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Isonymic Relations in the Bolivia-Argentina Border Region

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Abstract When migrating, people carry their cultural and genetic history, changing both the transmitting and the receiving populations. This phenomenon changes the structure of the population of a country. The question is how to analyze the impact on the border region. A demographic and geopolitical analysis of borders requires an interdisciplinary approach. An isonymic analysis can be a useful tool. Surnames are part of cultural history, sociocultural features transmitted from ancestors to their descendants through a vertical mechanism similar to that of genetic inheritance. The analysis of surname distribution can give quantitative information about the genetic structure of populations. The isonymic relations between border communities in southern Bolivia and northern Argentina were analyzed from electoral registers for 89 sections included in four major administrative divisions, two from each country, that include the international frontier. The Euclidean and geographic distance matrices where estimated for all possible pairwise comparisons between sections. The average isonymic distance was lower between Argentine than between Bolivian populations. Argentine sections formed three clusters, of which only one included a Bolivian section. The remaining clusters were exclusively formed by sections from Bolivia. The isonymic distance was greater along the border. Regardless of the intense human mobility in the past as in the present, and the presence of three major transborder conurbations, the Bolivian-Argentine international boundary functions as a geographical and administrative barrier that differentially affects the distribution and frequency of surnames. The observed pattern could possibly be a continuity of pre-Columbian regional organization.

For many human activities (e.g., finances, tourism, communication, and the arts) physical boundaries have practically disappeared, but international borders persist for migrants. A border or frontier, understood as a complex geopolitical entity, exceeds the simple idea of a natural or geographic boundary (Bailly 2013; Wilson and Hastings 2012)—it is a valid and necessary concept for understanding cultures and identities as a whole. Migrants can cut across an international border, with important effects on the population structures on both sides of the administrative boundary.

Argentina and Bolivia share an international border 773 km long (Figure 1), which was first drawn up in 1889 and rectified in 1925. The geographic region of the present frontier was an ethnic and cultural point of contact in the precolonial period, displaying significant migration movements that intensified during the colonial period. According to archaeological evidence and ethnohistorical documents, this region was inhabited in pre-Columbian times by a mosaic of ethnicities. The presence of Chichas in southern Bolivia, Aymara and Uru in the territory of Lipez in the southwest corner of Bolivia, and Atacama in the west and south of the Argentine Puna region has been documented. The Incas entered this area in 1480, changing cultures previously settled there (Celton and Carbonetti 2007; Albeck and

Ruiz 2003). During the colonial period, this territory was part of the Viceroyalty of Peru from 1542 and later of the Viceroyalty of the Río de la Plata from 1777. This means that for much of the colonial period the land where the frontier between these countries is currently established belonged to the same territory, without administrative divisions (Celton and Carbonetti 2007). This phenomenon was modified by the demarcation of international borders during the formation of the states.

Three areas in the Argentine-Bolivian frontier can be clearly geographically defined from west to east. The first sector is the high plateau of the Puna ecoregion, located more than 3,000 m above sea level, where the frontier is demarcated between Zapaleri (*trifinio* or tripoint for Bolivia, Argentina, and Paraguay; 5,619 m) and the Sierra de Santa Victoria (5,000 m). The second sector corresponds to the Andean forest ecoregion, or Yungas, where the international border is defined between the mountains of Santa Victoria and the Upper Seco River, crossing a stretch of the Bermejo River and Grande Tarija River. The last sector runs through the Sub-Andean Sierras and is limited by the Pilcomayo River (Benedetti and Salizzi 2011). Each area is in itself a real geographical barrier that influences human migration, due to fluvial (covering 320 km of frontier) or altitudinal limitations. These geographical features possibly explain why only three Argentine-Bolivian conurbations developed, one in each sector: La Quiaca–Villazón (identified as ID 65 and ID 23, respectively, in Table 1 and Figure 3) in the Puna sector, Aguas Blancas–Bermejo (IDs 73 and 41) in the Yungas sector, and Salvador Mazza–Yacuiba (IDs 74 and 46) in the Sub-Andean Sierras.

Migrating people carry with them their cultural and genetic history, changing the genetic structure of both transmitting and recipient populations. The analysis of surname distributions can supply quantitative information on the genetic structure of human populations, which can be defined by the deviations from random mating, or panmixia, such as those due to a limited number of ancestors, preference or rejection of certain types of inbreeding, and limited migration in the social or geographic space (Barrai et al. 2002). Deviations from panmixia can be evaluated through the inbreeding coefficient F (Wright 1951); a crude estimate of F is provided by the concept of isonymy, as defined by Crow and Mange (1965).

Surname acquisition in our study area dates from the beginning of the Spanish conquest, under the influence of the evangelizers. As a result, names and surnames became Spanish and generally had a spiritual or religious connotation. Changes were more sudden in the urban areas, reaching rural zones later. By 1786, after a long process of acculturation, only one-third of the inhabitants of Andean colonial cities were registered under aboriginal surnames (Sanchez-Albornoz 1974; Dipierri et al. 1991).

Surnames have been successfully used to investigate human populations (Sella et al. 2010), and the isonymic method has been used to assess the genetic structure of cities (Bronberg et al. 2009; Zagonel et al. 2013), regions (Barrai et al. 1987; Dipierri et al. 2005b, 2007; Herrera-Paz 2013), and countries (Barrai et al. 2001; Manni and Barrai 2001; Cheshire et al. 2010; Liu et al. 2012), including Argentina (Dipierri et al. 2005a, 2007) and Bolivia (Rodriguez-Larralde et al. 2011), as well as continents as a whole (Scapoli et al. 2007; Cheshire et al. 2011). However, analyses of surname distributions at an international frontier or border are scarce (Christensen 1999; Román-Busto et al. 2013; Boldsen and Lasker 1996). Therefore, we aimed to help fill this gap by analyzing the isonymic relationships between southern Bolivian and northern Argentine populations located on the international border between both countries.

Materials and Methods

Database and Surname Distribution.

In Bolivia and Argentina, voting is mandatory for all citizens 17 or more years of age. Voting registers are an excellent source of information in population studies, as large numbers of surnames are included at different levels of aggregation (electoral sector, municipality, state, etc.). In this study, the minor administrative divisions of Bolivia (municipalities) and Argentina (departments) were considered equivalent and were designated as "sections" (89 total; identified in Table 1). All sections were included in four major administrative divisions, two from each country (Potosí and Tarija from Bolivia, Jujuy and Salta from Argentina), which cover the international frontier (Figure 1).

For surname data, we used the Civil Registry from National Electoral Court of Bolivia (updated to 2006) and the Argentine Electoral Roll (2001), containing 12.1 million and 12.6 million voters, respectively. Permission to work with these documents was obtained from the corresponding national authorities (for details, see Rodriguez-Larralde et al. 2011 and Dipierri et al. 2005a). Surnames of men and women were jointly analyzed according to each country's political division. For Bolivia, the surnames of 1,767,938 voters from 39 sections in Potosí and 911,207 from 11 sections in Tarija were studied. For Argentina, the surnames of 302,395 voters from 16 sections in Jujuy and 621,089 from 23 sections in Salta were included.

Estimation of Surname Diversity within Sections.

Fisher's alpha (α) was used to estimate population diversity within sections. High alpha values indicate an abundance of surnames and migration and little inbreeding, while low alpha values suggest high levels of inbreeding and drift. Fisher's alpha was estimated as $\alpha = 1/I_{ii}$, where I_{ii} is random isonymy within section i and is given by $I_{ii} = \sum(p_{ij})^2$, where p_{ij} is the frequency of surname j in section i (Rodriguez-Larralde et al. 2003).

Calculation of Isonymic Distances between Sections.

Based on surname distribution, the matrices of isonymic distances between the 89 sections, taken two at a time, were calculated. The Euclidean distance (Cavalli-Sforza and Edwards 1967) between two groups/sections (i and j) was estimated as $E = (1 - \cos\theta)^{1/2}$, where $\cos\theta = \sum_k (p_{ik}p_{jk})^{1/2}$ and p_{ik} and p_{jk} are the relative frequencies of surname k in sections i and j, respectively.

The relationship of surname distributions among sections was graphically represented by an unweighted pair group method with arithmetic mean (UPGMA) dendrogram constructed with PHYLIP 3.6 software (Felsenstein 2005).

Comparison between Geographic and Euclidean Distances between Sections.

For all analyses concerning geographic distance, the capital city of each section was taken as a central point, and distance was measured in kilometers as a straight line. A simple linear regression analysis was used to estimate relationships between Euclidean and geographic distances, and a between-matrix correlation coefficient was calculated. Correlation significance was evaluated by the Mantel test (Mantel 1967), using PASSaGE 2 software (Rosenberg and Anderson 2011). All 89 sections under study were analyzed.

Isonymic relations between sections within each country and between countries were also explored. However, geographic distances between sections varied from 4 to 893 km. To account for the effect of geographic distance on Euclidean distance, section comparisons that evened out geographic distances were chosen through a process of trial and error. Ultimately, 446 comparisons were chosen for Argentina, 520 for Bolivia, and 98 for comparisons between sections of both countries. Geographic distances for each comparison were similar: 117.6 km, 116.7 km, and 115.7 km, respectively. Student's *t* test was used to study differences between the mean Euclidean distance for each comparison.

Results

Surnames and Population Diversity.

Table 1 summarizes the numbers of voters (*N*) and surnames (*S*) and Fisher's alpha (α) for each of the Argentine and Bolivian sections analyzed. Considering sample size, the maximum demographic difference was between La Poma (Argentina), with 1,067 voters, and the capital city of Potosí (Bolivia), with 528,266 voters.

Mean alpha values for the major administrative divisions Tarija, Jujuy, and Salta were 150, 141, and 143, respectively. However, the mean alpha for Potosí was 93, significantly lower than that of Tarija and Salta, indicating higher inbreeding and drift in this section. Seven alpha values lower than 20 were found in this analysis, six from Potosí (sections 8, 17, 18, 34, 35, and 39; see Table 1) and one from Jujuy (section 66). The highest alphas were found in the capital districts of Jujuy and Salta and in San Pedro (Jujuy), with values of 294, 325, and 315, respectively (Table 1).

Clusters.

To identify a useful number of clusters, an arbitrary line was drawn parallel to the base of the dendrogram (red line in Figure 2). As shown in Figure 2, five clusters could be roughly defined. The sections with the lowest Euclidean distances (i.e., the most closely related populations) were in cluster I, which was subdivided into two clusters, Ia and Ib, and consisted only of Argentine sections. Cluster II included five sections, four from Argentina and one from Padcaya (ID 40), a section of Tarija (Bolivia). Cluster III contained the remaining Argentine sections, while cluster IV and cluster V (subdivided into Va and Vb) consisted exclusively of Bolivian populations. The most distant clusters are clearly identified ("Others" in Figures 2 and 3). They are located in the northern portion of Potosí (Bolivia) and contained surnames different from those registered in other sections of the study area.

Figure 3 is a graphic representation of our calculated dendrogram overlaying a map with Argentine and Bolivian administrative divisions. It shows that cluster II was the only cluster formed by sections from both countries. With this sole exception, the political border was always evident in the cluster analysis.

In general, clusters were composed of sections from the same country that share similar geographic conditions and/or are separated by small geographic distances. Large parts of clusters Ia and IV are within the Chaco ecoregion, a vast, semiarid plain with no important physical barriers, considered one of the major wooded grassland areas. Differences in climatic and edaphic conditions, as well as overutilization of resources, are principal problems for economic and demographic development in this area. Clusters II, Ib, Vb, and part of Ia are within the Yunga ecoregion, a stretch of forest along the eastern slope of the Andes Mountains that includes parts of Peru, Bolivia, and northern Argentina. Its climate is rainy, humid, and warm. Clusters III, Va, and "Others" are within the Puna ecoregion. With altitudes more than 3,000 m above sea level, Puna's climate is cool with low annual precipitation but differs greatly between dry and wet seasons. Despite the fact that the Puna ecoregion has always had limited water resources, human occupation here has a long history, with evidence from prehistoric periods.

Comparisons between Euclidean and Geographic Distances.

The correlation coefficient between geographic and Euclidean distance was 0.51 ($p < 0.001$ after 1,000 permutations), showing that the relationship between both distances is statistically significant. This explains why, in general, sections with small geographic distances had small Euclidean distances and tended to cluster together in the dendrogram (Figure 2). Figure 4 summarizes the linear regression of Euclidean distance over kilometers.

Table 2 shows the differences in Euclidean distances (i.e., surname distribution) between Argentina-only sections, between Bolivia-only sections, and between Argentine and Bolivian sections, separated by an average distance of approximately 116 km. The largest average Euclidean distance was between Argentine and Bolivian sections (0.723), a significantly greater distance than that between Argentine sections (0.655, $p < 0.001$) but not significantly greater than the average Euclidean distance between Bolivian sections (0.704; $0.05 < p < 0.1$). The mean isonymic distance between Argentine sections (0.655) was significantly smaller than the mean observed between Bolivian sections (0.704; $p < 0.001$) and smaller still than that obtained when sections between countries were compared (0.723; $p < 0.001$).

Discussion

We used electoral registers to reconstruct the isonymic structure of 89 sections from four administrative divisions (Salta and Jujuy in Argentina; Potosí and Tarija in Bolivia), including the international border (Figure 1). With them, we were able to assess similarities between populations, their possible common origins, and the persistence of old colonial structures.

Population diversity, measured through Fisher's alpha, was significantly lower in Potosí than in Tarija and Salta but not significantly lower than in Jujuy. This higher isolation found in Potosí is probably due to its altitude, which may have worked as a geographical barrier, constraining population movements. Lower alpha values at high altitudes have been previously described for Bolivia (Rodriguez-Larralde et al. 2011).

An international border is basically an imaginary line between two nations. In this particular region, the two nations share a similar history and a common language. However, our results suggest that the political administrative boundary (i.e., the international border) has had a barrier effect, strengthened by fluvial and altitudinal limitations, which increased isonymic distances between sections located in different countries compared to sections within one country, even though they were separated by the same geographic distance (~116 km). This effect can also be observed in the dendrogram (Figures 2 and 3), where only cluster II included sections from both countries, one from Bolivia and four from Argentina. The other clusters included sections from one country only: clusters I and III included populations from both Argentine provinces, Salta and Jujuy, whereas clusters IV and V consisted of Bolivian sections exclusively from Tarija or from Potosí, respectively (Figure 3). Strangely, the dendrogram did not reproduce the frontier conurbations shown in Figure 1. Given that isonymic distances were significantly correlated with geographic distances, as expected in a model of isolation by distance, and given that a small Euclidean distance between two sections implies a similar distribution of surnames between them, our results suggest that, over time, migratory movements within this area of Argentina must have been stronger and more dynamic than those within Bolivia or between both countries.

These results contrast both with the economic dynamics of the region, where records show an intense mobility and continuous trade on the main border paths, and with the demographic characteristics of populations in the region. Regarding economic dynamics, from the perspective of the anthropology of migration proposed by Tarrius (2000), population movements in the Argentine-Bolivian border region could be interpreted as the preeminence of the mobile over the sedentary subject. The final effect of such movements in a border region is the creation of nonlocalized social structures instead of new settlement types (Mallimaci 2012). Subjects circulate in the international border area, without settling down, creating areas of passage "that arise as the effect of mobility and its practice" (Tapia Ladino and Santana 2013) but do not materialize new structured populations and do not affect the structure of neighboring border societies.

Regarding demographic characteristics, the Argentine-Bolivian border conurbations have experienced significant population growth, especially on the Bolivian side. Among residents in Yacuiba, Bolivia (ID 46, Figure 3), only 5% come from Argentina, and in Villamontes, Bolivia (ID 48, Figure 3), only 3.7% (Souchaud and Martin 2007; Martin 2007). Migration between Bolivia and Argentina is characterized by its asymmetry: while the Bolivian migration to Argentina has been steadily increasing since the first census of 1869, Bolivia, in relation to other Latin American countries, has received the fewest immigrants in their republican history (Vacaflores 2003). This is especially so in the eastern part of the country. With the exception of the colonial period, this demographic stability has enabled ethnic and cultural diversity to remain stable, with few substantial changes. The great migration movements of the late nineteenth century and those caused by World Wars I and II were not heading for Bolivia (Vacaflores 2003).

Bolivian migration to Argentina can be classified by different periods that correspond to frontier, regional, and transnational migratory patterns. In each period, migrants developed different strategies of relationship between their places of origin and destination, which affected the frequency and distribution of surnames in the frontier (Sassone 2009). The earliest period ran from 1880 to 1960 and saw a frontier model of migration in response to seasonal demands for male agricultural labor in northwestern Argentina. During 1960–1985 migration followed a regional pattern. Farmers temporarily left their communities and integrated into agricultural activities in other regions of Argentina. By the end of this period, Bolivian migrants tended to settle in urban areas of Argentina, especially in the province of Buenos Aires.

The transnational model started about twenty years ago and included a wider range of destinations for Bolivian migrants (Brazil, Chile, European countries, Japan, etc.). In this last stage, the distribution of Bolivian migrants in Argentina was characterized by two-thirds living in the metropolitan area of Buenos Aires and the rest spreading to urban and rural areas throughout the country. According to census data and historical-geographical characterizations of migration, few Bolivians are actually installed in the

Argentine territory neighboring the international border. For those who do stay, their migration is particularly attached to large cities (the capital cities of Salta and San Salvador de Jujuy), where migrant surnames do not substantially affect the frequency and distribution of the Argentine host populations' surnames. In the three migration periods (frontier, regional, and transnational), a mobile lifestyle predominated over a sedentary one (Tarrius 2000).

Another important factor to consider is the high frequency of Andean indigenous surnames (Quechua or Aymara) in southern Bolivia and northwestern Argentina. Dipierri et al. (2005a) published a list of the 100 most common surnames in Argentina taken from the same electoral roll used in the present study. These 100 names accounted for 29.5% of all voters, and all were classified by Faure Sabater et al. (2001) as being of Spanish origin. Among the original surnames, *Mamani* was the most common, ranking 149th nationally, with 19,725 carriers (Dipierri et al. 2005b). However, in the Argentine northwest this name ranked 21st among the 100 most frequent, with an occurrence of 14,395, which means that 73% of individual carriers were localized in this region. Rodriguez-Larralde et al. (2011), when analyzing the 50 most common surnames in Bolivia, found that *Mamani* was ranked first (913,705 individuals), followed by *Quispe*, *Condori*, and *Choque*. Among the surnames of Spanish origin, *Flores* was the most common (467,059 individuals), followed by *Vargas*, *Rodriguez*, *Rojas*, *Gutierrez*, *Lopez*, *Cruz*, *Fernandez*, and *Garcia*. Coincidentally, these surnames, both indigenous and Spanish, were most frequent in the Argentine provinces of Salta and Jujuy (Dipierri et al. 2005b).

The fact that these Argentine and Bolivian sections belonged to the same administrative region during the colonial period, when the use of surnames in the tax-paying population was established, means that they consequently have a high percentage of surnames in common. This greatly differs from other sections outside the studied area, in both Argentina and Bolivia. However, this common past does not have a homogeneous effect on the contemporary population. Quoting Cheshire (2014), surname adoptions "are systematic but not geographically uniform, resulting in spatial structuring of surname distributions that may subsequently be obscured by population movements." Migration processes and the establishment of new towns have always been asymmetric and oriented toward centers of economic allure, which are currently located far from the Argentine-Bolivian border zone.

Conclusion

According to the genetic distances estimated through the isonymic method and despite the existence of three major conurbations located on this international frontier, Argentine and Bolivian populations located in this large border area are not as related as expected. Regardless of intense past and present human mobility, the political administrative border between the two countries has certain geographical features that impose complications for the establishment of a population and thus would function as a barrier to the flow and exchange of surnames. On both sides of the border, populations have remained highly structured with clear differences in the frequency and distribution of surnames, which are a reflection of its complex pre- and postcolonial history.

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Table 1. Section Name and ID, Number of Electors (N), Number of Surnames (S), and Fisher's Alpha (α)

ID	*Section Name*	*N*	*S*	*α*
Potosí (Bolivia)				
1	Caripuyo	16,861	1,297	116
2	Villa De Sacaca	12,778	1,036	110
3	Uyuni	77,205	3,102	98
4	Tomave	25,369	1,038	35
5	Porco	17,433	1,036	72
6	San Pedro Buena Vista	19,586	2,452	231
7	Yambata	7,854	878	129
8	Toro Toro	4,189	512	10
9	Ocurí	16,280	1,850	211
10	Colquechaca	37,905	2,244	134
11	Ravelo	25,958	1,690	120
12	Pocoata	34,367	2,011	117
13	Betanzos	50,229	1,990	97
14	Chaquí	20,649	996	47
15	Tacobamba	19,326	1,820	126
16	Llica	7,198	327	23

17	Tahua	4,163	230	16
18	San Agustín	2,652	97	10
19	Arampampa	11,741	838	91
20	Acasio	9,091	737	107
21	Puna	85,047	2,760	76
22	Caiza	30,092	1,278	72
23	Villazón	76,769	3,469	155
24	Cotagaita	85,575	2,744	123
25	Vitichi	31,955	1,442	79
26	Colcha	17,897	702	36
27	San Pedro De Quemes	2,816	223	28
28	Uncía	51,491	2,858	216
29	Chayanta	35,884	2,116	135
30	Llallagua	138,344	5,011	206
31	Tupiza	125,889	3,989	143
32	Atocha	80,173	2,822	135
33	San Pablo de Lípez	4,862	290	26
34	Mojinete	1,865	126	8
35	San Antonio de Esmoruco	1,655	67	11
36	Potosí	528,266	8,907	160
37	Tinguipaya	24,859	1,418	73
38	Yocalla	17,045	658	39
39	Urmiri	6,620	221	15
Tarija (Bolivia)				
40	Padcaya	49,902	1,287	114
41	Bermejo	85,556	2,747	193
42	Uriondo	30,312	2,077	134
43	Yunchará	12,865	517	59

44	Entre Ríos	65,209	2,050	171
45	Tarija	334,632	6,218	212
46	Yacuiba	154,682	5,813	260
47	Caraparí	21,982	1,348	139
48	Villamontes	71,574	3,951	218
49	Villa San Lorenzo	55,200	1,381	102
50	El Puente	29,293	826	48
Jujuy (Argentina)				
51	Capital	115,019	8,689	294
52	Palpala	23,858	2,274	219
53	San Antonio	2,059	501	119
54	El Carmen	32,007	2,953	238
55	San Pedro	39,084	3,559	315
56	Santa Barbara	8,514	1,336	247
57	Ledesma	40,492	3,627	284
58	Valle Grande	1,445	158	39
59	Tumbaya	2,920	348	64
60	Tilcara	5,606	611	91
61	Humahuaca	10,499	713	81
62	Cochinoca	5,902	427	68
63	Rinconada	1,639	206	34
64	Santa Catalina	2,108	188	36
65	Yavi	9,626	1,150	104
66	Susques	1,617	91	17
Salta (Argentina)				
67	Capital	271,032	24,013	325
68	La Caldera	4,099	927	143
69	Güemes	24,569	2,698	276

70	Metan	24,974	2,588	262
71	Anta	29,477	2,461	183
72	Rivadavia	14,646	1,098	111
73	Oran	67,281	5,760	291
74	San Martin	77,888	6,540	274
75	Iruya	3,490	285	48
76	Santa Victoria	6,384	465	72
77	Cerrillos	14,825	2,020	167
78	Chicoana	11,249	1,092	117
79	La Viña	4,811	762	122
80	Guachipas	2,177	389	80
81	Rosario de la Frontera	17,679	1,862	217
82	La Candelaria	3,816	613	100
83	Cafayate	7,197	837	86
84	San Carlos	4,422	400	49
85	Molinos	3,328	252	37
86	Cachi	4,380	415	77
87	Rosario de Lerma	18,945	1,916	149
88	La Poma	1,067	160	55
89	Los Andes	3,353	350	42

Table 2. Comparisons of Euclidean Distances between Sections

Populations Compared	*Number of Comparisons*	*Euclidean Distance (mean ± SD)*	*Geographic Distance (mean ± SD)*
Argentina–Argentina	446	0.655 ± 0.103	117.6 ± 46.81
Bolivia–Bolivia	520	0.704 ± 0.100	116.7 ± 49.57
Argentina–Bolivia	98	0.723 ± 0.091	115.7 ± 37.71

Sections are separated by an average geographic distance of ~116 km.

Figure 1. International border between Bolivia and Argentina, showing the major divisions in departments (Tarija and Potosí, Bolivia) and provinces (Jujuy and Salta, Argentina). Three transfrontier conurbations are also shown.

Figure 2. Dendrogram obtained from the Euclidean distances matrix, calculated by the UPGMA algorithm. Section names and ID numbers (black, Bolivia; white, Argentina) are given in Table 1.

Figure 3. Clusters of sections, classified and colored according to the UPGMA dendrogram. Section ID numbers are given in Table 1. Cluster numbers correspond to Figure 2. Only cluster II contains sections from both Argentina and Bolivia.

Figure 4. Regression of Euclidean distance over kilometers.

FIGURES

Figure 1

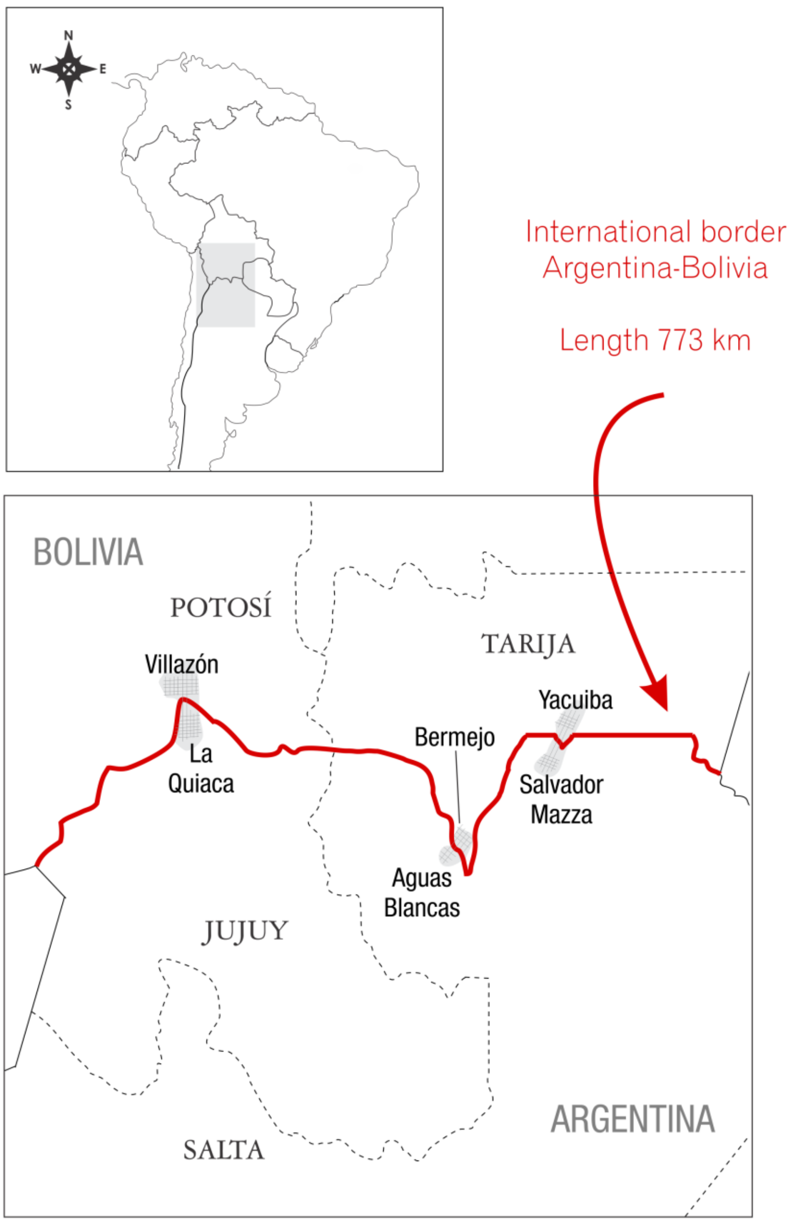


Figure 2

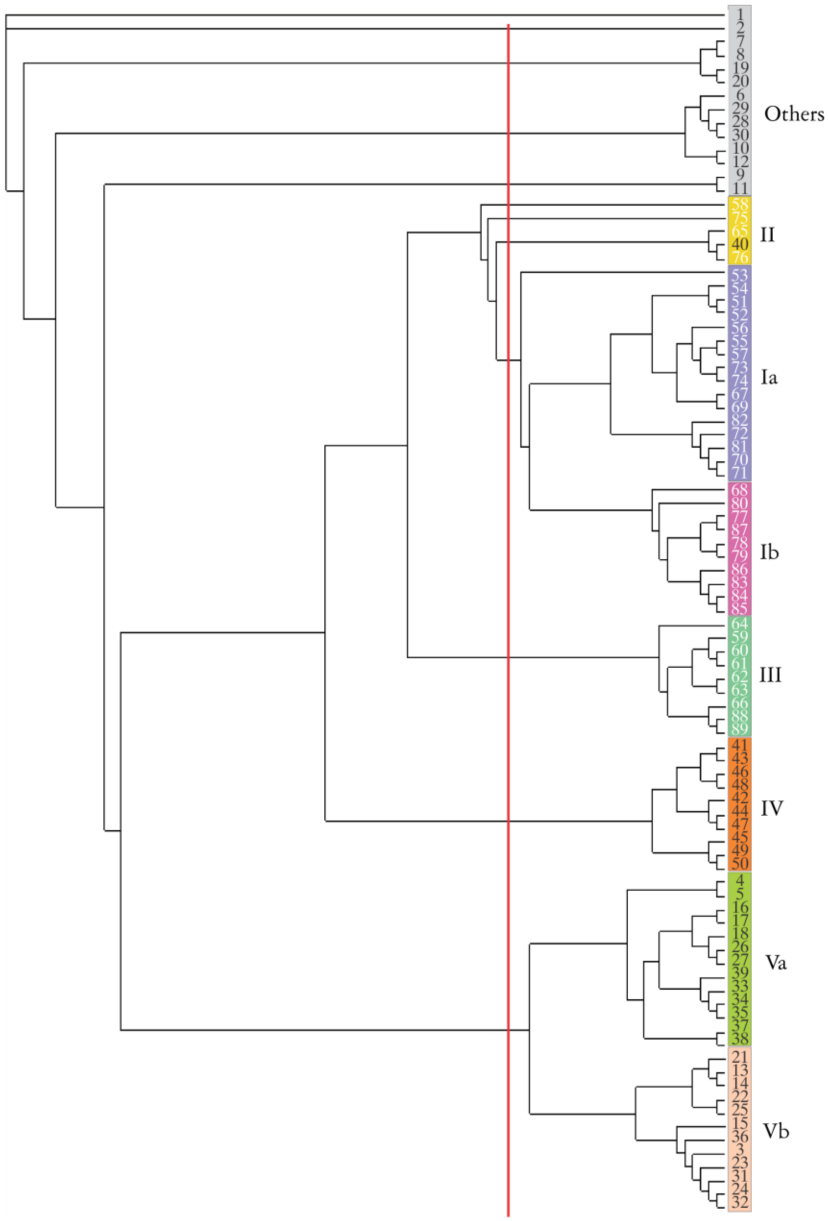


Figure 3

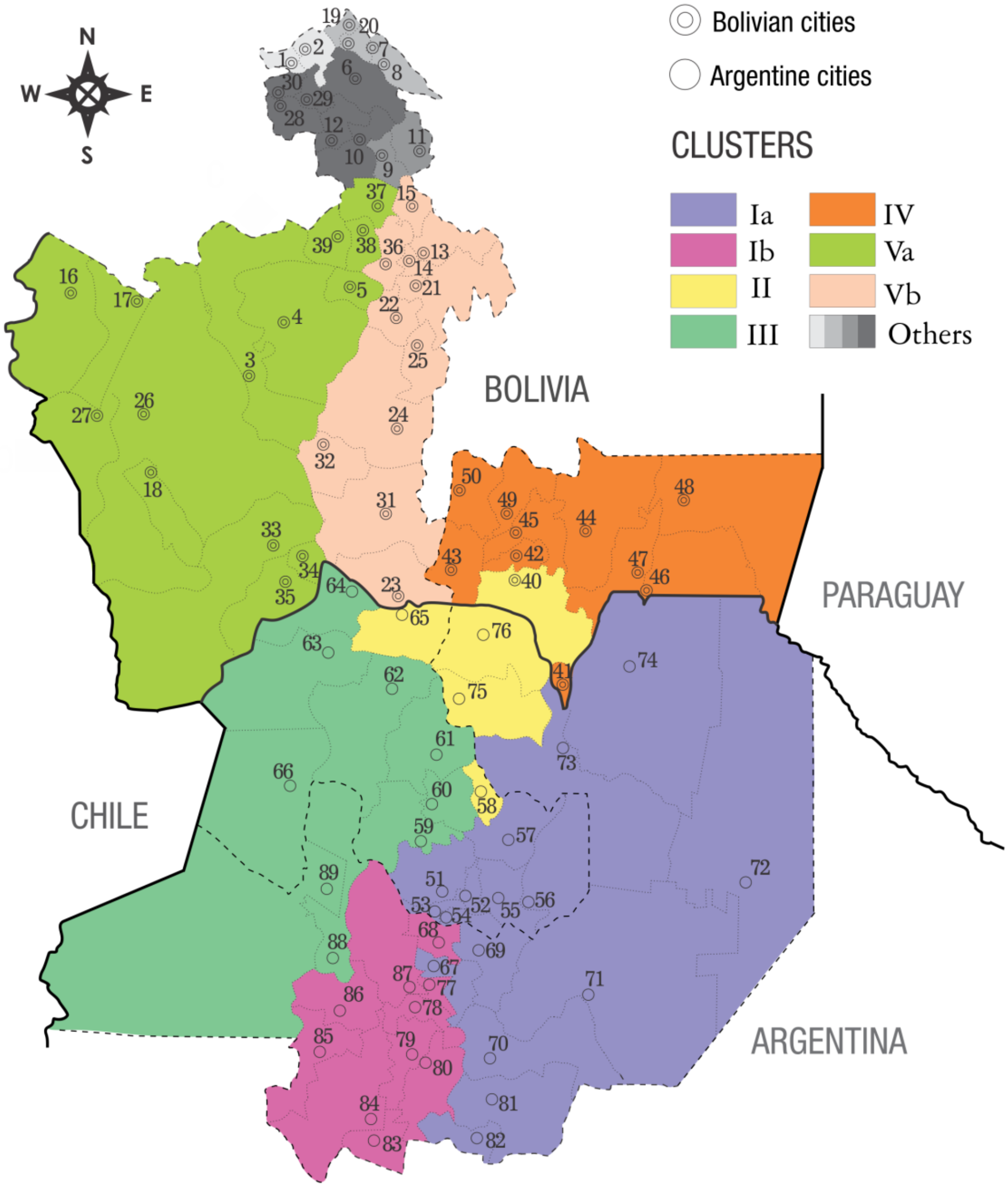
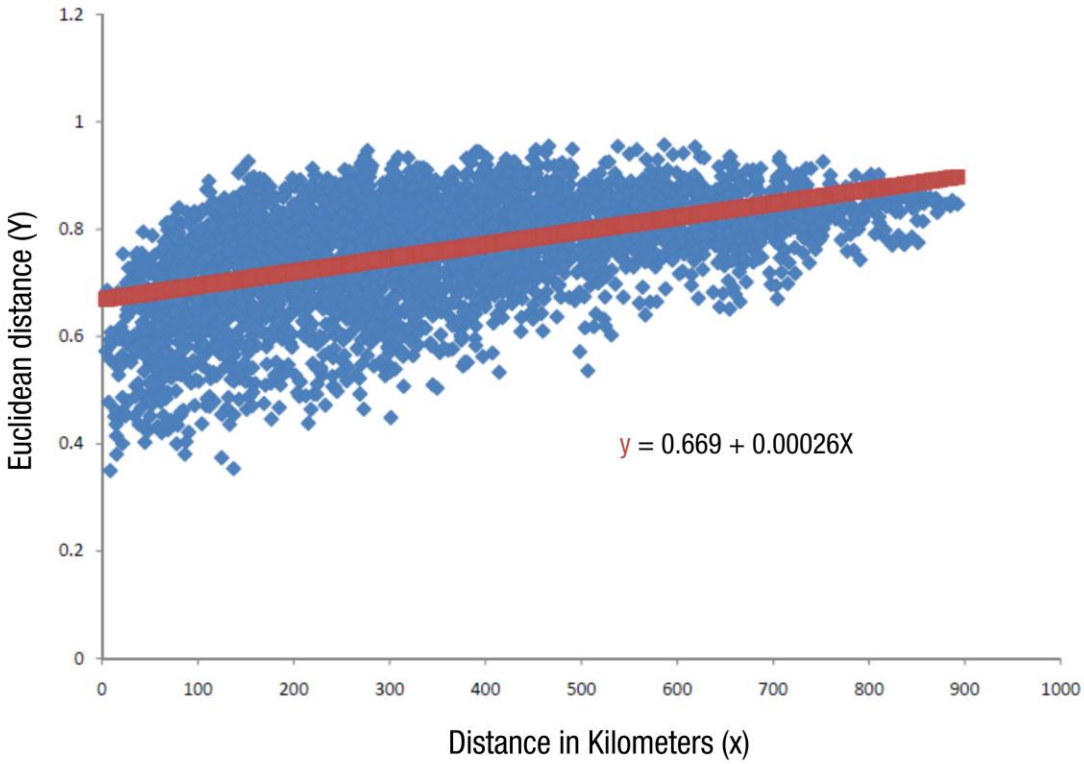

Bolivian cities
Argentine cities
CLUSTERS
Ia
Ib
II
III
IV
Va
Vb
Others
N
S
W
E
BOLIVIA
PARAGUAY
CHILE
ARGENTINA

Figure 4



1.2
1
0.8
0.6
0.4
0.2
0
Euclidean distance (Y)
y = 0.669 + 0.00026X
0
100
200
300
400
500
600
700
800
900
1000
Distance in Kilometers (x)