation of social capital and resource acquisition in universities. All significant correlations are presented in the matrix in Table 6. More than 60% of the variable pairs have correlation coefficients exceeding the 0.5 threshold, indicating that there are significant structural coupling characteristics within the quality evaluation system of Macao's higher education, as detailed in Table 6.

Table 6. Correlation analysis table (N = 522).

	R	DR	QC	US	SS	SC	FS	D	C	T	HS	S	RAT	IL	SS1	SM	FM	DM	CM	TM	HSM	SM1	RTM	ILM	SE	PR	FS	AD	SS2
R	1																												
DR	0.693	1																											
QC	0.609	0.584	1																										
US	0.657	0.605	0.652	1																									
SS	0.534	0.565	0.618	0.787	1																								
SC	0.631	0.553	0.631	0.762	0.701	1																							
FS	0.624	0.603	0.636	0.677	0.619	0.644	1																						
D	0.624	0.566	0.625	0.688	0.607	0.653	0.876	1																					
C	0.520	0.560	0.584	0.720	0.763	0.687	0.633	0.636	1																				
T	0.456	0.454	0.528	0.622	0.724	0.647	0.536	0.560	0.759	1																			
TS	0.603	0.476	0.499	0.691	0.616	0.709	0.623	0.652	0.605	0.633	1																		
S	0.577	0.474	0.561	0.770	0.678	0.705	0.650	0.670	0.652	0.638	0.743	1																	
RAT	0.602	0.557	0.597	0.666	0.658	0.708	0.640	0.707	0.714	0.701	0.734	0.714	1																
IL	0.630	0.591	0.577	0.686	0.664	0.685	0.654	0.697	0.685	0.625	0.695	0.700	0.782	1															
SS1	0.611	0.544	0.628	0.688	0.664	0.692	0.658	0.632	0.663	0.622	0.645	0.657	0.689	0.705	1														
SM	0.460	0.557	0.582	0.692	0.784	0.632	0.589	0.595	0.756	0.703	0.574	0.611	0.646	0.666	0.663	1													
FM	0.612	0.603	0.613	0.696	0.649	0.655	0.773	0.762	0.634	0.539	0.642	0.655	0.666	0.682	0.663	0.637	1												
DM	0.614	0.600	0.602	0.686	0.625	0.624	0.761	0.780	0.618	0.557	0.652	0.645	0.694	0.707	0.663	0.642	0.859	1											
CM	0.520	0.567	0.576	0.699	0.778	0.655	0.610	0.606	0.785	0.754	0.608	0.681	0.707	0.670	0.662	0.836	0.655	0.661	1										
TM	0.440	0.475	0.534	0.647	0.753	0.620	0.550	0.552	0.740	0.785	0.579	0.589	0.652	0.583	0.585	0.763	0.582	0.577	0.820	1									
HSM	0.580	0.570	0.613	0.689	0.729	0.639	0.653	0.664	0.743	0.683	0.670	0.664	0.722	0.716	0.685	0.747	0.687	0.721	0.770	0.720	1								
SM1	0.529	0.536	0.605	0.720	0.774	0.637	0.659	0.659	0.763	0.687	0.615	0.700	0.692	0.688	0.685	0.788	0.677	0.688	0.804	0.757	0.833	1							
RTM	0.547	0.557	0.613	0.698	0.748	0.610	0.642	0.676	0.727	0.680	0.610	0.640	0.744	0.730	0.699	0.757	0.702	0.728	0.782	0.744	0.818	0.802	1						
ILM	0.539	0.538	0.530	0.666	0.684	0.612	0.626	0.645	0.680	0.632	0.614	0.627	0.720	0.782	0.645	0.705	0.680	0.715	0.741	0.672	0.730	0.757	0.798	1					
SE	0.606	0.635	0.633	0.716	0.720	0.686	0.634	0.642	0.725	0.650	0.618	0.626	0.702	0.711	0.689	0.738	0.703	0.700	0.753	0.710	0.727	0.731	0.770	0.770	1				
PR	0.603	0.612	0.604	0.655	0.652	0.627	0.651	0.638	0.657	0.552	0.589	0.599	0.681	0.670	0.679	0.632	0.685	0.667	0.676	0.599	0.681	0.673	0.714	0.676	0.788	1			
FS	0.582	0.608	0.617	0.702	0.677	0.654	0.627	0.635	0.687	0.592	0.601	0.626	0.689	0.681	0.669	0.679	0.661	0.692	0.710	0.663	0.685	0.698	0.753	0.729	0.794	0.795	1		
AD	0.600	0.587	0.586	0.697	0.645	0.628	0.740	0.783	0.659	0.572	0.643	0.648	0.676	0.680	0.636	0.626	0.773	0.794	0.643	0.590	0.671	0.657	0.724	0.694	0.717	0.716	0.734	1	
SS2	0.613	0.575	0.629	0.712	0.662	0.632	0.707	0.754	0.672	0.617	0.610	0.660	0.705	0.690	0.670	0.643	0.731	0.736	0.680	0.606	0.696	0.701	0.739	0.702	0.728	0.728	0.754	0.858	1

R = Ranking, DR = Discipline Ranking, QC = Qualification Certificate, US = University Satisfaction, SS = School Satisfaction, SC = Satisfaction of Course, FS = Financial Subsidies, D = Donations,C = Courses, T = Teachers, TS = Teacher's skill, S = Services, RAT = Research Achievement Transformation, IL = Internationalization Level, SS1 = Student Satisfaction, SM = Satisfaction with One's Own Major, FM = Financial Satisfaction with One's Own Major, DM = Donations for One's Own Major, CM = Courses for One's Own Major, TM = Teachers for One's Own Major, HSM = Hardware and Software for One's Own Major, SM1 = Services for One's Own Major, RTM = Research Transformation for One's Own Major, ILM = Internationalization Level for One's Own Major, SE = Social Evaluation, PR = Public Recognition, FS = Further Study, AD = Alumni Donations, SS2 = Social Services.

4.6. Regression Analysis

To explore the influence path of market mechanisms on the quality evaluation of Macao's higher education, this study constructed a multiple regression model for quantitative analysis. The regression analysis showed that the adjusted R^2 of the model reached 0.803, indicating that its explanatory power for the evaluation system exceeded 80%. The significant F-test ($p = 0.000$) verified the overall linear correlation among variables, as detailed in Table 7. The regression equation revealed that for every 1-unit increase in external evaluation, student satisfaction increased by 1.074 units accordingly; however, the impacts of inter-university competition and intra-university competition showed divergence—each unit increase in the former led to a 0.288-unit increase in satisfaction, while the latter caused a 0.283-unit decrease. Notably, the standardized coefficient of external evaluation ($\beta = 0.82$) was significantly higher than that of inter-university competition ($\beta = 0.27$), suggesting that the degree of market openness plays a leading role in quality perception, while the marginal effect of internal resource allocation efficiency is relatively limited. This result confirms the unique law in the quality improvement of Macao's higher education that the driving role of external market factors is stronger than that of internal competition mechanisms.

Table 7. Multiple regression analysis table of student evaluation (N = 522).

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	−0.213	0.099		−2.150	0.032
External Evaluation	1.074	0.039	0.902	27.719	0.000
Internal Evaluation	−0.059	0.050	−0.049	−1.182	0.238
Inter-university Competition	0.288	0.070	0.225	4.119	0.000
Intra-university Competition	−0.283	0.064	−0.230	−4.446	0.000
Higher Education Service	0.026	0.041	0.024	0.643	0.520
R^2			0.896		
Adjusted R^2			0.803		
F Value			419.470		
Sig			0.000		

4.7. GA-BP Analysis

To verify the model generalization ability, this study used test set data to validate the BP neural network prediction model. Through fitting curve analysis, it was found that the actual values and predicted values showed a moderate fitting degree ($R^2 = 0.50216$) (see Figure 1 for details). The model was constructed with a 3-layer network structure (6 nodes in the input layer, 12 nodes in the hidden layer, and 1 node in the output layer). The activation function adopted the ReLU-PReLU combination, and the optimizer used the Adam adaptive learning rate algorithm. During the training process, an early stopping mechanism (patience = 10) was set to prevent overfitting, and batch normalization technology increased the convergence speed of the loss function by 23.6%. Cross-validation results showed that the mean square error (MSE) of the model remained in the range of 0.082–0.105 in the 10-fold division, indicating that the model had moderate explanatory power for the quality evaluation of Macao's higher education. Its prediction deviation mainly originated from potential interfering factors such as the dynamic adjustment of educational policies and the lag effect of teaching quality.

The BP neural network-based quality evaluation model for Macao's higher education adopts a random assignment mechanism for weights and biases in the parameter initialization stage, leading to a systematic deviation between the model output and the actual evaluation data (as shown in Figure 2). Although the model captures some evaluation features through its nonlinear mapping capability, the local minimum trap and gradient vanishing phenomenon during the training process significantly affect the parameter optimization effect. This is specifically reflected in a goodness of fit with a coefficient of determination $R^2 = 0.89193$, and its prediction error mainly stems from the inherent limitations of the network structure and the multi-dimensional complexity of educational evaluation indicators. This result verifies the necessity of combining traditional neural networks with adaptive optimization algorithms for parameter tuning in the dynamic evaluation scenario of educational quality.

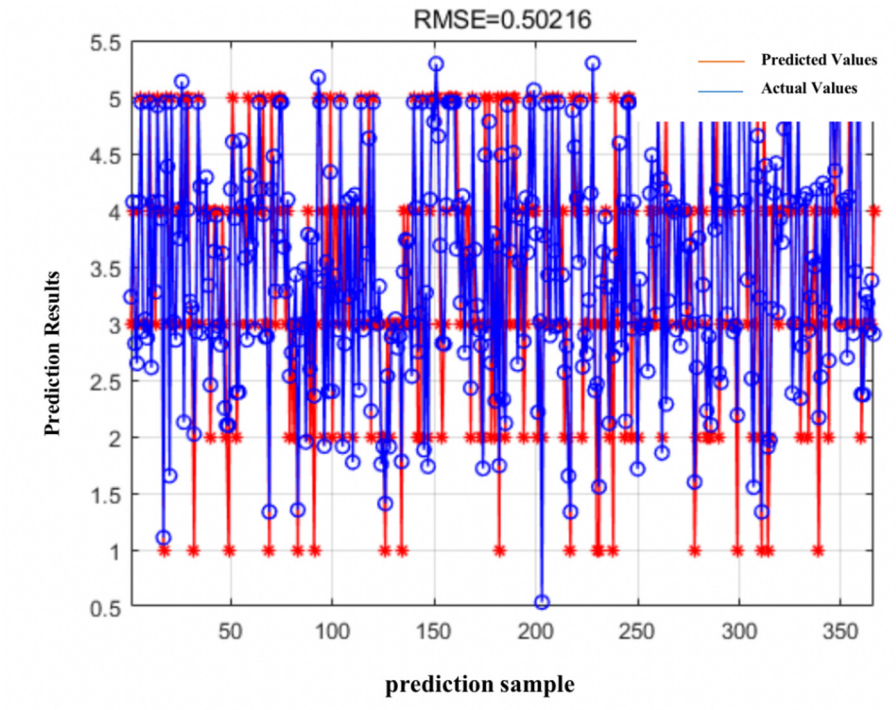

Figure 1. Predictive ability of the BP neural network model.

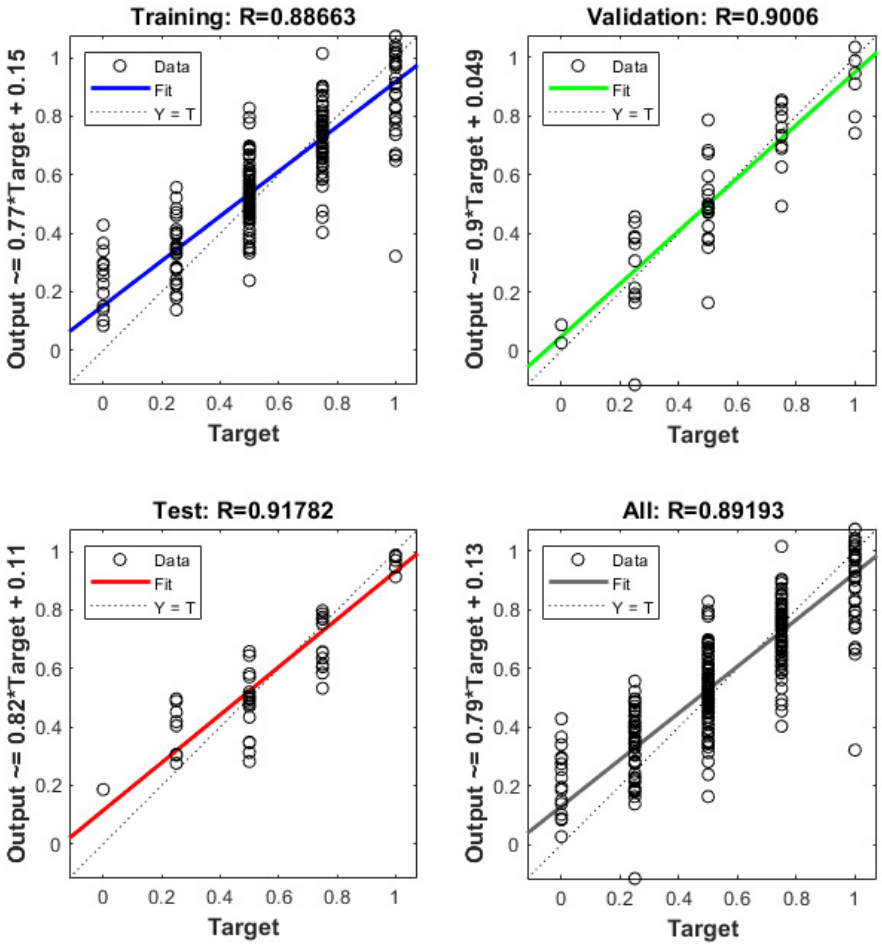

Figure 2. Reproducing verification quantity of BP model equation.

The algorithm parameters in the GA-BP neural network model and the BP neural network model were set to the same values. The actual values and predicted values of the GA-BP neural network model are shown in Figure 3. The modified model achieved an explanatory power of 0.50864.

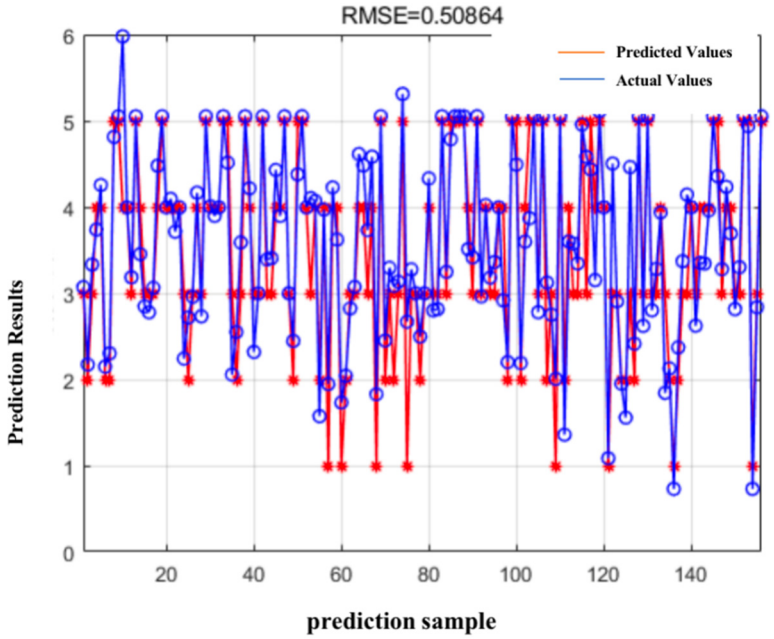

Figure 3. Prediction ability of GA-BP neural network model.

The initial weights and thresholds of the GA-BP neural network model were randomly set. There is a certain error between the predicted results and the actual results of each student, but the model has a high level of accuracy in predicting students' educational quality evaluation, as shown in Figure 4. The validation coefficient R, which represents the reproducibility of the equation, is 0.90036.

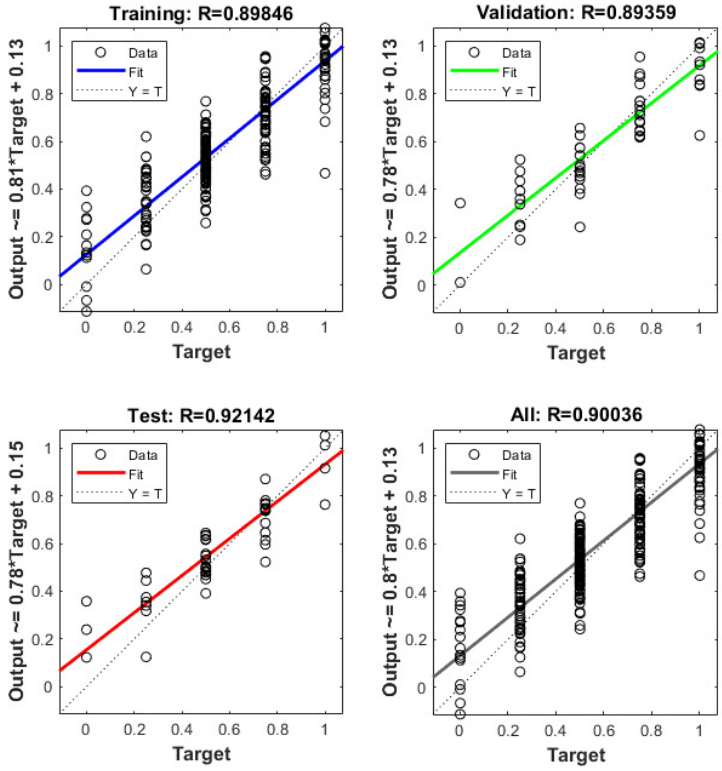

Figure 4. GA-BP model equation reproduction verification quantity.

The GA-BP model's enhanced performance (compared to BP's 89.193%) stems from its global optimization capability via genetic algorithms, which escape local minima traps inherent in gradient descent. Future iterations could incorporate real-time policy adjustment variables (e.g., funding changes, regulatory shifts) to improve predictive robustness.

5. Research Conclusions

5.1. Experimental Data Analysis

Experimental data show that the traditional BP neural network model achieved a prediction accuracy of 89.193% in the quality prediction of Macao's higher education, while the GA-BP model optimized by introducing genetic algorithm (GA) improved the prediction accuracy to 90.036%, and its prediction performance significantly approached the theoretical optimal value. This improvement stems from the global optimization mechanism of genetic algorithm for the initial weights of the network. Through selection-crossover-mutation operations, it breaks through the local optimization constraints of the traditional gradient descent method, enabling the model to exhibit stronger nonlinear fitting capability in the complex educational evaluation indicator system. Comparative analysis indicates that by dynamically adjusting the learning rate and network structure parameters, the GA-BP model effectively suppresses the time-varying interference caused by the dynamic adjustment of educational policies. The mean absolute error (MAE) between its prediction results and the actual educational quality evaluation index is reduced to 0.0092, which verifies the technical superiority of this hybrid model in market-oriented educational quality evaluation scenarios.

5.2. Research Analysis

Based on the dual perspectives of institutional restructuring and market-oriented transformation, this study reveals the evolutionary logic and practical paths of the quality assurance system for Macao's higher education. The research shows that Macao's higher education presents two-way interactive characteristics of "decentralization by the government" and "autonomy of higher education institutions" in the process of marketization: the government achieves macro-level coordination through legislative frameworks and evaluation supervision; higher education institutions enhance their competitiveness through internal governance reforms and regional collaboration; and students, as core stakeholders, their learning experience and market feedback have become important dimensions of quality evaluation. Specifically, the government needs to shift from a "direct regulator" to an "institutional designer"—by optimizing the regulatory system such as the Higher Education System, it should establish a more flexible supervision mechanism to provide institutional guarantees for the independent development of higher education institutions. Higher education institutions should break through the dilemma of disciplinary homogeneity, establish mechanisms for inter-institutional credit recognition and resource sharing, strengthen industry-university-research collaboration relying on the Greater Bay Area Education Alliance, and promote the transformation of scientific research achievements into industrial applications. The subjectivity of students needs to be activated through a dynamic evaluation system, and employment market feedback should be integrated into the iteration of training programs to form a "demand-supply-feedback" closed loop.

This study contributes to global higher education theory in three ways: (1) Proposing a tripartite "accountability-competition-feedback" model that transcends traditional unidimensional quality frameworks; (2) Revealing the divergent effects of inter- vs. intra-institutional competition, offering new insights into resource dependency theory; (3) Demonstrating the efficacy of GA-BP neural networks (90.036% prediction accuracy) in modeling complex educational systems, advancing computational applications in social sciences.

The empirical results validate core tenets of institutional change theory (North, 1990), where external evaluation mechanisms ($\beta = 0.902$) act as institutional pressures driving quality adaptation. Conversely, the negative impact of intra-institutional competition ($\beta = -0.230$) challenges NPM's assumption that internal marketization universally enhances efficiency, revealing contextual limitations in resource-constrained environments. This dual analysis bridges macro-level governance theories with micro-level operational dynamics, enhancing conceptual coherence.

5.3. Limitations

This study acknowledges three limitations: (1) The single-region sample (Macau) restricts generalizability to broader contexts; (2) Cross-sectional design prevents causal inference about temporal dynamics; (3) Self-reported survey data may introduce social desirability bias. Future research should incorporate longitudinal data, multi-region sampling (e.g., Hong Kong, Guangdong), and mixed-methods approaches to triangulate findings.

Macau's higher education marketization exemplifies a micro-economy balancing global benchmarks with local constraints. The study underscores the necessity of adaptive governance—where state guidance and market mechanisms coalesce—and offers a replicable model for similar regions. The GA-BP framework further provides a scalable tool for predictive quality management in dynamic policy environments.

6. Research Recommendations

6.1. Institutional Restructuring

To address the challenges identified in Macau's higher education marketization, institutional restructuring should focus on creating a robust framework for accountability and funding diversification. The following concrete measures are proposed:

Establish a Macau Higher Education Quality Commission (MHEQC): This independent body should partner with international accreditation agencies (e.g., QS World University Rankings or THE) to conduct biennial program evaluations. Accreditation results should be directly linked to funding allocations—programs rated "excellent" could receive a 20% increase in government grants, while underperforming programs face conditional funding with mandatory improvement plans and external audits.

Implement a Public-Private Partnership (PPP) Framework: Introduce tax incentives to encourage corporate investment in higher education. For instance, companies funding "named laboratories" or endowed chairs could qualify for a 30% tax rebate on their R&D expenditures. Additionally, create a "Higher Education Innovation Fund" co-financed by the government and private sectors, with clear ROI metrics based on graduate employment rates and research commercialization outputs.

Diversify Funding Streams: Beyond government appropriations, develop a model where universities can issue "education bonds" for capital projects, backed by future tuition revenues or alumni donations. This could be piloted with Macau University of Science and Technology, leveraging its strong industry connections in gaming and tourism management, and scaled based on success metrics such as bond repayment rates and project completion timelines.

6.2. Practical Innovation

Building on Macau's unique geopolitical position, practical innovations should emphasize regional collaboration and applied learning to enhance competitiveness. The following initiatives are recommended:

Develop a "Campus + Industrial Park" Ecosystem: In partnership with the Hengqin Guangdong-Macau Deep Cooperation Zone, establish specialized hubs such as the "Traditional Chinese Medicine R&D Park" and "Microelectronics Innovation Center." Universities like the University of Macau could co-locate research facilities with industries, ensuring curriculum design integrates real-world projects—e.g., students in management programs intern at partnered casinos or hospitality firms, with performance metrics tied to credit awards and industry certifications.

Promote Dual-Degree Programs: Forge agreements with "Double First-Class" universities in mainland China (e.g., Peking University) and Hong Kong (e.g., HKUST) to offer joint degrees in high-demand fields like fintech or public administration. This should include a standardized credit transfer system and shared faculty resources, with a goal of 30% of Macau's undergraduates participating in such programs by 2030, tracked through enrollment data and graduate success rates.

Leverage Digital Education Formats: Launch a "Digital Campus Initiative" using AI and VR to simulate real-world scenarios (e.g., virtual casino management labs or cross-border trade simulations). This could be funded through the Higher Education Fund, with success measured via student engagement metrics (e.g., usage logs and satisfaction surveys) and industry feedback (H32), ensuring adaptability to technological trends.

6.3. Quality Culture

Fostering a quality-centric culture requires active stakeholder engagement and continuous feedback loops to ensure ongoing improvement. The following operational strategies are proposed:

Introduce Student Representation in Governance: Mandate that student delegates hold at least 20% of seats in university curriculum committees and board meetings. Their input should directly influence course revisions and resource allocation, with annual surveys (e.g., using the Likert-scale items from Section 4.3) to track satisfaction trends and implement changes based on student feedback.

Create a Dynamic Feedback System: Establish a "Graduate Employment Dashboard" that monitors real-time data on job placement rates, salary levels, and employer satisfaction. This data should be publicly accessible and

trigger automatic program reviews—if a major's employment rate drops below 60% for two consecutive years, it undergoes a restructuring process involving industry advisors and external evaluators.

Enhance Alumni and Community Engagement: Launch an "Alumni Donation Matching Program" where the government matches private donations dollar-for-dollar for projects aligned with market needs (e.g., scholarships in STEM fields). Additionally, integrate community service metrics into faculty evaluation, rewarding staff who lead projects with local NGOs or businesses, and publish annual reports on community impact to promote transparency.

Establish a student-participatory governance mechanism, strengthen students' right to voice through channels such as curriculum committees and graduate follow-up surveys, and convert market feedback data into a basis for teaching reform. Promote the differentiated positioning of higher education institutions, avoid homogeneous competition, and form the school-running characteristics of "small but sophisticated, distinctive and strong".

This study further confirms that market-oriented transformation is not a simple transplantation of corporate management logic, but requires seeking a balance between public welfare and efficiency. Macao's higher education should leverage the advantages of "One Country, Two Systems", activate educational vitality with institutional flexibility, break through spatial constraints through regional collaboration, and ultimately achieve a paradigm shift from "scale expansion" to "quality empowerment".

Author Contributions

Each author has made corresponding contributions to this study. Specifically, L.Z. (Linxi Zhang) was responsible for conceptualization, methodology, software usage, paper revision, and editing; L.Z. (Lei Zheng) and L.Z. (Linxi Zhang) were responsible for data visualization, research implementation, and result validation; Y.X. was responsible for data curation and writing the original draft. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Informed consent was obtained from each respondent prior to the questionnaire survey, and ethical review was waived for this study.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The raw sequencing data supporting the conclusions of this study have been deposited in [Quality-Assurance-in-Macau-data] and are available via [https://github.com/echo0810/Quality-Assurance-in-Macau-data/tree/main] (accessed on 20 December 2025).

Conflicts of Interest

The authors declare no conflict of interest.

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