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Psychometric properties and invariance of the scale to measure attitude of researchers for university-industry collaboration

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The psychometric properties of the *Scale to measure the attitude of researchers for scientific-technological collaboration between universities and industry* (EA-COOPTEC, for its acronym in Spanish) were analyzed, specifically evidence of construct validity of the internal structure and invariance for gender and age was obtained. The EA-COOPTEC was administered to 179 academic Teachers–Researchers (T-Rs) involved in Universities-Industry Collaboration (UIC) activities: 50 women and 129 men. Participants had a median age of 36–40years. A descriptive analysis was implemented, as well as an Exploratory and Confirmatory Factor Analysis (EFA and CFA), and a method of succession of nested models for invariance testing. A four-factor model explaining the perception of UIC activities was generated and evidence of invariance for gender and partial invariance for age was obtained. Acceptable fit indices were obtained for the *configurational*, *weak*, *strong* and *strict*. Given the results, we recommend the use of the EA-COOPTEC v0.1 for the analysis of the mean differences between genders and age in T-Rs.

KEYWORDS

universities-industry collaboration, higher eduacation, academic teachers-researchers, invariance, confirmatory factor analysis

1. Introduction

Cooperation is seen as a process in which human capital skills are focused to produce ideas and knowledge (Bozeman et al., 2013). For cooperation to work, human capital must be able to communicate effectively with each other, have a willingness to work cooperatively or collaboratively, and be driven by a common goal (Taboada, 2004; Smit et al., 2020). Given its importance, organizations are increasingly focused on participating in a cooperative manner with the objective of obtaining competitive advantages; due to the fact that collaboration between organizations encourages the production of economic, material and intellectual resources (Etzkowitz, 1998; Agrawal, 2001; Lundvall, 2004).

García-Galván (2011) identifies different types of collaboration between organizations: vertical, when collaborative occurs between organizations with complementary activities; horizontal, when it occurs between competitors and the objective is to achieve economies of scale; and inter-organizational or transversal, when it occurs between universities and industry. In particular, the relationship between universities-industry brings notable benefits to society; some of them are: increasing competitiveness among industry (Burrone, 2005), promoting theoretical

and methodological progress in the field of science, encouraging the capitalization of knowledge (Etzkowitz, 1998, 2003), and turning universities and research centers into an important actor for economic development (García-Galván, 2018). According to Santoro (2000), and Santoro and Chakrabarti (2002), there are four types of Universities-Industry Collaboration (UIC): *research support, cooperative research, knowledge transfer, and technology transfer*. *Research support*, refers to financial and equipment contributions made to universities by industry. Cooperative research includes contract research with individual investigators, consulting by faculty, and certain group arrangements specifically to address immediate industry problems. *Knowledge transfer* encompasses highly interactive activities that include ongoing formal and informal personal interactions, cooperative education, curriculum development, and staff exchanges. *Technology transfer* also involves highly interactive activities, but its focus is on addressing immediate and more industry-specific issues.

Likewise, the relationships between universities-industry are not static and are influenced by different factors (García-Galván, 2008). In this regard, Ankrah and AL-Tabbaa (2015) identified that these can be classified as: *informal personal relationships* (e.g., individual consulting and conferences), *formal personal relationships* (e.g., internships and use of facilities), *third-party relationship* (e.g., institutional consulting and industry partnerships), *formal directed agreements* (e.g., patent and licensing agreements and joint research projects), *formal non-directed agreements* (e.g., funding of university positions and research grants), and *focused structures* (e.g., incubators and subsidiaries). Additionally, Morales and García-Galván (2019) distinguished that among the motivations for engaging in techno-scientific cooperation, the search for additional sources of funding and changing policies that promote collaboration stand out. They also emphasized other motivations such as technology transfer between organizations, technological complementarity, individual risk and cost reduction, and new business opportunities.

Since its origins, UIC has been studied from various perspectives: *Innovation systems*, as a normative approach to public policies (Lundvall, 1992; Freeman, 1995; Edquist, 1997; Vertova, 2014); *Mode 2 of knowledge production* (Gibbons et al., 1997), which integrates the business/industrial vision; the *Triple helix model* (Etzkowitz and Leydesdorff, 1995; Leydesdorff and Etzkowitz, 1996), as a pioneering antecedent of the university with a business vision; and, finally, the *Integrated Contemporary Institutionalism* (ICI) (Taboada, 2004; García-Galván, 2008), as an emerging theoretical approach that supports the formal study of the UIC. Especially, ICI gives meaning to the role of institutions through the multidisciplinary study of their relationships and their effects (García-Galván, 2008). From this point of view, UIC is considered a key asset for economic development and competitive advantages in the production sector (Teece et al., 1998). In turn, this relationship is motivated by the scarce public investment for scientific-technological development (García-Galván, 2008). The ICI, unlike classical models, does not make use of articles or patents as indicators of scientific-technological UIC (García-Galván, 2008) but employs both qualitative and quantitative methods to study the phenomenon and different factors organized in three domains: *Individual, Organizational,* and *Institutional* (Morales, 2019).

There are currently a variety of indicators to measure different types of UIC activities (Gardner et al., 2010; Seppo and Lilles, 2012). In particular, the measurement of perception of T-Rs to UIC is a little explored field, the closest studies are those of López-Martínez et al. (2007), Boardman and Ponomariov (2009), Giuliani et al. (2010), Cudic et al. (2021), Da Silva and Sartori (2022), and Morales (2019). Cudic et al. (2021) measured UIC by constructing indicators based on data reported by different sources with the purpose of studying the relationship between predictors of UIC and its outcomes. For the construct measures, the authors based the theoretical framework of this research on a systematic review of the relevant academic literature, taking into account the availability of variable data. Initially, the authors obtained 36 measures. These were grouped into six constructs, four of which focus on input factors and the remaining two on output factors: *institutional factors, human factors, linkage factors, framework factors, intangible output indicators and tangible output indicators*. The authors found that European countries that invest in measuring predictors of UIC perform better. Based on statistical analysis (partial least squares structural equation modeling), the authors identified that investments in knowledge, networking, and investment in Research and Development (R&D), in general, are the most significant predictors of fostering UIC. Likewise, the authors identified that some of the main obstacles to UIC are: the lack of alignment of incentives between researchers and companies (conflicts with companies), and the lack of academic procedures or intermediaries that facilitate interaction with companies (academic networking problems) where the attitude and perception of researchers play a relevant role (Muscio and Vallanti, 2014).

Da Silva and Sartori (2022) designed a questionnaire based on a systematic review of the literature to highlight and compare the main motivations and barriers to UIC in Brazilian and Irish Technology Transfer Offices (TTOs). The questionnaire was applied to the heads of nine TTOs and consisted of six questions (four open and two closed). The closed questions, which sought to analyze the degree of frequency, were transformed into quantitative data in percentage form, which were later tabulated. The open questions which were intended to raise general information about the university and the TTOs. The authors concluded that the TTOs from Ireland and Brazil have different motivations for cooperation, but face similar barriers despite the completely different contexts they are in. This highlights the importance of measuring indicators constructed based on stakeholder perspectives that help explain UIC barriers.

Boardman and Ponomariov (2009) used a national survey of tenured scientists and their careers in the United States to identify those personal and professional characteristics that arise from the interaction of university scientists with private companies, as well as the different forms of interaction. In particular, among their demonstrations, they identify professional and personal variables as significant predictors of the interactions of scientists with the private sector, including: funding sources, institutional affiliations, type of ownership, student support, scientific values and demographic attributes. Giuliani et al. (2010) analyzed the importance of the individual characteristics of researchers and their institutional environments to explain the propensity to participate in different types of UIC. Drawing on original databases, it presents evidence on three wine-producing areas: Piedmont, in Italy, Chile, and South Africa. Their findings reveal those individual characteristics of researchers, such as centrality in the academic system, age, and gender, matter more than the number of publications or their formal titles.

López-Martínez et al. (2007) conducted an exploratory survey of 31 researchers at the National Autonomous University of Mexico (UNAM, by acronyms in Spanish) and 28 Mexican entrepreneurs;

besides, they conducted a panel discussion among the respondents designed to obtain in-depth qualitative data on motivations and obstacles for UIC. The questionnaire scales were used to explore 19 motivations and 27 obstacles reported by academic researchers for UIC; and 15 motivations and 27 obstacles reported by business executives. The items were to be scored on a 5-point rating scale (0 = not important, to 4 = determinant), and respondents were asked to suggest and score additional motivations and obstacles that were not included in the instruments. With these instruments, the authors were able to: (a) learn the main motivations of university researchers to conduct technological research and seek links with industry, (b) learn the main motivations of industrial entrepreneurs to establish cooperation with universities to develop technology, and (c) identify the main barriers to a healthy relationship between the two institutions. However, the authors did not provide evidence of validity or reliability of the scales used. They concluded by presenting the factors identified in the study as key elements in the development of relations between the two sectors in Latin American countries, and argued the need to rethink our conceptions of motivations and obstacles to UIC within a theoretical framework of inter-institutional communication and organizational cultural change.

In particular, one of the most recent instruments in this field is the *Questionnaire to measure the perception of scientific-technological collaboration between universities and industry* (CP-COOPTEC), developed by Morales (2019). The CP-COOPTEC was made up of 71 items (k), organized into four sections: (a) Sociodemographic and labor data (k = 7), (b) *Individuals* variables associated with scientific-technological UIC (k = 39), (c) *Organizational* variables (k = 13), and (d) *Institutional* variables (k = 12). The *Individual* section refers to the knowledge, experiences, attitudes and motivations with respect to the Teacher-Researchers' (T-Rs) UIC. This is divided into two dimensions: *Attitudes about UIC* and *Institutional Supports*. The first, are defined as the beliefs, attitudes and values of individuals, and how these are continuously related, forming a system, which is a predictor of the individual's behaviors and responses (Rokeach, 1968). For its part, the dimension of *Institutional Supports* refers to the financial, formative and procedural help provided by universities and research centers to industries (Casalet and Casas, 1998; Etzkowitz, 1998; Bajo, 2006; García-Galván, 2013; López-Leyva, 2014). The *Organizational* section refers to the organizational behavior of UIC. It is made up of three dimensions: (a) *Structure*, (b) *Resources and Capabilities*, and (c) *Incentives*. The *Structure* dimension refers to the mode of organization and set of relationships, as well as internal and external factors that affect the internal behavior of universities (García-Galván, 2013). The *Resources and Capacities* dimension are all the human, material, intellectual and intangible elements available to carry out UIC activities (Taboada, 2004; García-Galván, 2018). The third dimension, *Incentives,* refers to the retribution received by academic T-Rs for carrying out UIC (Antonelli, 2008); these include economic, social, professional or personal rewards. The *Institutional* section refers to the norms of UIC. This area is divided into two dimensions: (a) *Formal Institutions* and (b) *Institutional Change*. The *Formal Institutions* dimension refers to the inclusion of UIC in the curriculum, documentation, and statutes of university (North, 1990; Hodgson, 2007; Attard et al., 2021). The *Institutional Change* dimension refers to document management, as well as training, participation and T-Rs' proposals for the improvement of norms and public policies related to UIC (North, 1990). Figure 1 shows the theoretical model with the domains and dimensions of T-Rs perception of scientific-technological collaboration between universities and industry.

According to Morales (2019), organizations can be considered as the operational base of institutions. Likewise, in the process of function of the organizations, they provide feedback to the institutions. For their part, the institutions support the normative bases of the organizations, while the organizations provide inputs for the subsequent development of the institutions. Consequently, if the organizational and institutional aspects are adequately addressed, providing the necessary support for the UIC activities, the TRs present a better attitude towards the UIC.

In particular, the CP-COOPTEC has six subscales to measure the attitude of researchers towards scientific-technological collaboration between universities and industry. The first subscale, which refers to the *Cognitive* component of the attitude towards UIC, measures the T-Rs' thoughts about it (Rokeach, 1968). The second subscale, which refers to the *Affective* component, measures the T-Rs' affect and beliefs (Rokeach, 1968). The third subscale, which refers to the *Perception about institutional supports* component, measure the perception of T-Rs about the interest of UIC (Casalet and Casas, 1998; Etzkowitz, 1998; Alcántara et al., 2006; Bajo, 2006; García-Galván, 2013; López-Leyva, 2014). The fourth subscale, which refers to the *Perception of the infrastructure and management* component, measures the aspects related to the performance of universities and research centers as organizations (Hodgson, 2006, 2007). The fifth subscale, which refers to the *Perception of the value of contributions* component, measures the benefits of carrying out UIC for universities and research centers, the productive sector and society in general (Antonelli, 2008). Finally, the sixth subscale, which refers to the *Perception of the institutional framework* component, measure the aspects related to the formal and informal norms that exist in universities and research centers with respect to the UIC (North, 1990; Aoki, 2007; Gandlgruber, 2007; Hodgson, 2007). Among the main advantages of the CP-COOPTEC we can mention: (a) it has evidence of validity of the design and content, based on theoretical foundation and expert judgment; (b) as well as some evidence of validity of the internal structure aspect; and (c) there are results of its application in qualitative and quantitative exploratory studies of UIC (Morales, 2019; Morales and Rodríguez, 2021; Pérez-Morán et al., 2021).

Based on the literature review, it can be said that there are few studies that measure the perception, motivation or attitude of T-Rs towards scientific-technological UIC. In this regard, Morales (2019)

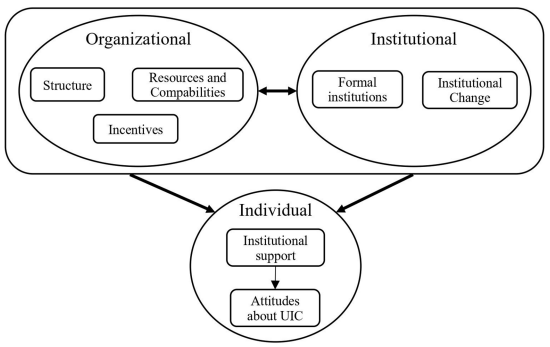

FIGURE 1
Theoretical model with the domains and dimensions of T-Rs perception of scientific-technological UIC.

mentions that it is important to measure the attitude of T-Rs towards scientific-technological collaboration because it is a factor that affects the effectiveness and impact of knowledge transfer between universities and other sectors. Although, the six subscales of the (EA-COOPTEC) to measure the attitude of researchers towards scientific-technological collaboration between universities and the productive sector are considered a methodological advance within the theoretical approach of the ICI, it is necessary to obtain evidence of construct validity through more robust methods that adhere to the recommendations and guidelines of emblematic organizations and authors (Messick, 1989, 1995; American Educational Research Association, American Psychological Association, and National Council on Measurement in Education, 2014). Therefore, the purpose of this study is to analyze the psychometric properties of the EA-COOPTEC to measure the attitude of researchers for scientific-technological collaboration between university and industry, in order to obtain evidence of construct validity of the internal structure aspect and invariance, and thereby propose a valid and reliable revised version that can be used by other researchers to conduct predictive and comparative studies at the state level.

2. Methods

2.1. Participants

A total of 184 Teacher-Researchers (T-Rs) selected by non-probabilistic purposive sampling participated. The selection criteria for the participants in the study were that they had to (1) work as T-Rs in a higher education institution or research center in the state of Baja California, and (2) belong to the National System of Researchers (SNI, by acronyms in Spanish) of the National Council of Science and Technology (Conacyt, by acronyms in Spanish) of Mexico. After a database cleaning process, 179 cases were analyzed (129 [72%] men and 50 [28%] women). The sample of T-Rs participants represents 21.3% of the researchers in the SNI 2017 census in the state of Baja California (N = 841; CONACyT, 2017), that is, one-fifth of the population under study. Participants had a mean age of 36 to 40 years, 21 belonged to the age group 35 years or younger, 39 to the age group 36 to 40 years, 31 to the age group 41 to 45 years, 14 to the age group 46 to 50 years, and 74 were older than 50 years. It is important to mention that the gender distribution of the T-Rs participating in the study is relatively similar with the information at the national participation level in the SNI in Mexico reported by CONACyT (2021) in the *General Report on the State of Science, Technology and Innovation. Mexico 2019*. In 2013 the participation of women in the SNI in Mexico was 37.01% (6,869 of 18,555), in 2015 was 35.79% (8,346 of 23,316), in 2017 was 36.72% (9,982 of 27,186), and, in 2019 was 37.61% (11,489 of 30,548).

2.2. Instrument

For the purposes of the present study, the EA-COOPTEC designed by Morales (2019) and adjusted by Pérez-Morán et al. (2021) was used. This instrument measures the attitude of the subjects in relation to the linkage activities between UIC and is composed of six self-report scales of 46 items with Likert-type response options ranging from 1 (strongly disagree) to 4 (strongly agree). The six subscales are organized in three domains: *Individual* (subscale 1, 2, 3, and 5), *Organizational* (subscale 4), and *Institutional* (subscale 6). Previous studies (Morales and Rodríguez, 2021) reported an adequate overall Cronbach's Alpha coefficient index ($\alpha = 0.92$), and an overall Rho Alpha and McDonald Omega index with excellent values (overall $\rho = 0.91$, overall $\omega = 0.94$, respectively) (see Table 1).

2.3. Procedure

An invitation was sent to their institutional e-mail address, in which they were informed about the general purpose of the study, their voluntary participation and the anonymity of their responses. A link to answer the CP-COOPTEC was also attached. If the T-Rs had any questions or concerns about the nature of the study, they had the possibility of contacting the investigators through the institutional e-mail address. From the data collected, a database cleaning was performed, following the recommendations of Hair et al. (2019), and Tabachnick and Fidell (2018). No missing data or erroneous values were found. Cases with outlier scores were identified and eliminated through a visual analysis of a box- and-whisker plot. Five outlier cases (overall index scores less than 95) were found, so the database was reduced to 179 cases (129 males and 50 females).

2.4. Data analysis

This section was organized in several stages. In the first stage, descriptive statistics were obtained, mean and standard deviation values were calculated, both for the items and for the general index of the EA-COOPTEC. Likewise, the assumptions of normality, linearity, sample adequacy and reliability were verified. Normality was analyzed by means of the Kolmogorov–Smirnov test with Lilliefors correction, as well as by obtaining the kurtosis and skewness values of the scores. Regarding the acceptance criteria, for the Kolmogorov–Smirnov test a value of less than 0.05 ($p > 0.05$) (Dallal and Wilkinson, 1986). Kurtosis and skewness had to be between the values of −1 to 1 ($-1 < p > 1$) according to the recommendations of Hair et al. (2019). For the calculation of reliability indices of the scale, Cronbach's test (α) was used. Given that the usefulness of Cronbach's Alpha test has been a matter of debate in recent decades (see McNeish, 2018; Raykov and Marcoulides, 2019), it was decided to accompany it with the standardized ordinal Rho's Alpha (ρ) and McDonald's Omega

TABLE 1 Overall and subscale internal consistency values of EA-COOPTEC.

Subscale	α	ρ	ω
1	0.64	0.66	0.68
2	0.90	0.90	0.88
3	0.84	0.85	0.88
4	0.87	0.87	0.88
5	0.65	0.64	0.80
6	0.67	0.68	0.75
Overall	0.92	0.91	0.94

coefficient (ω). The cut-off criteria were $\alpha \geq 0.70$, $\rho \geq 0.70$ (Hair et al., 2019) and $\omega \geq 0.80$ (Nájera-Catalán, 2019). For its part, for the sample adequacy measure, it was determined through Bartlett's test of sphericity and the Kaiser-Meyer-Olkin coefficient (KMO). The cutoff criteria for acceptance were: a *value of p* ≤0.50 for Bartlett's test, and a value ≥0.70 for the KMO coefficient (Hill, 2011; Hair et al., 2019).

In the second stage, a series of analyses were carried out to obtain evidence of construct validity of the internal structure aspect. For the dimensionality analysis, with the support of three specialists in the subject of UIC was proposed a four-factor model EFA was applied from a deductive approach. A new revised version of the instrument was adjusted and proposed, consisting of four factors: *Community benefits* (k = 15), *Personal benefits* ($k = 13$), *Institutional responsibility* ($k = 14$), and *Regulation and normativity* (k = 4). For this, a varimax extraction method was applied (Tabachnick and Fidell, 2018). Model fit was also evaluated according to the suggestions of Hu and Bentler (1999); given the sample size (N = <250), the fit indices and their criteria were: Comparative Fit Index (CFI) ≥ 0.90, Tucker-Lewis Index (TLI) ≥ 0.90, Standardized RMSR ≤0.08 and RMSEA ≤0.08. Because that the four-factor model proposed explains only 45% of the total variance, which is less than the recommendation by specialists (Tabachnick and Fidell, 2018) and did not show evidence of good fit (CFI = 0.74; TLI = 0.72; GFI = 0.70; NFI = 0.60; RMSEA = 0.08; SRMR = 0.08), it was decided to adjust the items by subscale: *Community benefits* (k = 10), *Personal benefits* (k = 7), *Institutional responsibility* (k = 9), and *Regulation and normativity* (k = 3). The option of eliminating problematic items was explored to improve the statistical fit of the model based on modification indices, standardized factor loadings, and error variances. Once a model that met the established fit criteria was obtained, the analysis of the internal structure of the scale was complemented with a maximum likelihood estimation model for the AFC following the suggestions of Hu and Bentler (1999) for the evaluation of model fit.

In the third stage, an MFCMG was applied to test the factorial invariance of the adjusted version of the scale (EA-COOPTEC v0.1) according to the gender and age variables. For the gender variable, the groups were divided into men and women. Likewise, for the age variable, two large age groups were considered: T-Rs under 45 years of age and T-Rs 45 years of age or older. For the measurement of invariance, the recommendations of Jöreskog and Sörbom (1979) and Vandenberg and Lance (2000) were followed. The four-factor model, product of the previous stage, was taken as a basis and a sequential constraint procedure for nested models was used. The criterion for acceptance of invariance was that the chi-square difference ($\Delta\chi 2$) between the nested models was not significant ($p > 0.05$). Because the calculation of $\chi 2$ is sensitive to sample size (Vandenberg and Lance, 2000; Cheung and Rensvold, 2002) the analysis was accompanied with CFI and RMSEA indices. The criteria for these indices were: a CFI difference (ΔCFI) between models less than −0.01 and an RMSEA close to or less than 0.08.

3. Results

3.1. Descriptive analysis

The mean score for the EA-COOPTEC v0.1 index was 85.98 (SD = 11.31). Also, the means for each of the subscales were 2.70 (SD = 0.53) for the first, 2.98 (SD = 0.41) for the second, 2.25 (SD = 0.51) for the third and 3.37 (SD = 0.0) for the fourth. The means of the item scores presented values ranging from 2.23 (SD = 0.84) to 3.55 (SD = 0.61). These results indicate that the majority of the T-Rs respondents answered the items by marking the response options *Agree* and S*trongly agree*. Regarding the internal consistency of the EA-COOPTEC v0.1, acceptable internal reliability indices were obtained. The overall Cronbach's Alpha coefficient presented a value of 0.91. Likewise, the standardized ordinal Rho Alpha test obtained acceptable results (overall ρ global = 0.91). Similarly, the McDonald Omega index presented excellent values (ω global = 0.93). The results of the scale were acceptable, given that they presented scores ranging from moderate to excellent. Based on these results, the assumption of reliability of the internal structure of the overall scale is accepted (see Table 2).

The assumptions of normality and linearity were verified. As evidence of normality, low values of kurtosis (0.84) and skewness (−0.04) were obtained. In addition, the results of the Kolmogorov-Smirnov normality test with Lilliefors correction showed a value lower than the established criterion ($p > 0.50$, $gl = 182$), so it is considered that the data are normally distributed. For the linearity assumption, a Q-Q plot was visually evaluated and it was found that the data behave linearly (see Figure 2).

The results obtained indicate a good measure of sample adequacy in the EA-COOPTEC v0.1. Bartlett's test of sphericity yielded a significant result ($p < 0.00$), suggesting the presence of sample adequacy among the variables. Likewise, the KMO coefficient presented an index greater than the cut-off criterion (KMO = 0.86). The above results allow the application of multivariate analysis, such as the EFA and CFA to obtain a theoretical model underlying the EA-COOPTEC v0.1 (Tabachnick and Fidell, 2018).

Moreover, the findings show high means for factors 1 (*Community benefits*), 2 (*Personal benefits*) and 4 (*Regulation and normativity*). This suggests that the T-R respondents have a positive perception of the *Community* and *Personal benefits* of engaging in UIC activities, as well as the importance of regulation and standardization of these activities. With respect to the results of factor 3 (*Institutional responsibility*), the mean for the response of the items presents the lowest value of all the factors (M = 2.23, SD = 0.84). This suggests that, in the universities and research centers where the subjects work: (a) there is little economic, material and human support to carry out UIC; (b) few training activities or courses are provided; and (c) the institutional plan does not include activities related to UIC.

On the other hand, the correlation coefficients between factors 1, 2 with factor 4 present positive and moderate values (r between 0.34 and 0.35), in particular, factors 1 and 2, which show a strong correlation coefficient ($r = 0.56$), suggesting that the perception of *Community benefits* and the perception of *Personal benefits* are closely related. However, factor 3 presents low correlation with factors 2 ($r = 0.15$) and 4 ($r = -0.01$) suggests that the support and interest perceived by universities and research centers does not have an impact on the motivation and perception of the *Personal benefits* of this activities, as well as the perception of the importance of generating and implementing manuals, protocols, public policies and peer reviews to improve UIC, respectively.

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TABLE 2 Reliability indices and factor loadings of the EA-COOPTEC-v0.1 items and subscales.

Factor	Item	Factor loading	M (SD)	α	ρ	ω
F1	Q_CB.01	0.43	3.0 (0.56)	0.89	0.89	0.90
	Q_CB.02	0.42				
	Q_CB.03	0.32				
	Q_CB.04	0.65				
	Q_CB.05	0.59				
	Q_CB.06	0.68				
	Q_CB.07	0.63				
	Q_CB.08	0.50				
	Q_CB.09	0.58				
	Q_CB.10	0.67				
F2	Q_PB.01	0.37	3.4 (0.46)	0.83	0.83	0.89
	Q_PB.02	0.53				
	Q_PB.03	0.33				
	Q_PB.04	0.40				
	Q_PB.05	0.47				
	Q_PB.06	0.47				
	Q_PB.07	0.51				
F3	Q_IR.01	0.49	2.5 (0.57)	0.89	0.89	0.87
	Q_IR.02	0.51				
	Q_IR.03	0.53				
	Q_IR.04	0.46				
	Q_IR.05	0.58				
	Q_IR.06	0.58				
	Q_IR.07	0.49				
	Q_IR.08	0.61				
	Q_IR.09	0.48				
F4	Q_RN.01	0.53	3.4 (0.54)	0.83	0.83	0.73
	Q_RN.02	0.51				
	Q_RN.03	0.47				

3.2. Factor structure

The EFA of the adjusted version of the four-factor model with 29 items of the EA-COOPTEC v0.1 explained 51% of the total variance. In general, the items presented good factor loadings. The standardized factor loadings for the revised model presented an acceptable correlation between items: for the first factor these ranged between 0.32 (Q_CB.03) and 0.68 (Q_CB.06); for the second, between 0.33 (Q_PB.03) and 0.53 (Q_PB.02); for the third, between 0.46 (Q_IR.04) and 0.61 (Q_IR.08); and for the fourth, between 0.47 (Q_RN.03) and 0.53 (Q_RN.01). The CFA of the adjusted version of the four-factor model met the criteria for adequate fit indices ($\chi 2 = 558.08$, $gl = 366$, $p < 0.00$, CFI = 0.92, TLI = 0.91, GFI = 0.82, NFI = 0.81, RMSEA = 0.05 [95% CI = 0.04, 0.06], SRMR = 0.06). Table 3 shows the comparison between the fit parameters of the revised four-factor model of the EA-COOPTEC with 46 items and the revised four-factor model of the EA-COOPTEC v0.1 with 29 items.

The structure of the model is described as follows: the first factor, *Community benefits* of universities-industry collaboration, is made up of 10 items and describes the perception that T-Rs have about to the enhancement of the individual, social, developmental and linkage aspects that these activities bring to the region in which they take place. The second factor, *Personal benefits*, is made up of seven items and refers to the improvement of the academic and collaborative dimensions for the T-Rs, as well as a description of their motivation and stance towards the institutions involved in these activities. The third factor, *Institutional responsibility*, is made up of nine items that explain the support, training and regulatory planning obligations that have to generate UIC. Finally, the fourth factor, *Regulation and normativity*, is made up of three items that measure the documentation activities in universities and research centers, government management and the peer review process necessary for these activities. Table 4 shows the distribution of the domains and items of the adjusted scale (EA-COOPTEC v0.1).

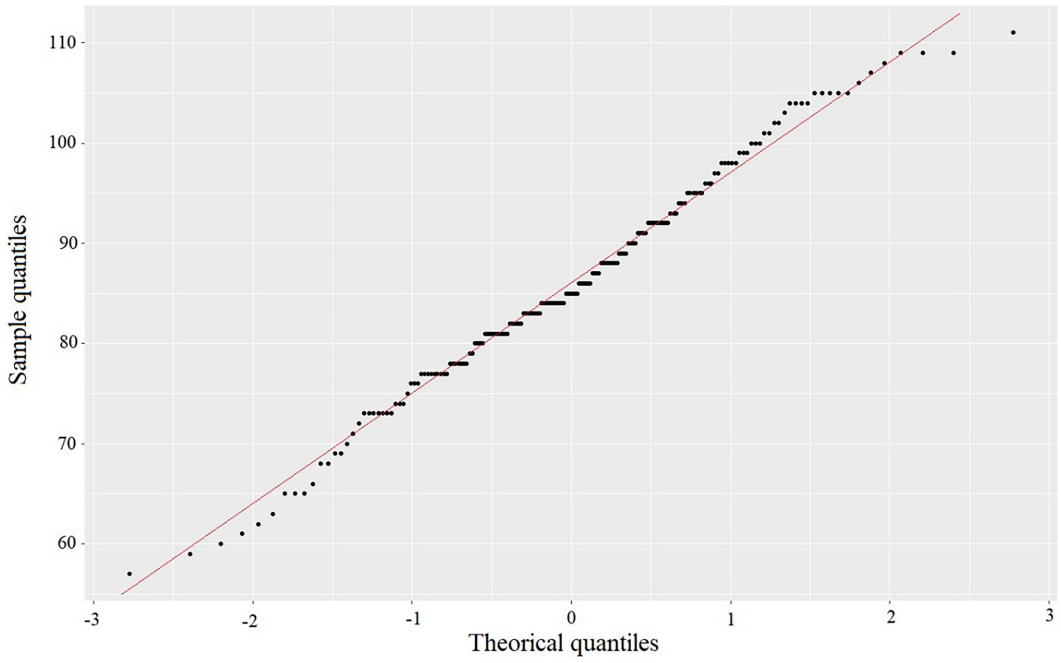

FIGURE 2
Q-Q Plot for EA-COOPTEC v0.1 results.

TABLE 3 Comparison between the fit parameters of the four-factor model of the EA-COOPTEC with 46 items and the revised four-factor model of the EA-COOPTEC v0.1 with 29 items.

Model	X^2	*gl*	*p*	CFI	TLI	GFI	NFI	RMSEA	SRMR
Four-factor model (k = 46) EA-COOPTEC	1803.98	854	< 0.01	0.74	0.72	0.70	0.60	0.08	0.08
Revised four-factor model (k = 29) EA-COOPTEC v0.1	558.08	366	< 0.01	0.92	0.91	0.82	0.81	0.05*	0.06
*95% CI = 0.04; 0.06									

3.3. Factorial invariance

An MFCMG was applied to examine the evidence of factorial invariance between T-Rs men and women in the four-factor model of the EA-COOPTEC v0.1. First, the factor structure of the model was evaluated to be the same for men and women; according to the results of the analysis, it was found to have a moderate fit according to the criteria established *a-priori* ($\chi2 = 1164.9$; $gl = 732$; $p < 0.00$; CFI = 0.841; RMSEA = 0.081 [95% CI = 0.072, 0.090]). Similarly, the values obtained in the fit indices allow the acceptance of factorial invariance of the weak model ($\Delta\chi2 = 16.36$; $p = 0.90$; ΔCFI = −0.003), of the strong model ($\Delta\chi2 = 31.28$; $p = 0.18$; ΔCFI = −0.002) and of the strict model ($\Delta\chi2 = 22.872$; $p = 0.78$; ΔCFI = −0.002). These results suggest that factor loadings, intercepts, and residuals are the same for both groups. The fit indices and values of the different nested models can be seen in Table 5.

We also examined the evidence of factorial invariance between T-Rs with an age equal to or less than 45 years and those older than 45 years. The factor structure of the model was the same for T-Rs with an age equal to or less than 45 years and those older than 45 years; according to the results of the analysis, the model was found to have a moderate fit according to the criteria established *a-priori* ($\chi2 = 1069.4$; $gl = 732$; $p < 0.00$; CFI = 0.873; RMSEA = 0.072 [95% CI = 0.062, 0.081]). The values obtained in the fit indices allow the acceptance of factorial invariance of the weak model ($\Delta\chi2 = 29.966$; $p = 0.22$; ΔCFI = −0.002), so it is considered that the factor loadings of the model are equal for both groups. As for the strong invariance model, the results do not provide evidence to support that the intercepts are equal for both groups ($\Delta\chi2 = 38.500$; $p = 0.041$; ΔCFI = −0.005). The recommendations of Byrne et al. (1989) on parameter release for obtaining a partial invariance model were followed, so the intercept of item Q_PB.05 ("I sympathize with teacher-researchers engaged in universities-industry collaboration") was released, which allowed us to accept a strong partial invariance model ($\Delta\chi2 = 32.887$; $p = 0.10$; ΔCFI = −0.003). However, the values for the acceptance of the strict invariance model were not adequate ($\Delta\chi2 = 78.192$; $p = 3.5e\text{-}6$; ΔCFI = −0.018) for acceptance.

4. Discussion

This study constitutes an advance in the field of measuring University-Industry Collaboration (UIC) from the perspective of

TABLE 4 Distribution of the items of the EA-COOPTEC v0.1 by four factors model.

Factor	Item (description)
Factor 1: Community benefits of universities-industry collaboration	Q_CB.01. Community benefits of universities-industry collaboration.
	Q_CB.02. The professors-researchers carry out universities-industry collaboration because they are aware of the benefits of carrying them out.
	Q_CB.03. The T-R carry out universities-industry collaboration because they have had good experiences in the past about it.
	Q_CB.04. The universities-industry collaboration of university and research centers with the productive sector denotes a greater commitment of these with society in general.
	Q_CB.05. The consolidation of universities-industry collaboration implies a more direct role of university and research centers in the economic and social development of the regions.
	Q_CB.06. The quality of graduate education is closely related to the deepening of collaborative ties between university and research centers with productive sector.
	Q_CB.07. The quality of research developed in university and research centers is closely related to the deepening of collaborative ties between universities-industry collaboration.
	Q_CB.08. As universities-industry collaboration is strengthened, university and research centers acquire greater prestige in the eyes of the various sectors of society.
	Q_CB.09. As universities-industry collaboration is strengthened, university and research centers acquire greater legitimacy in the eyes of the various sectors of society.
	Q_CB.10. Postgraduate training must respond directly to market requirements.
Factor 2: Personal benefits of universities-industry collaboration	Q_PB.01. Universities-industry collaboration support the training of students.
	Q_PB.02. I have always enjoyed working in a team.
	Q_PB.03. I like to carry out techno-scientific cooperation activities.
	Q_PB.04. I am interested in solving practical problems in the production field.
	Q_PB.05. I sympathize with T-R who carry out universities-industry collaboration.
	Q_PB.06. I am in favor of the current managers of the central administration to promote universities-industry collaboration.
	Q_PB.07. I am in favor of the current directors of the academic units promoting universities-industry collaboration.
Factor 3: Institutional responsibility for universities-industry collaboration	Q_IR.01. Your institution provides sufficient financial support for the development of universities-industry collaboration.
	Q_IR.02. My institution provides training to T-R in universities-industry collaboration.
	Q_IR.03. My institution establishes clear procedures in relation to universities-industry collaboration processes.
	Q_IR.04. The institution makes efficient use of TICs for the development and promotion of universities-industry collaboration.
	Q_IR.05. The institution has specialized personnel to manage universities-industry collaboration (e.g., linkage executives, knowledge brokers, innovation managers).
	Q_IR.06. The institution promotes the development of entrepreneurial skills and links with the productive sector.
	Q_IR.07. The regulation of your institution's universities-industry collaboration is adequate.
	Q_IR.08. Your facility's institutional planning includes elements related to universities-industry collaboration.
	Q_IR.09. Your institution's educational model exhibits elements related to universities-industry collaboration.
Factor 4: Regulation and normativity of universities-industry collaboration	Q_RN.01. It is necessary to establish action protocols related to universities-industry collaboration (operation, organization and procedure manuals).
	Q_RN.02. Changes are needed in public policies to help foster universities-industry collaboration.
	Q_RN.03. It is important to involve research professors in the review of regulations on technical and scientific cooperation.

The items were translated from its original version in Spanish.

researchers. By way of discussion, achievements and limitations are presented and contrasted with precedents concerning the study and measurement of UIC. First, it can be said that the psychometric properties of the EA-COOPTEC v0.1 meet the quality criteria of linearity, normality and reliability, as well as sample adequacy and construct validity of the internal structure and invariance for gender and age. In particular, based on the results of the EFA and the recommendations of UIC specialists, it can be argued that the six-factor version of the EA-COOPTEC is not the best organization of the items and therefore of representing the construct. For it, an inductive-deductive approach analysis was conducted in order to find an optimal model solution. As a result, a revised four-factor model was proposed that demonstrated adequate goodness-of-fit for the sample of T-R participants. With this, it is confirmed that the *attitude of researchers for scientific-technological collaboration between universities and industry* underlying the EA-COOPTEC v0.1 is a multidimensional construct, this finding is consistent with how several scholars

TABLE 5 Analysis of factorial invariance of the EA-COOPTEC v0.1 as a function of gender and age.

Variable	Model	χ^2	$\Delta\chi^2$	p	gl	Δgl	CFI	ΔCFI	RMSEA
Gender	Configurational	1164.9	–	–	732	–	0.841	–	0.081
	Weak	1181.3	16.36	0.90	757	25	0.844	0.003	0.079
	Strong	1212.5	31.28	0.18	782	25	0.842	−0.002	0.078
	Strict	1235.4	22.87	0.78	811	29	0.844	−0.002	0.076
Age	Configurational	1069.4	-	-	732	-	0.873	-	0.072
	Weak	1099.4	29.966	0.22	757	25	0.871	−0.002	0.071
	Strong	1137.9	38.500	0.04*	782	25	0.866	−0.005	0.071
	Strong partial	1132.3	32.887	0.10	781	24	0.867	−0.003	0.071
	Strict	1210.5	78.192	3.5e-6*	811	30	0.849	−0.018	0.074

*$p < 0.05$.

conceptualize it (Etzkowitz, 1998; Etzkowitz et al., 2000; Bodas et al., 2013; Wanda, 2015).

Compared to other studies (López-Martínez et al., 2007; Boardman and Ponomariov, 2009; Giuliani et al., 2010; Morales, 2019; Cudic et al., 2021; Da Silva and Sartori, 2022), only López-Martínez et al. (2007) and Morales (2019) applied instruments similar to the EA-COOPTEC to measure UIC from the researchers' perspective. However, López-Martínez et al. (2007) reported no evidence of validity or reliability. For his part, Morales (2019) obtained evidence of validity of the design and content of the instrument used, as well as some evidence of validity of the internal structure aspect; in particular, he reported a Cronbach's Alpha of 0.92. In this sense, the results of the internal consistency analyses of the improved version of the EA-COOPTEC v0.1 of the present study (Cronbach's Alpha = 0.91, ordinal Rho Alpha test = 0.91 and McDonald's Omega index = 0.94) coincide relatively with that reported by Morales (2019). Despite this, it is important to highlight that there are few studies with which the results of the present study can be compared, especially where the measurement of a similar construct is addressed and evidence of internal structure and invariance is shown.

Second, the results support the evidence of factorial invariance on *configurational*, *strong* and *strict* models for gender and factorial invariance on *configurational* and *strong* models (with the exception of item Q_PB.05 "I sympathize with teacher-researchers engaged in universities-industry collaboration") for the age in a sample of Mexicans T-Rs. Thus, indicating that participants conceptualize the universities-industry collaboration construct in the same way regardless of gender or age. Therefore, valid comparisons of mean scores of the EA-COOPTEC v0.1 subjects can be made, and it is not necessary to use normative scores for different groups according to gender or age. Also, it is hypothesized that these results may be different in a sample of T-Rs belonging to universities and research centers with a greater focus on research and development activities than those focused on teaching.

Regarding gender and UIC, no studies were found that apply methods for obtaining evidence of factorial invariance between *genders*; when this relationship between variables is addressed, it is commonly assessed whether there is a difference between men and women in the patterns of participation in these activities (Bozeman et al., 2013; Tartari and Salter, 2015). The same is true with respect to the *age* variable, no studies of invariance as a function of age were found; likewise, most of these investigations operationalize age differently (Bozeman et al., 2013). For example, Boardman and Ponomariov (2009) and Giuliani et al. (2010) conducted studies to explore UIC or make comparisons between different groups of participants. Boardman and Ponomariov (2009) drew the data for their analyzes from a survey of US university scientists. The dependent variables analyzed were nine and the explanatory variables were 15, including age and sex. In their findings, they report that male T-Rs carry out more activities related to the UIC. In particular, these authors mention that women are hired in the academic world in increasing numbers only recently. Likewise, they identified that the activities related to the UIC in which to be an older T-R is relevant are the generation of patents and the co-authorship of research articles with industry personnel. Giuliani et al. (2010) collected their data through a survey applied in person. This survey included aspects related to the background of the researcher and his personal collaborations with other academic researchers and with the industry. Based on their results, they reported that women are more likely than male T-Rs to carry out UIC-related activities. Also, in their study they found that younger T-Rs are more likely to form U-I bonds than their older colleagues. However, none of the mentioned studies reported evidence of confiability, validity and factorial invariance of their instruments.

Although this study constitutes a contribution to the measurement of scientific-technological cooperation between university and industry, some limitations should be considered: first, since the EA-COOPTEC v0.1 is a self-report scale, it is necessary to conduct social desirability studies of it; second, although the sample represents 21. 3% of the researchers in the 2017 SNI census in the state of Baja California ($N = 841$; CONACyT, 2017), it was taken from a specific geographic area, which implies that generalization of the findings to other regions or at the national level should be done with caution; third, the participation of women in the study is relatively similar, but lower than the trend in 2019 (37.61%) at the national level of participation in the SNI in Mexico reported by CONACyT (2021) in the latest *General Report on the State of Science, Technology and Innovation. Mexico 2019*; fourth, the factor Regulation and Normality, is composed of three items barely meeting the minimum acceptable range of items (Streiner, 1994); fifth, no information was collected from other indicators used to measure different types of UIC activities (Gardner et al., 2010; Seppo and Lilles, 2012) that provide evidence of concurrent, discriminant and predictive validity; and sixth, the criterion of strict invariance as a function of age is not met.

5. Conclusion

In conclusion, the EA-COOPTEC v0.1 presents adequate psychometric properties of reliability and internal structure aspect validity to measure the attitude and perception of T-Rs towards University-Industry Collaboration (UIC). The results support the hypothesis of the multifactorial nature of the measurement of T-Rs' attitude towards UIC. From the theoretical point of view, with the four-factor model of the instrument (*Community Benefits, Personal Benefits, Institutional Responsibility, and Regulation and Normativity*), it contributes to the delimitation of the construct supported by *Integrated Contemporary Institutionalism* (ICI; Taboada, 2004; García-Galván, 2008), which provides a theoretical approach for the analysis of UIC from the T-Rs' perspective.

Also, evidence of factorial invariance indicates that participants conceptualize the construct in the same way regardless of gender or age. The results support evidence of factorial invariance for the *configurational*, *strong* and *strict* models for the gender variable and factorial invariance for the *configurational*, *strong partial* models for the age variable, indicating that participants conceptualize the construct in the same way regardless of gender or age. This is particularly valuable in the study of UIC, since there are no scales designed for its exploration from the T-Rs' perspective that report this type of measurement invariance and with it the possibility of conducting comparative studies.

Finally, the results of this study contribute to the creation of robust indicators for the measurement of scientific and technological cooperation between university and industry from the T-Rs' perspective. The EA-COOPTEC v0. 1 is the only instrument at present that has evidence of reliability, validity, and invariance at the state level in Mexico, and that has a robust theoretical frame of reference from which to analyze and predict UIC outcomes: increasing competitiveness among industry (Burrone, 2005), promoting theoretical and methodological advancement in the field of science, fostering the capitalization of knowledge (Etzkowitz, 1998, 2003), and turning universities and research centers into an important actor for economic development (García-Galván, 2018).

For future research, it is recommended: (a) to conduct social desirability studies of the EA-COOPTEC v0. 1; (b) expand the sample to be representative by age strata and other variables of interest so that the results can be generalized to other states, at the national level, and in other countries in the region with a similar science and technology system; (c) expand the sample of participating female researchers to reduce possible biases when comparing with the male sample; (d) increase, based on the recommendations of UIC specialists and solid theoretical foundations, the number of items of the *Regulation and Normality* factor so that the construct faithfully represents the reality to be measured; (e) accompany the application of the EA-COOPTEC v0. 1 with the measurement of other variables in order to provide evidence of concurrent, discriminant and predictive validity, especially those variables associated with *institutional factors, human factors, linkage factors, framework factors, intangible product indicators and tangible product* indicators (Cudic et al., 2021); and (f) Conduct a study based on the Bayesian Mindsponge Framework (BMF) to consolidate the conceptualization, construction and fit the theoretical model underlying EA-COOPTEC v0. 1 and improve estimation with small sample sizes used for the study of UIC in science and technology systems worldwide (Nguyen et al., 2022).

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The study procedure was supervised and approved by a committee of researchers from the Autonomous University of Baja California. For the application of the questionnaire, the voluntary participation of research professors was requested, who were previously informed about the objectives and procedures of the study and were informed of the confidentiality, safeguarding, and use of the results for research purposes. The application of the survey did not represent any risk to the physical or occupational integrity of the participants.

Author contributions

JP-M contributed to the idea of research, its conceptualization, implementation, and methodology. He was in charge of writing the manuscript. He also contributed to the analysis and interpretation of data, and to the revision of the English version and writing in Frontiers format. MM-P contributed to implementation of the methodology. He also contributed to the analysis and interpretation of data, and to the revision of the first version and writing in Frontiers format. BB-B directed the analysis and interpretation of data, contributed to the conceptualization of the research, and to the writing of the manuscript. He was also in charge of the revision of the English version and the writing in Frontiers format. JC-G collaborated in the analysis and interpretation of data, supported the search for additional bibliographic information, and reviewed the style of the article. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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