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RESEARCH

# Assessment of integration level of the Cross-border Regional Innovation System for table grapes in the Sonora – Arizona region

## Valoración del nivel de integración del Sistema Regional de Innovación Transfronterizo de la uva de mesa en la región Sonora - Arizona

Date received: September 26th, 2019

Date approved: December 19th, 2019

Martín Alberto Delgado Saldívar [1] and
Pablo Wong-Gonzalez [2]

[1] Master's in Industrial Engineering (Texas A&M University). PhD Candidate in Regional Development (Centro de Investigación en Alimentación y Desarrollo A.C), Project evaluation consultant, and adjunct professor in the Department of Management at Faculty of Economic and Administrative Sciences, Universidad de Sonora.
Email: martin.delgado@unison.mx.

[2] Master of Science in Regional and Urban Planning, The London School of Economics and Political Science (University of London); PhD in International Development (University of East Anglia). Professor-researcher at the Regional Development Coordination of CIAD.
Email: pwong@ciad.mx.

## Abstract

The Sonora-Arizona region has a historical background and strong economic and social ties that lead to considering it as a binational region. In recent years, apart from the growth and intensification of the cross-border integration of productive activities, attempts have also been made to promote collaboration in the areas of science and technology, seeking the creation of Cross-Border Regional Innovation Systems (CBRIS). The objective of this work is to make an assessment of the level of integration of the CBRIS in a specific sector, the table grape. The assessment was carried out using the methodology originally proposed by the Organization for Economic Cooperation and Development (OECD), which is made up of ten dimensions comprising a set of variables that are considered as "proximities". The original variables were operationalized to use available secondary statistics and assess the dimensions to thereby define the level of integration. This methodological process is proposed to evaluate asymmetric regions such as this cross-border region.

**Keywords:** Cross-Border Regional Innovation System, Sonora-Arizona Region, "proximities", table grape.

**JEL Code:** F1, F15,O, O3, O31, O32, R1, R12

## Resumen

La región Sonora-Arizona tiene antecedentes históricos y fuertes vínculos económicos y sociales que conllevan a considerarla como una región binacional. En años recientes, aparte del crecimiento e intensificación de la integración transfronteriza de actividades productivas particulares, también se ha intentado impulsar la colaboración en las áreas de ciencia y tecnología, buscando la creación de Sistemas Regionales de Innovación Transfronteriza (SRIT). El objetivo de este trabajo es realizar una valoración del nivel de integración del SRIT en un sector específico, la uva de mesa. La valoración se llevó a cabo mediante la metodología propuesta originalmente por la Organización para la Cooperación y el Desarrollo Económicos (OECD por sus siglas en inglés), la cual se integra por diez dimensiones, a su vez conformadas por variables que son consideradas como "proximidades". Las



https://doi.org/10.36792/rvu.vi84.10

variables originales se operacionalizaron para utilizar estadísticas secundarias disponibles y valorar las dimensiones para con ello plantear el nivel de integración. Este proceso metodológico se propone para evaluar regiones asimétricas como es esta región transfronteriza.

**Palabras clave:** Sistema Regional de Innovación Transfronteriza, Región Sonora–Arizona, "proximidades", uva de mesa

**Código JEL:** F1, F15,O, O3, O31, O32, R1, R12

## Introduction

Globalization and the internationalization of the economy have promoted partnerships and strategic alliances between regions to increase their levels of competitiveness, take advantage of complementarities and geographical location, access markets and sources of investment, as well as benefit from technological innovation (Perkmann & Sum, 2002: 3-21; Wong-González, 2005: 78). In the knowledge society, competitive advantage lies in innovation, which is defined as the implementation of a new or significantly improved product or process (good or service), a new marketing method, or a new organizational method in business practices, workplace organization, or external relations (OECD, 2013: 16).

The knowledge embedded in products is what makes them competitive. Innovation, by bringing a greater value proposition to the market, becomes the generator of new levels of competitiveness (Sakaiya, 1994: 73-74). It is a fact that the knowledge society has changed manufacturing systems (Chase, Jacobs, & Aquilano, 2009: 372-374), which is why regions tend to promote their knowledge-based development (Wong-González, 2005: 78).

Innovation is evaluated by the dynamism of the relationships between actors dedicated to knowledge exploration (multidisciplinary teams of researchers), knowledge exploitation (actors who interact with researchers to commercialize results), and the "expert advocates" (consultants or venture capitalists involved in production processes, service development, or marketing systems) (Cooke, 2004: 628-629).

Currently, regions have comparative and competitive advantages that are essential for their economic development and seek to enhance their advantages in natural resources or manufacturing infrastructure with new value propositions to the market. To operationalize these processes, various countries have promoted the creation of Sistemas Nacionales de Innovación (SNI) and, when limited to a region, Sistemas Regionales de Innovación (SRI) (Iammarino, 2005: 3). When these schemes are established between two (or more) nations, Sistemas Regionales de Innovación Transfronterizos (SRIT) emerge, as an effort to promote development at different levels—territorial, national, regional, or binational (Boisier, 2002: 11; OECD, 2013: 13).

The SRI emerge as a territorially focused analytical perspective, and in many cases with activity specialization linked to global, national, and other regional systems to commercialize new knowledge (Cooke & Memedovic, 2006: 3). The reasons behind the formation of an SRIT lie in the potential complementarities of knowledge and innovation that contiguous regions can obtain (Chaminade & Nielsen, 2011: 12; OECD, 2013: 25-27, 41, 44; Trippl, 2009: 153-154). These complementarities can stimulate innovation activities and be economically beneficial for the regions involved. For example, in the European Union (EU), the creation of Eurorregions is encouraged to promote a policy of European cohesion through greater innovation and with regional «smart specialization» strategies supporting knowledge-based development (OECD, 2013: 74).

Studies in Europe on SRIT indicate that it is necessary to assess the following factors to define the dimensions that measure the integration of a cross-border region (Trippl, 2006: 7-13): (1) the scientific base and innovation infrastructure; (2) the business strategies of companies, cross-border clusters, and knowledge bases; (3) cross-border innovation interactions; (4) socio-institutional actors; and (5) innovation policies.

With the aim of measuring the degree of integration between two regions in different nations, cross-border regions have been studied, particularly European SRIT (K.-J. Lundquist & Trippl, 2009: 3, 11-25; Nauwelaers, Maguire, & Marsan, 2013: 10-40; OECD, 2013: 17; Trippl, 2006: 6-15), and a methodological model provided by the OECD (2013: 145-160) has been developed, in which ten dimensions are defined to evaluate different proximities through the variables that compose them.

In a trend similar to that of Europe, several regional initiatives have been identified on the Mexico–United States border that seek to promote binational integration and innovation processes through cross-border associative regions or economic and commercial corridors (Conferencia de Gobernadores Fronterizos, 2009; Conferencia de Gobernadores Fronterizos & Wong-González, 2007: 108-109; Pavlakovich-Kochi, 2006: 49-51; Wong-González, 2005: 81-82). One effort occurred between Universities of Arizona and Sonora, businesspeople, and government officials from Sonora and Arizona upon the entry into force of the North American Free Trade Agreement in 1994, with the project Visión Estratégica del Desarrollo Económico de la Región Sonora-Arizona (VEDERSA), which sought to go beyond traditional cultural and social ties and strengthen interactions in the fields of economy, trade, and investment (Wong-González, 2005: 91).

The attributes and conditions are particularly relevant in the context of the cross-border space of the Sonora-Arizona Megaregion, considered as an asymmetric region regarding many factors. This asymmetry compels reconsideration of the region's future, considering that the formation of an SRIT is an alternative regional development path based on innovation and cooperation ("High Road" Path), unlike the development path based on exploiting the differentiation in factor costs ("Low Road" Path) (Trippl, 2006: 8-9), which has traditionally been followed in this type of cross-border region between countries with different levels of development, such as Mexico and the United States.

The objective of this article is to carry out an assessment of the integration level of the SRIT for table grapes in the Sonora-Arizona region, considered an asymmetric region due to its development levels. The assessment will be conducted through an adaptation of the methodology defined by the OECD (2013: 145-160), where dimensions are composed of variables that represent "proximities," which are evaluated using publicly available statistics. This is a first attempt to assess the integration of this region.

## The Sonora-Arizona Region: Brief overview

It should be considered that the Sonora-Arizona region has an economic and social history that has led it to be regarded as a binational region despite its asymmetry. In fact, despite the significant national differences and the existence of an international political border, some analysts consider that in this cross-border space, a regional identity has been preserved that constitutes a binational cultural region (Gomezcésar Hernandez, 1995: 11-13). Three historical stages can be distinguished (Bracamonte-Sierra, 2019: 31-32): until 1930 with a mining-livestock export model, from 1940 to 1970 with a primary export model focused on agriculture, and since 1970 an export-oriented manufacturing model with maquiladoras expanding into technology-based industries such as aerospace, ICT, and biotechnology development. The economy of Sonora has been much more dependent on the maquiladora sector and the automotive industry (Pavlakovich-Kochi, 2006: 4).

As the maquiladora sector expanded in Sonora and the rest of Mexico, so did the trade of goods between Arizona and Mexico. Even before the entry into force of the North American Free Trade Agreement (NAFTA) in 1994, Mexico was already Arizona's main foreign trade partner. By leveraging family and business ties on both sides of the border, the fresh produce industry became a unique cross-border agro-industrial block (Alisha, Kim, & Pavlakovich-Kochi, Vera, 2019: 84).

Geographical proximity and the presence of superior North American capital accelerated the process of Sonorans' approach to the material culture of the Anglos. Of particular importance was the introduction of the railroad, large-scale copper mining on both sides of the border, and the colonization of the agricultural valleys in southern Sonora, where farmers emerged using production techniques similar to those of North Americans. Furthermore, due to its social and cultural significance, the history of several indigenous ethnic groups of Sonora also plays a role, as in 1995 a third of the Yaqui tribe, almost all of the Pápagos (Tohono O'odham), and the majority of the Cucapá population lived in Arizona (Gomezcésar Hernandez, 1995: 18, 22).

As shown in Table 1, the two states exhibit asymmetries in various variables. Sonora barely reaches 38% of the surface area of its neighboring state. Regarding population, although in 2016 Arizona had 6.93 million inhabitants and Sonora 2.85 million (2015), their proportion relative to the country was practically the same, 2.14% and 2.38%

respectively. With a very different GDP, Sonora surpasses Arizona in exports to the neighboring country. Table 2 and Figure 1 show that the largest cities in Arizona are Phoenix and Tucson, with a combined population of 5.17 million in 2012, while Hermosillo and Ciudad Obregón together had 1.19 million inhabitants in Sonora in 2010 (Gibson, Pavlakovich-Kochi, Wong-González, Jaewon, & Wright, 2016: 42).

**Table 1.** Comparative data of Sonora and Arizona

| Concept | Arizona | Sonora |
|---|---|---|
| Surface area km2 | 475,030 | 179,354 |
| Inhabitants (2016, 2015) | 6,931,071 | 2,850,330 |
| Percentage of population relative to the country (2016, 2015) | 2.14% | 2.38% |
| Students in state universities in Arizona 2012 | 139,603 | |
| Total students in universities in Sonora 2010-2011 | | 80,716 |
| Percentage of population in universities | 2.0% | 2.8% |
| GDP (Millions of Dollars 2013) | 274,734 | 36,389 |
| Exports to the neighboring country (millions of Dollars 2013) | 6,992 | 14,045 |

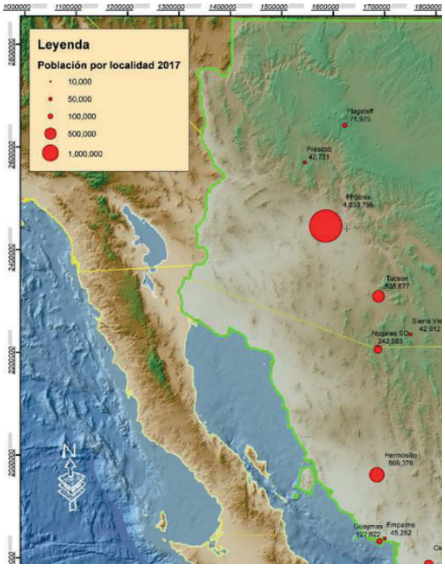
Source: Own elaboration based on data from Wilson et al. (2015), and individual pages of the institutions.

**Table 2.** Population of the main cities in the Sonora-Arizona region for 2012- 2020.

| County/Municipality | Arizona | Sonora |
|---|---|---|
| Flagstaff | 65,870 | |
| Prescott | 7,866 | |
| Phoenix | 4,192,887 | |
| Tucson | 980,263 | |
| Sierra Vista | 43,888 | |
| Nogales | 20,837 | 220,292 |
| Hermosillo | | 784,642 |
| Guaymas/Empalme | | 203,430 |
| Ciudad Obregón | | 409,310 |
| Navojoa | | 157,729 |
| Álamos | | 25,848 |
| **Total** | **5,311,611** | **1,801,251** |

Source: Gibson, Pavlakovich-Kochi, Wong-González, Lim & Wright (2016)

**Figure 1.** Sonora-Arizona Megaregion




Source: Own elaboration based on data from population.

The Gross Domestic Product of Sonora represents between 11.5% and 15.2% of Arizona's GDP.[1] Comparing the GDP of the border states on both sides of the border, it is observed that Texas in the United States and Nuevo León in Mexico are the most outstanding. In exports to Mexico, Texas accounts for 76% of the total of the four American states, while Chihuahua constitutes 25% and Sonora 10% of the exports of Mexican states to the United States (see Table 3).

**Table 3.** State GDP and exports (2013, Millions of Dollars)

| State | State GDP | State exports to Mexico | State exports to USA |
|---|---|---|---|
| California | 2,212,991 | 23,510 | |
| Arizona | 274,734 | 6,992 | |
| Nuevo Mexico | 90,828 | 720 | |
| Texas | 1,557,193 | 100,030 | |
| Baja California | 34,030 | | 25,396 |
| Sonora | 36,389 | | 14,045 |
| Chihuahua | 34,044 | | 34,490 |
| Coahuila | 40,011 | | 25,924 |
| Nuevo León | 85,827 | | 20,421 |
| Tamaulipas | 35,682 | | 18,079 |
| **Total** | | **131,252** | **138,355** |

Source: (Wilson et al., 2015) https://www.wilsoncenter.org/publication/competitive-border-communities-mapping-and-developing-us-mexico-transborder-industries

[1] Based on information from the University of Arizona's economic indicators, https://azmex.eller.arizona.edu/

In terms of formal integration, state governments and the Arizona-Sonora and Arizona-Mexico Commissions have played a highly relevant role (Wong-González, 2005 and 2019). The states of Sonora and Arizona initiated formal relations in 1959 through the Sonora-Arizona Economic and Social Promotion Committee and the Arizona-Mexico West Trade Commission, predecessor organizations of the current binational commissions. Within these commissions, joint working meetings were held to analyze and discuss issues of interest in the areas of education, health, communications, and economy. As previously indicated, in anticipation of the formation of a free trade zone in North America through the signing of NAFTA, as well as due to the growing process of globalization, in the early 1990s Sonora and Arizona decided to elevate the strategic partnership to a higher level of integration and formalization, proposing to conceive themselves as a single economic region that would allow them to take advantage of location advantages and economic complementarities before NAFTA. Thus, a Strategic Vision for the Economic Development of the Sonora-Arizona Region was designed (Pavlakovich-Kochi, 2006; Wong-González, 2005 and 2019).

More recently, the governments of Sonora and Arizona decided to transform the cross-border cooperation model then in force. In June 2016, the governors of both states announced the formalization and promotion of the formation of a binational Megaregion that seeks to leverage shared economic strengths and ongoing collaboration, allowing them to enhance their competitive position at a global scale. Among other aspects, it aims to increase flows of trade and investment and promote the cultural wealth of both states. The scope of action of the states of Sonora and Arizona around the Megaregion has led to the deployment of a broad exercise of regional cross-border paradiplomacy (Wong-González, 2019).

To apply the methodological process to evaluate the degree of integration of the SRIT for table grapes in the region, this article analyzes the case of table grapes produced in Sonora and distributed worldwide through distributors located in Nogales. Currently, Sonoran farmers have developed or contracted the creation of new varieties to extend market windows, that is, they have sought technology in various academic and technological development institutions in different countries, more than in the region under study.

## Integration assessment

Innovation systems are generally confined to regions, since the set of actors produces generalized and systemic effects that stimulate the region's companies to develop specific forms of capital, derived from social relations, norms, values, and interactions within the community in order to reinforce innovation capacity and regional competitiveness (Doloreux & Parto, 2004: 3). That is, innovation systems appear as networks where actors exchange codified and tacit knowledge in their activities (Kraemer-Mbula & Wamae, 2012: 45). Recently, international integration and globalization processes have induced the formation of SRIT in subnational spaces of neighboring countries (OECD, 2013: 13-14).

For some analysts, these forms of cooperation through SRIT constitute the latest and most advanced form of cross-border construction based on the success of incremental integration schemes, and their complexity makes the evaluation of cross-border integration complicated and only recently studied (K.-J. Lundquist & Trippl, 2009: 1, 2011: 8-13; K. Lundquist & Trippl, 2011: 12-21; Trippl, 2009: 151).

A key concept and category for the analysis of the degree of integration of an SRIT is “proximity.” In this sense, considering the multiplicity of factors to assess SRIT, dimensions have been derived that evaluate functional proximity and relational proximity (Boschma, 2005: 64-72; K.-J. Lundquist & Trippl, 2009: 10, 2011: 3-6; Trippl, 2009: 7-13). Functional proximity refers to geographic proximity in interactive learning and innovation, which is neither a necessary nor sufficient condition for learning to take place, but too little or too much proximity can harm the process (Boschma, 2005: 3). It is, in summary, the geographic or physical dimension of distance understood through travel times and transportation costs, rather than kilometers traveled. Relational proximity is a general term for all types of non-spatial proximity, including cognitive, cultural, institutional, social, organizational, and technological (Makkonen & Rohde, 2016: 1626).

The analysis process to evaluate integration of an SRIT is based on ten dimensions defined by the OECD (2013: 20, 37, 61), in the document “Regions and Innovation: Collaborating Across Borders,” which are the following: 1. Geographic accessibility,

2. Socio-cultural proximity, 3. Institutional context conditions, 4. Cross-border integration, 5. Economic specialization, 6. Business innovation model, 7. Knowledge infrastructure, 8. Innovation system interactions, 9. Governance, and 10. Policy mix. These dimensions form the methodological basis of this article.

To understand the dynamics of an SRIT, it is necessary to clarify that the dimensions originate as a logical consequence when measuring the degree of interaction of the proximities that compose them (Boschma, 2005: 71). When there are regions with different economies and levels of development, degrees of border difference, complementarity or asymmetry—in terms of economic equality/inequality, political compatibility/incompatibility, and cultural and national identities—determine the potential of the different types of cross-border relationships, which are in turn affected by the degree of "openness" of the border in question (Trippl, 2006: 10). In summary, the dimensions derive from the concept of functional proximities (physical or geographic) and relational proximities (intangible based on degree of similarity and affinity) (OECD, 2013: 37).

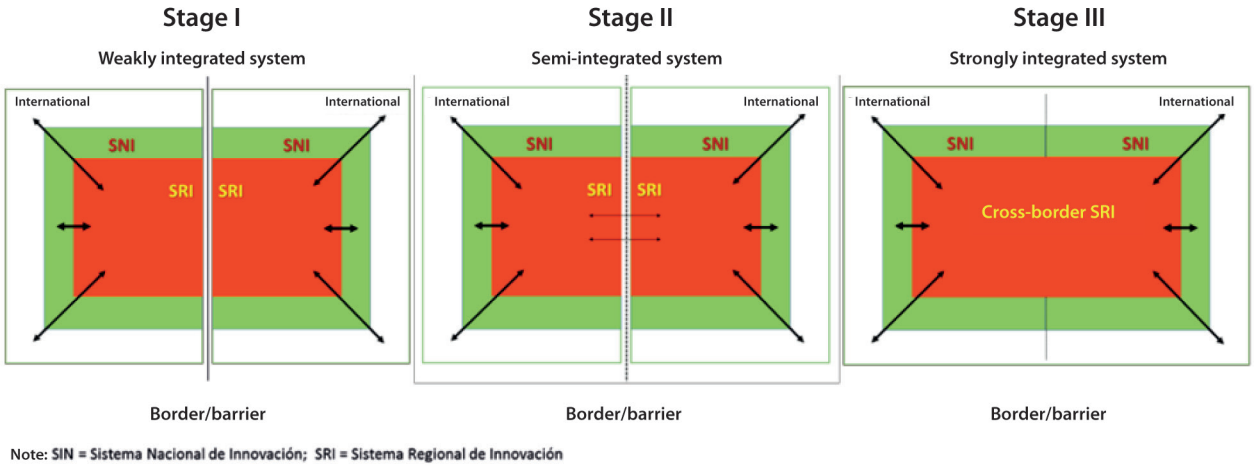
## Methodology

The methodological model used in this work is described by the OECD (2013: 145-160), where the dimensions are integrated by variables with semantic differential questions to be evaluated by experts according to their experience. The ten dimensions are disaggregated into variables to measure proximity and thus assess the degree of integration of two border states or regions hosting an SRIT, as shown in Figure 2 (K.-J. Lundquist & Trippl, 2011: 35; OECD, 2013: 39). When there is full integration in all dimensions, physical and/or economic borders disappear, even though national innovation systems remain different. Three stages are identified: 1. Weakly integrated system, 2. Semi-integrated system, and 3. Strongly integrated system (K. Lundquist & Trippl, 2011: 10-13; OECD, 2013: 39). Thus, an SRIT overcomes the obstacles associated with an international border to reach a more integrated system.

In this work, the variables originally defined by the OECD (2013) were taken and operationalized to measure them using publicly available statistics rather than expert perception. These are presented in Table 4. The model was applied to the Sonora-Arizona Megaregion and specifically to the SRIT of table grapes, a Sonora product marketed to 36 countries through distributors in Nogales, Arizona. There are 39 variables (or proximities) that make up the adaptation of the dimensions of the OECD model (2013: pp. 145-160).

For the evaluation of each variable, it was considered that proximity is defined as balanced actions or flows between both states, for which the Likert scale was used (Matas, 2018: pp. 41-43), based on available published statistics. Since there are no recorded experiences of evaluations made with this type of variables for Mexico or the United States, the operationalization was carried out under the authors' criteria, and its assessment was done on a Likert scale from 1 to 7, where 1 is very unbalanced and 7 is very balanced.

**Figure 2.** Stages of integration of Cross-Border Regional Innovation Systems




Note: SIN = Sistema Nacional de Innovación; SRI = Sistema Regional de Innovación

Source: (K.-J. Lundquist & Trippl, 2011: 35; OECD, 2013b: 39)

**Table 4.** Dimensions, proximities, and variables used in the SRIT of table grapes in the Sonora-Arizona region

| Dimension | Proximity | Variable |
|---|---|---|
| **1. Geographic accessibility.** Assesses total population by state, major localities and settlement density in the region, as well as crossings, travel times and types of transport used: car, airplane, cargo, charter, etc.; accessibility between nodes. | **Geographic proximity.** The similarities between regions and balanced flows define a geographic proximity based on communication, transport, and people. | 1.1 Population by main localities and by state<br>1.2 Passenger transport<br>1.3 Cargo transport companies in Sonora with service to Arizona<br>1.4 Cargo crossings<br>1.5 Crossing frequency and fluidity |
| **2. Sociocultural proximity.** Measured by the balance of flows, their direction, tourism and event attendance, perception of closeness between societies, and shared cultural identity. | **Value proximity.** (The values of societies are different). Proximity of shared identity is defined by education, cultural and labor flows, as well as consumption trends (what is bought in Arizona vs. Sonora). Relational proximity(Sonora is closer to Arizona than to other Mexican states due to purchases, events, work, and other aspects). | 2.1 International norms and certifications<br>2.2 Sonora-Arizona Commission - Specialized Committees<br>2.3 Sonora-Arizona Commission - Subcommittees and calls<br>2.4 Sonora-Arizona Megaregion |
| **3. Contextual and environmental conditions.**Refers to the economic, budgetary and political context for decision-making. Differences in rules and taxes have an impact. | **Institutional proximity.** Importance of differences between formal institutions like taxes, regulations, and also differences in culture and language. | 3.1 Cross-border trade and investment facilities<br>3.2 Sonora-Arizona Commission: Agriculture and Transport<br>3.3 Alignment of government support and programs<br>3.4 Agricultural production and trade<br>3.5 Foreign direct investment (FDI)<br>3.6 Agricultural treaties |
| **4. Knowledge integration.** Cross-border workers. Participation in binational research, alignment of public policies, salaries, foreign direct investment. | **Cognitive proximity.** The closeness and complementarity in industrial structures and knowledge bases (also known as "related variety" and "proximate diversity"). | 4.1 Characteristics of AALPUM creation<br>4.2 GDP and employment |
| **5. Economic specialization.** Dominant economic sectors by state and comparison, Employment and GDP percentages, Product variety | **Cognitive Proximity.** The proximity and complementarity within industrial structures and knowledge bases (also referred to as "related variety" and "proximate diversity"). | 5.1 GDP and Employment<br>5.2. Agricultural Production in Sonora and Arizona<br>5.3 Production costs of table grapes<br>5.4 Wages and salaries by sector<br>5.5 Agricultural sector patents<br>5.6 Sonoran companies developing new varieties |
| **6. Innovation business model.** Patents, innovative companies on both sides, knowledge-intensive companies, innovation financing initiatives. | **Relational proximity.** Structures, relations, and processes that give rise to social dynamics, governance structures, regulations, and cultural identities that sustain the basis of social action. | 6.1. Distribution companies in Nogales, Arizona, with Sonoran capital<br>6.2. Logistics of the table grape industry<br>6.3. The Current Technological Innovation System in Sonora<br>6.4. Technology transfer centers and extension programs |
| **7. Knowledge infrastructure.** Quality of educational institutions on both sides, "Third mission" among universities, scientific fields on both sides, map of key institutions. | **Cognitive proximity.** Proximity and complementarity both in industrial structures and knowledge bases (also known as "related variety" and "cognitive proximity"). | 7.1. Budgets of educational and research institutions<br>7.2. Schools of agriculture<br>7.3. Institutional agricultural research<br>7.4. AALPUM research project<br>7.5. Sonora-Arizona Inter-University Alliance Fund |
| **8. Interactions of the innovation system.** Balance of student flows, R&D staff, joint patents, joint publications, venture capital investments, innovation interactions. | **Functional proximity.** Specific to the innovation system and comprises the differences or asymmetries between regions in innovation capacity. | 8.1. International students<br>8.2. Joint publications<br>8.3. Agricultural patents<br>8.4. Technological development support through PEI-CONACYT<br>8.5. Scholarships |

| | | |
|---|---|---|
| **9. Government.** Level and balance of cross-border, local, regional, national, and international political commitment. | **Relational proximity.** Structures, relations, and processes that give rise to social dynamics, governance structures, regulations, and cultural identities that sustain the basis of social action. | 9.1. Research and education budgets<br>9.2. Safe corridors |
| **10. Political mix.** Participation among actors on both sides. Monitoring and evaluation mechanisms for cross-border initiatives. | **Relational proximity.** Structures, relations, and processes that give rise to social dynamics, governance structures, regulations, and cultural identities that sustain the basis of social action. | 10.1. Collaboration in joint research |

Source: Own elaboration.

## Analysis of the results

Each selected variable was analyzed and evaluated separately. The results are shown in Table 5, where the average of the dimensions is 3.90, a value below 4, which is the midpoint of the Likert scale, indicating that the SRIT of table grapes in the Sonora-Arizona region has weak but existing integration. When evaluating all 39 recorded variables, the average is 4.00.

The best-evaluated dimension is 4. Cross-border integration with 4.75, where the production and export of table grapes and the characteristics of the Local Agricultural Association of Table Grape Producers (AALUMP) stand out. Next is dimension 5. Economic specialization, with 4.67, where well-rated variables include agricultural production in Sonora and Arizona, production costs of table grapes, agricultural sector patents, and Sonoran companies developing new varieties.

**Table 5.** Dimensions, variables, and main results of the table grape SRIT in the Sonora-Arizona region

| Dimension | Variable | Observations | Variable rating | Dimension rating |
|---|---|---|---|---|
| 1. Geographic accessibility | 1.1 Population by main localities and by state | Similar population growth rates at the state level but Arizona is much more populated. Phoenix grows rapidly, followed by Hermosillo. | 1 | 3.50 |
| | 1.2. Passenger transport | From Hermosillo to Phoenix: 1 daily flight (1 hr 16 min), 5 hours by car plus customs (400 km); 18 daily bus departures (8 hr 30 min plus customs). Hermosillo has various charter van and air transport companies. | 1 | |
| | 1.3 Freight transport companies in Sonora serving Arizona | Optimized crossing times for fruits and vegetables from Sinaloa and Sonora. Many specialized transport companies. Table grape logistics processes stand out. | 6 | |
| | 1.4. Freight crossings | Fresh exported products have a value equivalent to 28% of imports. Crossings optimized. | 6 | |
| 2. Sociocultural proximity | 2.1. Mobility and crossing flows | Land passenger crossings are unbalanced and there is only air connection to Hermosillo. | 1 | 4.60 |
| | 2.2. International standards and certifications | Farmers comply with most certifications for export to the USA and 36 other countries. | 7 | |
| | 2.3. Sonora-Arizona commission- Specialized committees | Committees are mostly formed by officials from both state governments with few private actors. Having a framework for resolving concerns is an advantage. | 5 | |
| | 2.4. Sonora-Arizona commission- Subcommittees and calls | Very specific and limited to agreements that do not require federal government involvement. | 5 | |
| | 2.5. Sonora-Arizona megaregion | Detailed studies are lacking for each defined area. | 5 | |
| 3. Contextual institutional conditions | 3.1. Business creation facilities, taxes, and profits | Easier to start a business in Arizona, which also has lower tax rates. In Mexico, ISR is 30% paid by the company and profit withdrawals through CUFIN are taxed at 10%. | 2 | 2.67 |
| | 3.2. Sonora-Arizona commission: Agriculture and transport | Greater involvement of federal entities is needed. | 5 | |
| | 3.3. Alignment of federal government support and programs | There is no resource support for state agreements. | 1 | |

| | | | | |
|---|---|---|---|---|
| 4. Cross-border integration | 4.1. Table grape production and export | Sonoran producers reach 36 countries meeting all requirements at competitive prices. | 7 | 4.75 |
| | 4.2. Foreign direct investment (FDI) | Sonora is among the border states with the lowest FDI. | 2 | |
| | 4.3. Relevant actors | The role of distributors is not well defined. Their contribution to the innovation system is limited to short- and long-term trends. | 4 | |
| | 4.4. AALUMP creation characteristics | The association helps seek markets and facilitates compliance with certifications and export requirements. | 6 | |
| 5. Economic specialization | 5.1. GDP and employment | Very disparate GDP due to different economic activities and differences in hourly wages. | 2 | 4.67 |
| | 5.2 Agricultural production in Sonora and Arizona | Products are different and complementary. | 6 | |
| | 5.3. Table grape production costs | High production costs, but among the highest profitability crops in Sonora. | 6 | |
| | 5.4. Wages and salaries by sector | Wages in Arizona are 6 to 13 times higher than in Sonora. | 1 | |
| | 5.5. Agricultural sector patents | There are grape patents like plant breeders' rights held by Mexican growers. | 6 | |
| | 5.6. Sonoran companies developing new varieties | 9 companies have varieties developed in California, Israel, or locally. | 7 | |
| 6. Innovation business model | 6.1 Distributor companies in Nogales, Arizona with Sonoran capital | Companies are from Sonora or Sinaloa but hire American personnel experienced in marketing agricultural products in the US market. | 5 | 4.50 |
| | 6.2. Table grape industry logistics | Process is largely dominated by Sonorans. | 5 | |
| | 6.3. Current technological innovation system in Sonora | Sonoran growers are world-class. | 5 | |
| | 6.4. Technology transfer centers and extension programs | Centers have different research or specialization areas, so collaboration is not complete. | 3 | |
| 7. Knowledge infrastructure | 7.1. Budgets of educational and research institutions | Highly different budgets between Sonoran and Arizona institutions. | 2 | 4.40 |
| | 7.2. Agricultural schools | Number of students in agricultural schools in each state is similar. | 6 | |
| | 7.3. Institutional agricultural research | Centers have different research areas or specializations, limiting collaboration. | 2 | |
| | 7.4. AALUMP research Project | A major effort was carried out for nearly 10 years. | 6 | |
| | 7.5. Sonora-Arizona Inter-University Alliance Fund | Very well received among Sonoran researchers. | 6 | |
| 8. Innovation system interactions | 8.1. International students | No Arizona students identified in Sonoran institutions. | 1 | 2.20 |
| | 8.2. Joint publications | It's unclear whether joint publications exist between researchers from both states. Researchers are scattered and production is low. | 1 | |
| | 8.3. Agricultural patents | There are grape patents like plant breeders' rights held by Mexican growers. | 6 | |
| | 8.4. Technological development support through PEI-CONACYT | Not applied to agricultural aspects. | 1 | |
| | 8.5. Study scholarships | Only the Sonora-Arizona Commission scholarships exist. | 2 | |
| 9. Government | 9.1. Research and education budgets | Highly different budgets between Sonoran and Arizona institutions | 1 | 3.50 |
| | 9.2. Secure corridors | A very effective coordinated action that receives strong follow-up in both states | 6 | |

| | | | | |
|---|---|---|---|---|
| 10. Political mix | 10.1. Joint research collaboration | No joint publications but the Sonora-Arizona Inter-University Alliance is fostering relations. | 3 | 3.00 |
| | | **Averages** | **3.92** | **3.78** |

Source: Own elaboration.

The dimension with the lowest score is 8. Innovation system interactions, with a value of 2.20, in which only the variable Agricultural patents stands out with 6, while the rest—International students, Joint publications, Support for technological development through PEI-CONACYT, and Study scholarships—were rated very low. Next is dimension 3. Institutional context conditions with 2.67, affected by the variables: Ease of business creation, taxes and profits, and alignment of federal government supports and programs. A graphical summary of the dimension evaluations is shown in Table 6.

When evaluating the stages of SRIT integration for table grapes based on K. Lundquist and Trippl's approach (2011:5) across six dimensions, the results shown in Table 7 are obtained. As can be seen, in Stage I, "asymmetric cost system" or weakly integrated system, there are imbalances regarding salaries, institutional budgets, specialization of different research institutions, lack of support for student mobility, and lack of joint projects. In Stage II, "emerging knowledge-based system" or semi-integrated system, external factors are found such as taxes, ownership of distribution companies by Sonorans, AALUMP, Sonora-Arizona Commission, Megaregion, and passenger infrastructure between both states. In Stage III, "innovation-driven symmetric system" or strongly integrated system, factors related to table grapes and specialized fresh product freight transport infrastructure are identified.

The variables can be viewed from the general regional context or from the particular SRIT perspective. The former refer to the achievements of the region, such as improvements in the crossing of fresh products from Sonora and Sinaloa into Arizona; the creation of secure corridors, especially the Lukeville-

**Table 6.** Evaluation of SRIT dimensions for table grapes in the Sonora-Arizona region

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **1. Geographical accessibility** | 1. Very unbalanced | 2. Mostly unbalanced | 3. Slightly unbalanced | 4. Undefined balance | 5. Slightly balanced | 6. Mostly balanced | 7. Very balanced |
| **2. Sociocultural proximity** | 1. Very unbalanced | 2. Mostly unbalanced | 3. Slightly unbalanced | 4. Undefined balance | 5. Slightly balanced | 6. Mostly balanced | 7. Very balanced |
| **3. Contextual institutional conditions** | 1. Very unbalanced | 2. Mostly unbalanced | 3. Slightly unbalanced | 4. Undefined balance | 5. Slightly balanced | 6. Mostly balanced | 7. Very balanced |
| **4. Cross-border integration** | 1. Very unbalanced | 2. Mostly unbalanced | 3. Slightly unbalanced | 4. Undefined balance | 5. Slightly balanced | 6. Mostly balanced | 7. Very balanced |
| **5. Economic specialization** | 1. Very unbalanced | 2. Mostly unbalanced | 3. Slightly unbalanced | 4. Undefined balance | 5. Slightly balanced | 6. Mostly balanced | 7. Very balanced |
| **6. Innovation business model** | 1. Very unbalanced | 2. Mostly unbalanced | 3. Slightly unbalanced | 4. Undefined balance | 5. Slightly balanced | 6. Mostly balanced | 7. Very balanced |
| **7. Knowledge infrastructure** | 1. Very unbalanced | 2. Mostly unbalanced | 3. Slightly unbalanced | 4. Undefined balance | 5. Slightly balanced | 6. Mostly balanced | 7. Very balanced |
| **8. Innovation system interactions** | 1. Very unbalanced | 2. Mostly unbalanced | 3. Slightly unbalanced | 4. Undefined balance | 5. Slightly balanced | 6. Mostly balanced | 7. Very balanced |
| **9. Government** | 1. Very unbalanced | 2. Mostly unbalanced | 3. Slightly unbalanced | 4. Undefined balance | 5. Slightly balanced | 6. Mostly balanced | 7. Very balanced |
| **10. Political mix** | 1. Very unbalanced | 2. Mostly unbalanced | 3. Slightly unbalanced | 4. Undefined balance | 5. Slightly balanced | 6. Mostly balanced | 7. Very balanced |

Source: Own elaboration.

**Table 7.** Factors determining the leve lof SRIT integration of the Sonora-Arizona region

| Dimensions of cross-border regional innovation systems | STAGE I Cost-asymmetric system (Weakly integrated) | STAGE II Emerging knowledge-based system (Semi-integrated) | STAGE III Symmetric innovation-driven system (Strongly integrated) |
|---|---|---|---|
| **Economic structure / specialization pattern** | Use of "low road" development; wages in Arizona are 6 to 13 times higher than in Sonora GDP and lead to very different economic activities. | It is easier to start a business in Arizona and tax rates are lower.<br><br>Distribution companies are 60% owned by Sonorans and Sinaloans who dominate the process and reach 39 countries. | Sonoran companies have world-class quality as they own patents for two types of plant propagator rights of winegrowers, and 9 companies have varieties developed in California, Israel, or locally. |
| **Scientific base / infrastructure and knowledge creation** | Highly different budgets between institutions in Sonora and Arizona.<br><br>Centers have different areas of research or specialization, so there is no full collaboration. | The number of students in agricultural schools is similar.<br><br>A comprehensive study for AALPUM was carried out for 10 years.<br><br>The Inter-University Alliance Fund Sonora-Arizona has gained greater acceptance among Sonoran universities. | Specialized farmers' associations strengthen their global presence. |
| **Nature of links** | No Arizonan students are identified in Sonoran institutions.<br><br>No joint publications identified between researchers from both states; they are poorly disseminated and have low output.<br><br>No financial support programs applicable to agricultural aspects.<br><br>No scholarships for students except those from the Sonora-Arizona Commission. | There are patents for two types of plant propagator rights by Mexican winegrowers. | |
| **Institutional configuration** | | The committees of the Sonora-Arizona Commission are a platform to solve binational concerns and issues.<br><br>The creation of the Sonora-Arizona Megaregion facilitates joint promotion. | Sonoran farmers meet certifications for export to the U.S. and 36 other countries. |
| **Political structures** | Highly different budgets between institutions in Sonora and Arizona.<br><br>No federal support or resources for binational state agreements. | The Sonora-Arizona Commission has been operating for 6 decades in both states. | |
| **Accessibility** | Passenger crossings are unbalanced. | Infrastructure and travel frequency from Sonora to Arizona exist. | Border crossing times for fruits and vegetables from Sinaloa and Sonora have been optimized. Numerous specialized transportation companies operate in Sonora, with particular emphasis on the logistics processes for fresh products. |

Source: Own elaboration.

Sonoyta-Puerto Peñasco corridor to provide safety for American tourists traveling to this port from Phoenix or Tucson; and the designation of the megaregion as a way to give the region a promotional image or "brand." The variables or proximities that stand out relative to the table grape SRIT focus on the achievements of table grape farmers who have sought solutions in different institutions, while the negatives relate to the limited participation of distributors in Nogales, Arizona; low foreign investment in Sonora; unbalanced frequency of travel between both states; and differences in hourly wages.

## Conclusions and policy implications

The results indicate that the degree of integration of the table grape SRIT in the Sonora-Arizona region is "weakly integrated," although it presents elements of the "semi-integrated" stage. The highest indicators relate to the dynamics of table grape production from the sectoral and productive specialization perspective, as well as the region's operation in terms of border port infrastructure, geographic accessibility, socio-cultural proximity, and the binational image of the Megaregion. The lowest indices were obtained in the "proximities" related to the specific elements of the formation of the table grape SRIT, such as the dimension on innovation system interactions between both states.

The analysis of the variables indicates that current innovation policies between Mexico and the United States show neither similarities nor a particular focus on cross-border innovation potential. It is perceived that efforts have been made by the border states; furthermore, national policy instruments do not allow for cross-border financing, and the national R&D and innovation councils of both countries do not work jointly. It is necessary to involve national governments more to strengthen state actions in cross-border cooperation.

The region is perceived as a logistics and transportation hub, where Arizona is the entry point for products from northwest Mexico into the United States, but there is a lack of future scenarios and plans related to local and regional transportation systems. To date, joint initiatives related to transportation, infrastructure development, and tourist security systems stand out. While data on cross-border flows of goods, people, and capital have met the area's needs, they do not cover knowledge flows. Data on knowledge potential and flows are lacking, which prevents identifying opportunities and bottlenecks for cooperation and cross-border innovation initiatives.

Based on some of the results from the aforementioned OECD study (2013), it can be argued that the case of table grapes in the Sonora-Arizona Region reflects a situation in which, for the development of cooperation projects and innovation actions, more than geographic proximity, access to the best global partners is the priority. This is because when excellence is required to compete globally, it becomes more relevant for companies to seek partners at the international level, based on always obtaining strength in specific fields of research and innovation (Ibid).

Complementary to the actions of governmental instances, it is necessary to integrate a business-academic analysis of cooperation, so the creation of a joint R&D and innovation council as a permanent "Think Tank" would be appropriate to provide an updated vision of potential R&D areas (life sciences, ICT, new materials, and electronic society).

The current governance structure of the region fundamentally includes public actors. The Sonora-Arizona Commission has little permanent staff and infrequent meetings with its counterparts from member public entities, so its role in leading the partnership and identifying successful trends is limited. It is necessary to create a vision for innovation development for the Sonora-Arizona Megaregion, involving more federal officials, businesspeople, and civil society actors, so that the Commission becomes a management entity with a broader base of regional actors on a binational scale.

A scientific bridge project is required to develop cross-border university cooperation, for science parks where key actors are universities on both sides of the border that carry out networking events, exchange office facilities, as well as students, teachers, and researchers, and conduct joint research, reports, researcher training, publications, conferences, and cooperation projects funded by national or international entities.

Insecurity in Mexico has negatively impacted, limiting educational relations, so it is advisable to use cutting-edge technology to deliver classes without the need for professors or students to travel,

and to encourage dual-degree programs, joint programs with incubator companies with mentors and joint tutors, training of incubation managers, and selection and evaluation of technological development and innovations.

The Helsinki-Tallinn region (Nauwelaers et al., 2013: pp. 5-40) in Europe is one of the regions most similar to Sonora-Arizona due to its degree of existing asymmetry. It is noteworthy that integration was facilitated by passenger ferry transportation across the Baltic Sea, especially workers from Estonia to Helsinki, Finland, and Finnish tourists to Tallinn, Estonia. Both border Russia. In this region, the Twin Cities relationships play a strong role in bilateral planning. For this reason, it is proposed to strengthen and improve the old Sister Cities ties and move from solely social, educational, and cultural relations to broader planning relations, which would allow expanding the academic-scientific and business network on both sides of the border, ultimately forming a "cross-border innovation region."

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