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"Kärnten" = Austria, "Koroška" = Yugoslavia? A Novel Perspective on the 1920 Carinthian Plebiscite

Guido Tiemann *

Abstract: »„Kärnten“ = Österreich, „Koroška“ = Jugoslawien? Eine neue Perspektive auf die Kärntner Volksabstimmung von 1920«. In 1920, the Carinthian plebiscite was organized to decide whether an ethnically and/or linguistically heterogeneous part of South-East Carinthia was to be part of the newly established German-Austrian rump state or of the newly established Kingdom of Slovenes, Croats, and Serbs (SHS). Although ethnic or linguistic "Slovenes" constituted a majority of almost 70 percent within the referendum zone, more than 59 percent of the voters opted to integrate into Austria. The allegedly victorious German side quickly turned the choice for Austria into a nationalist narrative fueled by claims of cultural superiority, fostered by the invention of an integrated, publicly funded memorial culture, and vigorously defended against any objections or revisionism from "the outside." In this paper, however, we utilize an ecological inference model to show that nationalist authors on both sides severely overrated the causal impact and empirical significance of the alleged ethnic cleavage, underestimated the share of "Slovenian" voters, and overestimated the share of "German" voters that selected to join the Austrian state. Instead of the reported 10,000, more than 13,000 Slovenes, roughly 60 percent, had voted for Austria, while only 9,000 German-speaking voters, roughly 75 percent, supported Austria.

Keywords: Ethnic groups, electoral research, referendum, ecological inference, Carinthian plebiscite, Carinthia, Austria, Yugoslavia.

1. A Matter of Choice

Almost exactly one hundred years ago, the Carinthian plebiscite was held. The demise and break-up of the multi-ethnic Austria-Hungary and the emergence of various successor states after World War I led to numerous territorial disputes, contested borders, and (even to militarized) border conflicts upon its previous territories. Within Carinthia, the plebiscite has since been a symbol of local identity, of German nationalist celebration, and of Germanic triumphalism.

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Likewise, the referendum, its aftermath, and its canonization by Carinthian, Austrian, Slovenian, and international historians has been turned into a focal point of bitter division, of an institutionalized memorial culture, and principled, ideological, and deeply polarized political, public, and scientific debates (cf., among many others, Neumann 1997; Ogris et al. 2019; the contributions to two edited volumes provide a first glance of past and present controversies; cf. Rumpler 1981; Valentin, Haiden, and Maier 2002).

The Carinthian plebiscite was a notable historical event for many reasons: substantively, it marks one of the first instances when territorial borders, instead of being drawn top-down by ruling elites or war profiteers, were settled bottom-up by a vote of directly affected citizens. Formally, the referendum marked also the first time ever when female citizens in South-East Carinthia were officially enfranchised and given the right to participate in political life. Ideologically, however, local authors focused on other aspects: the German-nationalist Carinthian historiography has been drafted, canonized, and vigorously defended by a tiny, sectarian group of publicists. Slovenian historians entered the fray and provided heated refutations. Below the line, this rift produced a polarized, bitter debate, but at the same time yielded a stunning shortage of quality research and fruitful scientific discussion.

Frequently, nationalist accounts do not care too much about the preferences of individual citizens or their organization into social and political groups. Notwithstanding an abundance of publications on the Carinthian border conflict and plebiscite, evidence-based research on the determinants of electoral choice has not only been restricted by the provision of extensive and valid data, but has also been held back by the scope and interests of key proponents in publicistic controversies. The tallies of the referendum are formally uncontested: among 39,291 local citizens who were legally enfranchised, 22,025 (59.04 percent) selected Austria and 15,279 (40.96 percent) chose Yugoslavia. Adopting the last Austro-Hungarian census as a yardstick, the choice for Austria was only possible because of the support of a significant and sizable share of ethnic and/ or linguistic Slovenes. Capitalizing predominantly, if not solely, on the ethnic underpinnings of vote choice, German-nationalist authors in Carinthia therefore claimed that their side was able to sway 10,000 (Wutte 1922, 180; 1943, 398; Ogris 1981), 10,500, or 11,000 (Wadl 2019, 181) “Slovenes.”

This article utilizes some updates in the historical data and, perhaps more importantly, modern and novel techniques of statistical analysis to shed some additional light onto the determinants of electoral behavior in the Carinthian plebiscite and to evaluate the significance of ethnic divisions vis-à-vis other drivers of electoral choice. Focusing on the 1910 Austro-Hungarian census and the official returns of the 1920 referendum from 51 local communities (German, “*Gemeinden*”), we apply Gary King’s (1997) solution to the ecological inference problem in order to obtain more reliable estimates for the decisions by the German and Slovene population segments. These complex, but well-

established statistical tools provide a feasible way forward, whenever researchers need to use aggregate data in order to draw inferences about individual behavior. In electoral research, applications have become quite common in historical cases when survey data is not at hand (cf. King et al. 2008). Ecological inference is also required, when survey-based responses are available and feasible, but most likely biased. Thus, no other field has seen more applications of ecological inference than the evaluation of and litigation on the U.S. Voting Rights Act of 1965 which concern aspects of race and vote choice or race and voter registration in American politics (cf., for instance, the almost countless examples in Achen and Shivley 1995; King 1997; King, Tanner, and Rosen 2004; Wakefield 2004; Imai, Lu, and Strauss 2007).

Building upon empirical data and modern statistical tools, we are able to show that previous guesses by biased and nationalist historians systematically underestimate the share of linguistic Slovenians that opted for Austria, and almost entirely blank out the substantive portions of Germans that desired to become a part of Yugoslavia. Our assessments differ significantly from the previously published numbers and reveal that as many as 51 percent of the Slovene- and less than 77 percent of the German-speaking citizens opted to join the new Austrian rump state. These findings do not only enable us to rectify biased and malinformed guesses on electoral choice that dominate the imminent literature. The updated figures cogently demonstrate that the Carinthian plebiscite, in contrast to the misrepresentations by parochial pride and historiographic prejudice, was by no means exclusively or even predominantly determined by ethnic and/ or linguistic cleavages. It neither delivered a race-based armageddon between the German defenders and Slavic invaders of Carinthia, nor was it a contest for loyalty among different peoples and polities. Rather, the referendum was usual politics when different ethnic, economic, ideological, linguistic, and social groups pursued different interests and conflicting goals. Nothing special.

Before proceeding, we need to add some caveat to this introduction, to our vocabulary, and to our general treatment of the Carinthian plebiscite. By definition, this contribution to positive political science addresses what is there, what is documented, and what is thus leftover for any meaningful and systematic analysis at the present day. Throughout this paper, we identify “Germans” and “Slovenes” living in Carinthia by their self-declared conversational language as recorded in the census. While we acknowledge the ideological interest of these surveys and the direction of implied measurement bias, we can do very little to quantify the magnitude of these distortions. Likewise, we are well aware that contributions from different angles and backgrounds tend to consider Germans and/ or Slovenes living in Carinthia as ethnic, linguistic, ethno-linguistic, as majority or minority groups, or refer to official labels such as “*Volksgruppe*,” our positivist perspective prevents us from suggesting unfounded speculations about some “true nature” of these groups. We do not plan to attach any label to

anyone (or any group), and instead use all the above expressions in an exchangeable manner. Finally, to prevent some awkward wording and writing, we do not care too much about changing labels of the involved states and simply write “Austria” and “Yugoslavia” throughout this paper.

2. Organizing a Referendum

The defeat and break-up of Austria-Hungary in and after World War I resulted in the emergence of numerous successor states and sparked territorial conflict among the German-Austrian rump state and the newly established Yugoslavian kingdom. These border struggles were from the outset decided within two inter-linked arenas: one was local and concerned administrative affairs, clashes among organized Yugoslavian military with improvised Austro-Carinthian defense forces, and intense propaganda efforts by both sides; the other was international and addressed the complex negotiations among the victorious allied forces at the Paris Peace Conferences.

The newly founded Yugoslavian kingdom initially strived for control and possession of the entire Carinthian territory, but later restricted its claims to an ethnically heterogeneous part of South-East Carinthia. So as to reinforce and hedge these territorial claims, Yugoslavian police and military forces entered the disputed settlements on 5 November 1918, gained control over Arnoldstein/Podklošter, Ferlach/ Borovlje, the Jaun Valley, and the Loibl Pass, and captured further contested areas. On 5 December 1918, the provisional German-Carinthian government decided to counter the Yugoslavian police and army units with federal and improvised local troops. Depending on diverse ethnopolitical, ideological, and national viewpoints, these events marked the beginning of the Carinthian Defensive Struggle (German, “Kärntner Abwehrkampf”), the Struggle for the Northern Border (Slovenian, “boj za severno mejo”), or the Carinthian border conflict (which we prefer for this paper as the most impartial and unprejudiced label). In the course of these events, German-Austrian units temporarily managed to cast Yugoslavian police and military out of the occupied communities and regions. In response, the much larger Yugoslavian kingdom mobilized additional troops, swept most of the Carinthian territories, and captured the capital Klagenfurt in May/ June 1919 (a much more detailed, albeit heavily biased account of these events is narrated by Wutte 1922, 1943).

A key touchstone of dissent in current and modern historiography refers to the impact of these struggles on the results of the Paris Peace Conference. German-nationalist Carinthian authors have persistently tried to link both events and argued that the military defense action (German, “Kärntner Abwehrkampf”) was a necessary condition for the granting and the implementation of the Carinthian plebiscite (cf., instead of many others, Kromer 1970;

Neumann 1997). Military clashes in the Klagenfurt Basin certainly alarmed the allied politicians and led to a fact-finding mission directed by the American Lt. Col. Sherman Miles. The main goal of these efforts was to look for a “good” border between the Austrian Republic and the Yugoslavian kingdom, which was based both on the right of ethnic and national self-determination and the consideration of geographical barriers which differentiated these territories. The initial reports were very much in favor of German-Carinthian interests when they underscored the economic and geographical unity of the Klagenfurt Basin, found that even many linguistic Slovenians gravitated towards the Austrian Republic instead of the Yugoslavian kingdom, and considered the Karawanks mountain range a natural barrier and, therefore, a “good” border (Carinthian historical journalism has extensively stressed the importance of the Miles Mission, and emphasized interventions by American diplomatic, military, and political actors; cf. Wutte 1922, 1943; Kromer 1970; Neumann 1997). Negotiators at the Paris Peace Conferences unanimously agreed to hold a referendum within the entire Klagenfurt Region on 12 May 1919 (Kromer 1970, 155-6). However, interventions by Yugoslavian delegates for predominantly strategic reasons advocated and asserted a division of the common Klagenfurt Basin into two different electoral units or zones (Kromer 1970, 186-7).

Figure 1: Mapping Two Referendum Zones



Notes: Some explanations of the German notes to this map are in order: the hatched areas mark territories that have been “cut off” without holding a referendum, namely the Kanal valley (German, “Kanaltal”) became a part of Italy, and the parishes of Seeland/ Jezersko, Mießtal/ Mežiška, and Unterdrauburg/ Dravograd were incorporated into Yugoslavia. Moreover, the geographical borders of the referendum Zones I and II are clearly marked on the map. In the header, the German text reiterates the three stipulations for voter enrollment established for the Carinthian plebiscite.

Figure 1 provides a geographical overview of these newly demarcated zones. Initially, a referendum was to be organized in Zone I or A which was considered asymmetrically dominated by the Slovene-speaking group that allegedly made up almost 70 percent of the local population. Note that Zone I comprised of the thinly populated Southern border lands and the cities of Bleiburg/Pliberk, Ferlach/ Borovlje, Eisenkappel/ Železna Kapla, and Völkermarkt/ Velikovec. For administrative purposes, Zone I was subdivided into the districts of Rosegg/ Rožek (A.), Ferlach/ Borovlje (B.), Bleiburg/ Pliberk (C.), and Völkermarkt/ Velikovec (D.). If, and only if, the first vote resulted in a decision to incorporate Zone I into Yugoslavia, another referendum was to be organized in the more North-Western Zone II which included the capital Klagenfurt. Unlike Zone I, a potential second referendum was from the outset considered a safe bet for the German-Austrian camp, because more than 90 percent of the population had been classified as German-speakers by the Habsburg census. Due to the results of the referendum in Zone I, the second round was never held.

Basic stipulations concerning the holding of a referendum, its formal organization, and the geographical borders of the Klagenfurt Basin and the Zones I and II are laid out in the Treaty of Saint-Germain-en-Laye, Articles 49 and 50 (1919). Of course, the determination of active suffrage, i.e., the right to vote in the referendum, was a crucial and contested issue. Basic provisions for enfranchisement have also been established in the Treaty of Saint-Germain-en-Laye, Article 50:

- 1) eligible voters needed to have turned 20 years old before 1 January 1919,
- 2) they needed to be permanent residents of the respective Zone I or II on the same day, and
- 3) they either needed to be born or were required to have had permanent residency within the respective Zone since 1 January 1912.

Both sides found ample reason to complain: while German nationalists were concerned about extending franchise to (allegedly Slovenian) citizens who had lived for only seven years in Zone I, Slovenian nationalists were bothered about elective franchise for (allegedly German) citizens who had been residents of Zone I at the beginning of 1919, but moved to another place or fled the local Yugoslavian authorities. For instance, Wadl (2019, 169) objects that many Slovenian immigrants had moved into Zone I before 1910 and thereby established an additional pool of 5,000 (within the Völkermarkt/ Velikovec district), and 2,500 (Klagenfurt/ Celovec district) likely SHS supporters. In contrast, Pleterski (1970, 78; 2002, 241-2) argues that the Austrian side unlawfully enrolled thousands of formally disenfranchised voters, but apparently do not believe or claim that these alleged irregularities ultimately tilted the result of the referendum.

Some final comments on franchise and voter enrollment are in order: the registration process was evidently complex and costly. It involved a lengthy

questionnaire and personal presence before a bi-national Austrian/ Yugoslavian commission which heard the applicants and, in case of a stalemate, deferred the cases to an allied body that took the final decision (cf. further formal details are provided by Wadl 2019, 169). Yet, this also implies that the extensive turnout of more than 95 percent in the referendum should not come as a surprise and cannot be meaningfully construed as empirical evidence of nationalist euphoria when the actual enrollment procedure per se was yet that lavish. Just to be sure, Austrian propaganda efforts successfully created the impression that voting was mandatory and fines for no-shows would be severe.

Figure 2: Ballots and Voting



Notes: German and Slovene slogans for "This is the way Carinthia wins." Fräss-Ehrfeld (2010, 170-83) notes that the Austrian side printed more than 600,000 copies of the above leaflet in order to instruct less than 40,000 registered voters.

Figure 2 shows the two historical ballot papers each enrolled citizen was provided with: a green ballot, which represented the Austrian Republic, and a white ballot paper that stood for the Yugoslavian kingdom. Both political propaganda by the interested sides and electoral engineering by the allied referendum commission considered and respected that many local voters only had elementary levels of educational attainment and literacy. The formal voting procedure implied to tearing up the ballot of the rejected option and then to submitting both papers to the local election commission: i.e., selecting Austria meant to tearing up the white ballot, as suggested in Figure 2, while those who supported Yugoslavia were supposed to rip apart the green ballot.

3. Determinants of Vote Choice

Nationalist historiography, both on the Austrian and the Yugoslavian side, has often insinuated that vote choice in the referendum was predominantly, if not exclusively, determined by ethnic affiliation: those who indicated Slovenian as their conversational language were assumed to vote for Yugoslavia, those indicated to speak German were expected to cast a vote for Austria. These simplistic ideas were then quickly inweaved into grand nationalist stories on why the Austrian side managed to sway so many Slovenes for their cause, and why Yugoslavia lost so many of “its” votes to the other side. These one-dimensional interpretations are, next, closely linked with accounts that refer to the smarter and more effective design of the (Austrian) political campaign and propaganda so as to also yield tales about heroic efforts by local activists and elites (cf., among many others, Wutte 1922, 1943; Deuer et al. 2019).

It is indeed remarkable that the Carinthian plebiscite has been prominent in local political and remembrance culture and some publications, predominantly on diplomatic affairs, but very little scientific effort has been invested to uncover more specific calculus and motives of the voters (Moritsch 1981, 215). But if we adopt a wider perspective and consider that vote choice may also be thoroughly affected by other cultural motives and values and by very pragmatic assumptions concerning individual life chances and well-being, there is effectively a catalogue of alternative motives. Besides ethno-nationalist appeals, a number of reasons may have motivated the voters to select Austria:

- 1) For liberals, leftists, and organized workers, Austria, governed by a social-democratic chancellor and, then, a focal point of socialist aspirations in Europe, may have offered a more attractive perspective than being turned into subjects of a militarized kingdom. Unlike Austria, Yugoslavia still ran military campaigns and had compulsory conscription in the army, which likely caused existential threats to small-scale family farming.
- 2) Likewise, the Austrian state was organized as a federal union, while the Yugoslavian kingdom was heavily centralized and dominated by (greater) Serbian interests. Therefore the option for Austria most likely guaranteed broader and deeper perspectives for local self-government.
- 3) The Austrian propaganda was more effective and certainly better tailored to the specific interests of its recipients. The campaign predominantly addressed the Slovenian majority in Zone I. It almost entirely skipped the usual Greater-Germany ideology and rhetorics, but instead emphasized the traits of a common heritage of the German and the Slovene groups and appealed to the idea of Carinthian unity. Perhaps the most effective arguments concerned the economic benefits and the preservation of economic exchange relations within Carinthia (cf. Deuer et al. 2019; Wutte 1943, 331-45).

- 4) The Austrian social-democrats, at that time a well-organized party and very capable to influence and sway likely voters, issued an unequivocal recommendation to cast a vote in favor of Austria. Provided that the predominantly rural Carinthian region tended to have sizable segments of voters who leaned towards the social-democrats, the preferences of this political camp have been considered crucial by both German and Slovenian historians (cf. Moritsch 1981; Pleterski 2002; Valentin 2002).
- 5) Apparently, many voters, Germans and Slovenians, were rather occupied with the unity of historical Carinthia than with the selection of either option. This was substantiated both by long-standing cultural, historical, and political ideas and traditions. While the outcome of the referendum in Zone I was in doubt and likely decided by a narrow margin, it was expected that Zone II, where only about eight percent of the population used Slovenian as a first language, would overwhelmingly vote for Austria. Choosing Austria was therefore the safest bet to ensure the unity of the state. But the deep economic integration of the Klagenfurt Basin was also a key aspect: due to the division of the Zones I and II by a line of demarcation, established economic exchange routes had been blocked and guarded by Yugoslavian police and military forces in 1919/ 20. Local peasants, who depended upon the access to the markets of Klagenfurt and/ or some other towns, thus learned about the economic fallout of being shut out from well-established economic exchange channels.
- 6) The literature on the socioeconomic underpinnings of the Carinthian plebiscite is characterized by divergent assessments: some publications suggest that across the board economic prospects were more favorable in Austria than in Yugoslavia and cite the higher standard of living or the provision of an encompassing system of social protection, etc. In contrast, Moritsch (1981) adopts a more differentiated perspective and forcefully argues that the German-Austrian rump state was probably the more attractive option for farmers who were eager to sell their products. The shrunken Austrian state did have problems to properly feed its citizens after World War I, and the high demand for agricultural products resulted in comparatively high prices. Selecting Austria meant to ensuring business opportunities and to fostering economic well-being. In this vein, the local peasant population may have been moved by economic opportunism rather than by a national awakening.
- 7) Authors from the German-nationalist tradition have emphasized the oppressive nature of the Yugoslavian occupation and extensively reported on severe restrictions of political and public life, unfounded punishments of civilians, and the banishment and expulsion of critical voices and opposition members. These arbitrary assaults, so the argument states, had demonstrated the true nature of the Yugoslavian regime and had alienated many likely supporters (cf. Fräss-Ehrfeld 2010, 170-6, many passages in

Wutte 1922 and Wutte 1943, but also Suppan 1994, 603-6 and Suppan 2002).

- 8) We conclude this brief account with a final argument that does not posit straightforward causal effects, but rather refers to empirical regularities. Referenda on territorial issues are apparently characterized by some conservative bias. Strongly dependent on the successful framing of the issue by one side or the other, a majority of voters in a number of contests appeared to favor the state they are in and are not overly eager to switch their affiliations. For the Carinthian plebiscite, the Austro-German propaganda successfully created the image that voting for Austria implied to stay, while the choice for Yugoslavia meant to go (Deuer et al. 2019).

But there are also manifold motives to choose Yugoslavia:

- 1) Secession attempts did not begin during the border conflict and the referendum, but instead started in the 18th century and were reinforced during World War I. These tendencies were also fueled by an intense pressure to assimilate minority groups in the Austro-Hungarian Empire.
- 2) The Yugoslavian political propaganda likely adopted an ill-designed angle by predominantly centering on ethno-nationalist arguments and, in terms of negative campaigning, persistently characterizing the German-Austrian rump state as a domain of prostitutes, jews, and losers. Yet, propaganda efforts by the Catholic Church were certainly more effective.
- 3) As laid out above, Moritsch (1981) adopts a differentiated perspective which posits that different occupational groups may differ in their assessments of economic prospects offered by either option. In this view, the economic considerations that drove peasants to vote for the Austrian marketplace also had a reverse. The future of industrial workers in Austria was allegedly unpredictable, and unemployment rates were substantial. Concomitantly, the Yugoslavian kingdom largely lacked an industrial infrastructure so that many commercial products were more marketable, and business opportunities for entrepreneurs and industrial workers may have appeared more favorable than in neighboring Austria (Moritsch 1981, 2002).
- 4) Another group of socioeconomic arguments invoked and addressed the fear of socialism. For the contemporary standards social protection in Austria was encompassing and generous, but, depending on specific ideological angles, this was also framed as the advance of socialism. Predominantly conservative entrepreneurs or other affluent strata of the society not only focused in economic opportunities with the much larger Yugoslavian state, but were also afraid about perspectives of and rumors about a socialism in Austria, and many of them were even afraid of potential disappropriation measures by a socialist Austrian government.

- 5) Ultimately, allegations about atrocities, erratic, unlawful rule, and expulsions are not restricted to actions by the Yugoslavian side, but have also been directed at Austrian military and Carinthian militias. Notably within the predominantly Slovenian settlements, rape, looting, and pillages were so often widely-used instruments of warfare that prominent Austrian actors started worrying about the fallout and the impact of these atrocities upon the outcome of the referendum (Haas and Stuhlpfarrer 1977, 31-8).

4. Data and Data Limitations

This section advances from political and historical background towards the presentation and discussion of the empirical data at hand. Our contribution is able to focus on detailed aggregate election returns from the Carinthian plebiscite in 1920 which have been gathered for the 51 administrative/ electoral communities which comprise Zone I. Unfortunately, the key explanatory variable applied in the historiographic literature and adopted in this analysis, the alleged ethnic composition of these territories, could not be measured and matched simultaneously and is most likely affected by systematic measurement bias. Turning towards the additional contextual controls, some key features of local communities have been derived from official statistics. We briefly comment on each of these dependent and independent variables, in turn.

4.1 Results of the Carinthian Plebiscite

The formal referendum was organized and overseen by an allied commission, and the voting and counting procedures followed a formalized, thick rulebook (cf. Wutte 1943, 358-79; Wadl 2019, 169-75). The literature quotes a number of alleged irregularities that have alternatively been blamed upon Austrian, Yugoslavian, or partisan allied actors (cf. the accounts by Wutte 1922; Pleterski 1970; Wadl 2019). However during the referendum on 10 October 1920, electoral integrity appears to have been preserved, voting was by and large unobstructed, and generally followed the established rules of the game. In addition, the electoral process was monitored by an inter-allied referendum commission that did not command military units, but was able to field more than 50 election observers. The final vote count was conducted by allied personnel and both Austrian and Yugoslavian representatives were only able to oversee and watch the counting process from the sidelines (cf. the detailed but biased narrative by Wutte 1943, 358-400).

While the entire Zone I formed a unified electoral district and the matter was to be decided by simple majority at this level, voting was organized in 97 electoral precincts, and the official tally of the vote has been broken down to four administrative districts and 51 distinct electoral communities. For each of these

territorial units, we know the number of eligible citizens and the count of voters who selected either Austria and Yugoslavia (cf. the summaries printed in Wutte 1922, 194-5; reprinted in Wutte 1943, 471-2 and Wadl 2019, 178-9). Note, however, that not all of the parishes exactly correspond to the official communities and their borders, since the line of demarcation, which separates the referendum zone I and II, also divided some established administrative communities. (Appendix A presents data at the level of the 51 local communities, adds some extensions, and comments on some factual errors in this data.)

4.2 Counting "Germans," Discounting "Slovenes"?

The inconsistencies mentioned above effectively complicate the matching of official electoral returns from the Carinthian plebiscite, and the census data comes with a number of problems and biases per se. In all territories of Austro-Hungarian Empire or the Dual Monarchy, a public census was to be conducted every ten years. The pandemic events in the aftermath of World War I, during the extended period of the Austrian-Yugoslavian border conflicts, did not allow for conducting the formal census which was scheduled for 1920. This especially applies to Zone I which was provisionally governed by Yugoslavian authorities and temporarily sealed off from the other territories. Therefore, detailed data on the ethnic composition of individual communities may only be taken from the previous census conducted in 1910. The ten-year gap in the data used as a dependent (i.e., the aggregate referendum results) and the key independent variables (i.e., results of the census concerning the ethnic composition of the 51 communities and some additional controls) is certainly noteworthy: the census registers the overall population including minors, foreigners, etc. These figures will always exceed the count of eligible and enrolled voters, but there are also good reasons to assume that both will generally be proportional.

Demographic changes certainly affected the terrains of South-East Carinthia in the decade from 1910 to 1920, and at least parts of the male population will have fought and/ or died in World War I. However, both Austrian and Slovenian historians agree that, provided that the Carinthian territories in Zone I were not exposed to abrupt changes in the agrarian and general socioeconomic structures and not directly affected by hostile action in World War I, the decade from 1910 to 1920 was, in contrast to the subsequent 1920s, not at all characterized by significant demographic upheaval in the disputed terrains (Moritsch 1981, 217). Therefore, we follow the vast majority of previous work and presume that, in spite of the time gap, the 1910 census may still be applied as a valuable proxy for the ethno-linguistic context during the referendum ten years later (cf. Wutte 1922, 1943; Pleterski 1970, 2002; Pleterski and Druškovic 1983; Moritsch 1981, 2002; Wadl 2019).

We have mentioned above that some of the territorial units used to organize the referendum do not exactly match with administrative community borders. For instance, the Eastern part of the administrative community Finkenstein/

Bekštanj was merged with the administrative community of Latschach/ Loče , and parts of the administrative communities Kienberg, Lavamünd/ Labot, and Legebuch were fused into the newly established electoral community of Lavamünd/ Labot. However, these issues were confined to some communities which were proximate to the demarcation line that inclosed Zones I and II or close to some newly established borders that now separated the Carinthian, Italian, and Yugoslavian territories. Below the line and provided that detailed and high-quality census data was also gathered for subunits of administrative communities (German, “*Kastalgemeinden*”), these temporal gaps and inconsistencies may be satisfactorily addressed and corrected by some reasonable assumptions.

Given the methodological options and restrictions of the time, the Austro-Hungarian census provides detailed and high quality data. But much more crucial problems emanate from biased and prejudiced measurement of individual ethno-linguistic affiliation with the German or the Slovenian group. Therefore, estimates and figures discussed in public and scientific debates are likely affected by systematic measurement bias. In principle, separating Germans and Slovenes is ostensibly easily and uni-dimensionally operationalized by the self-reported conversational language (German, “*Umgangssprache*”).

The first issue is that minority citizens in larger communities have been put under much more intense pressure to assimilate and switch to speaking German. Small-scale farmers working in a subsistence economy likely had little exchange with customers who were located further away and came from different villages or ethnic groups. Yet, those who ran larger estates which produced marketable surpluses needed to look out for practical market places, and access to these more profitable outlets likely required assimilating in terms of, at least in business affairs, switching to the dominant German language. While local demographics did not change much from 1880 to 1910, the share of those who indicated Slovenian as their conversational language remained stable in remote, rural areas and small villages, but declined constantly and rapidly in more densely populated areas and larger communities. Industrial workers and the few Slovenes who had risen to the higher strata of society (or planned to do so) were likely under even more intense pressure to assimilate (cf. Moritsch 1981, 223-6; Wendel 1920, 576-7). In ethnic and/ or linguistically mixed communities, any measure of a conversational language will usually and systematically be biased in favor of either the language of the majority group or the more empowered group (Brix 1981, 236-7).

The dichotomous choice to indicate one, and the restriction to name only one, conversational language was certainly at odds with empirical bi- or multilingualism in Carinthia and many other parts of Austria-Hungary. This dichotomous alternative reveals the census to rather be an instrument of ethno-nationalist assimilation and domination efforts than of sober and unbiased bureaucratic and/ or political planning. Additional systematic measurement

bias was introduced by census interviewers who were eager to under-represent minority groups, but instead to underscore the German character of their local communities and to fabricate evidence for successful assimilation efforts led by their administration (cf. the numerous examples from Carinthia and other parts of Austria-Hungary gathered by Brix 1981, 234-9).

Note that this contribution to positive political science will sidestep any essentialist discussion about the true contents or even nature of being “German” or “Slovene.” Effectively, the detailed and rich records compiled by the Austro-Hungarian census from 1880 to 1910 are without any feasible measurement alternative and have been concurrently and persistently utilized by the “German,” the “Slovenian,” and the “Viennese” camps in an often polarized debate. Throughout this paper, we thus define group membership only and strictly by self-ascribed conversational language as recorded in the census. We do, however, hasten to add that data on local ethnic affiliation and ethnic shares of the population gathered by the Austro-Hungarian census is affected by systematic measurement error, likely biased downwards for the number and share of Slovene-speaking citizens, and beclouds meaningful comparisons among rural and urban areas or peasants’ and industrial workers’ political interests and preferences. We thus hasten to record that the estimates for the Slovenianspeaking shares of the local populations provide a lower bound rather than an unbiased point estimator.

5. Historiographic Myth and Empirical Reality

Almost by nature, nationalist angles, be it in politics, public discourse, or in (distorted) contributions to science, do not tend to adopt multi-faceted perspectives. Instead, these statements often select a narrow, uni-dimensional perspective and refrain from both meaningful and transparent definitions of key terms, from systematic data collection and documentation, and from methodical, thorough data analysis. Concerning the Carinthian plebiscite, nationalist historical accounts provided by the German and also by the Slovenian camps explicitly or, at least, implicitly assume the dichotomous choice for Austria or for Yugoslavia were informed exclusively, if not solely, by ethnic or linguistic cleavages. In the subsequent discussion, we can only provide some brief sketch of these accounts:

- 1) The German-nationalist camp in Carinthian historiography cogently relies on and persistently defends the obsolete publications by Wutte (1922 and 1943). While the author provides detailed and mostly correct data on the 1910 census and vote choice in the 1920 referendum, he does not fully interpret this material and implicitly assumes that all German and an additional 10,000 Slovenian voters chose to become members of the new Austrian republic. Later, these numbers are, with or without references,

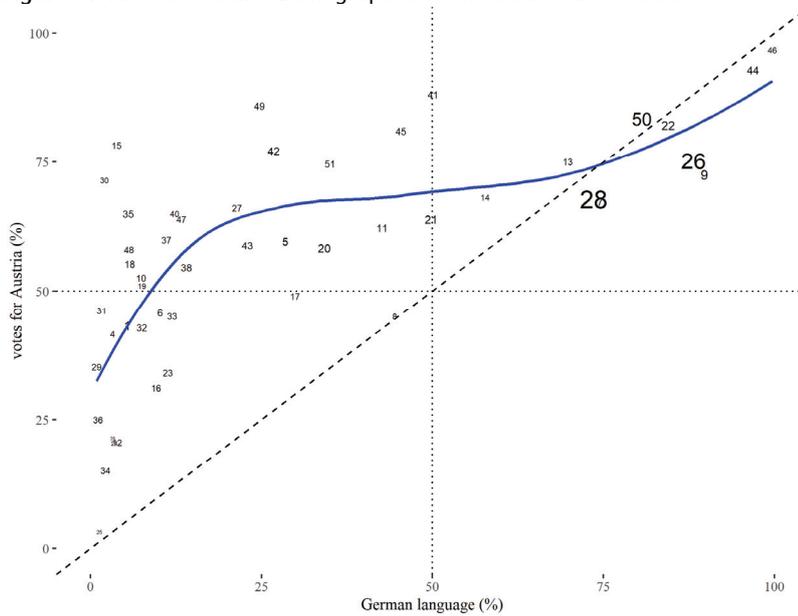
regularly copied by other authors who relate to this tradition (cf. Wadl 2002, 167; Webernig 2019, 57).

- 2) Within this tradition, only the piece by Wadl (2019, 180-1) bothered to take a somewhat closer look at the community-level electoral returns reported by Wutte (1922, 180; 1943, 398). This somewhat more fine-grained inspection of some local electoral returns, for instance from Ferlach/ Borovlje, revealed that at least 500 German voters apparently selected Yugoslavia, and these findings vice versa implied an upward correction towards 11,000 Slovenian votes for Yugoslavia. These numbers have also been copied by Fräss-Ehrfeld (2010, 193).
- 3) Strikingly, key authors in Slovenian historiography at least implicitly adopt very similar ethno-nationalist viewpoints, underscore the paramount importance of ethnic or linguistic cleavages and adopt identical accounts of 10,000 (roughly 40%) ethnic and/ or linguistic Slovenes that casted a vote for Austria (cf. Valentin 2011, 18). The calculations by Pleterski (1970, 84-5) unambiguously assumes that Germans vote for Austria, while Slovenes prefer Yugoslavia and suggest that the pseudo-exact number of 10,527 Slovenes or 40.80% cast a vote for Austria. In another publication, Pleterski and Druškovič (1983, 5) reiterate similar numbers and explicitly state that certainly all (!) German-speaking voters had supported Austria.
- 4) The guesses presented by the “Viennese” camp of historians are regularly somewhat higher, but are usually also not underpinned by any empirical evidence or reference. Some publications adopt numbers from the German-nationalist mainstream and posit that roughly 10,000 Slovenes had voted for Yugoslavia. Suppan (2002, 108) believes that about 11,000 Slovenes supported Austria; Haas and Stuhlpfarrer (1977, 49) rather speculate that about 12,000 ethnic “Slovenes” (however defined) voted “German” (whatever that may be). Moritsch (1981, 215) draws upon the literature and reports a wide interval ranging from 10,000 up to 15,000 linguistic Slovenes that selected Austria. Yet, his references back up the lower bound of 10,000 with empirical evidence (cf. Wutte 1943, 398), while the upper bound of 15,000 may only be derived from a simple numerical example in an opinionated article by Wendel (1920, 577).

The pivotal goal of this contribution is to replace these wild guesses and unfounded speculations by descriptive inferences that exhaust the information available at the community level. In the remainder of this descriptive section, we seek to provide a first glance at the electoral and demographic data gathered for an empirical re-assessment of the 1920 Carinthian plebiscite. Key data on electoral returns and demographics has been recounted above: in the aggregate, 59.04 percent of the enfranchised citizens opted to join Austria, while only 31.40 percent of them were linguistic Germans. At the community level, 33 voted for Austria and only 18 favored Yugoslavia. North of the river Drau/

Dráva, Austria won 20 of 24 local communities, south of it, it managed to pick up only 13 of 27 (cf. Appendix A for a breakdown of the results into four electoral districts and 51 communities).

Figure 3: Vote Choice and Demographics in the Carinthian Plebiscite



Notes: This simple illustration ignores the ecological inference problem and plots the aggregate share of Germans against the aggregate votes cast for Austria at the community level. The numbers label the local communities (cf. Table 3 in Appendix A), and the size of the labels is parallel to the number of citizens in a community. The dashed line indicates identity, i.e., for observations to the upper-left the share of votes for Austria exceeds the share of "Germans," and to the lower-right the share of votes for Austria falls behind the share of ethnic "Germans." We have also added a LOESS smoother to indicate non-linear associations.

Figure 3 provides a comparison of electoral returns from the referendum (here, the share of votes cast for Austria: y-axis), and measures for the ethnic composition of local communities (here, the share of German-speaking voters: x-axis). The case labels indicate a running number of the communities (cf. Appendix A), and the size of these labels represents the population density within these diverse and heterogeneous regions. Finally, note that the diagonal line ranging from the lower left to the upper right indicates identity: if any community is situated directly upon this line, the choice between Austria and Yugoslavia appears to systematically reflect its ethnic composition. Locations above the diagonal indicate that the vote share for Austria exceeds the assumed share of linguistic Germans as proxied by the 1910 census. Of course, this must be true for a number of communities so as to account for the aggregate majority

for Austria in Zone I. Some explicit examples are the (smaller) villages Mieger/ Medgorje (15), Gallizien/ Galicija (30), or Tainach/ Tinje (49). Vice versa, when local community is situated below the diagonal, the vote share for Austria undercuts the share of linguistic Germans. This applies to eight communities, for instance to Ferlach/ Borovlje (9), and also in the comparatively industrialized communities of Viktring/ Vetrinj (22), Bleiburg/ Pliberk (26), or Eisenkappel/ Železna Kapla (28).

In a nutshell, this simple graphical presentation illustrates that the ethnic dimension certainly mattered for vote choice in the Carinthian plebiscite. However, these alleged cleavages are often superimposed by other potential determinants of the vote, e.g., rural vs. industrial interests, the proximity to borders, or other aspects of (economic) geography. In this vein, vote choice in the referendum does not appear to be a mere reflex of some demographic element. Rather, electoral behavior appears to be structured by complex interactions of ethnic or linguistic heterogeneity, with contextual variables.

6. Ecological Inference as a Way Forward

The ecological fallacy has been a key problem in social sciences and applied statistics. This error arises when observers naively rely on aggregate or group characteristics, but attempt to draw causal or descriptive inferences at the individual level. The key logical and statistical problem is how to deal with aggregation bias, i.e., how to address the information loss that occurs when individual actions, preferences, or properties are aggregated and only reported at a higher level (cf. the seminal contributions by Ogburn and Goltra 1919; Robinson 1950 and the historical survey by King 1997, 3-12).

In the modern quantitative toolbox, ecological inference is a common label for an array of techniques and perspectives that intends to provide a way forward and enable researchers, in spite of aggregation bias and a number of related complications, to draw some meaningful inferences based on aggregate data. Ecological inferences are required when individual level data is not available. This is true, for instance, when researchers dig into historical cases which occurred before the widespread availability of (high-quality) survey data. A common application refers to the social and ideological underpinnings of the Nazi vote in Weimar Germany, when survey data is not available, but a way forward could be found by relying on complete, community- or district-level election returns and detailed socio-demographic data for the same units (cf. Falter 1991). Ecological inference techniques are also required when survey data is available, but notoriously unreliable in ethnically or racially polarized conflicts. Therefore, in American politics, many details of the U.S. Voting Rights Act require alternative conceptual angles. Studies on race and literacy, race and voter registration, race and vote choice have therefore become ubiqui-

tous in this subfield (cf. almost countless examples in Achen and Shivley 1995; King 1997; King, Tanner, and Rosen 2004; Wakefield 2004; Imai, Lu, and Strauss 2007).

Essentially, the Carinthian plebiscite is almost an ideal and textbook case of an ecological inference. At the level of 51 electoral communities, we are able to draw upon detailed electoral returns of the 1920 referendum, and, as long as we are willing to accept the validity of the 1910 census, we have data on the relative shares of ethno-linguistic groups within the same units. This data enables us to construct a simple 2x2 table of the ecological inference problem at hand, which we formally present in Table 1. We only know the marginal distributions of linguistic self-identification in 1910 and vote choice in the referendum in 1920: In the rows, $Y_i = 59.04\%$ of the voters (i.e., 22,025 individuals) selected Austria, while the remaining $100 - Y_i = 40.96\%$ (i.e., 15,279 voters) opted for Yugoslavia. Turning towards the columns of Table 1, we also know that only $X_i = 31.4\%$ of the population indicated German as their conversational language, while the other $100 - X_i = 68.6\%$ allegedly indicated to conduct everyday conversations in Slovenian.

Table 1: Known and Unknown Variables in the Carinthian Plebiscite/ the Ecological Inference Problem

		ethno-linguistic group		
		German	Slovenian	
vote choice	Austria	$W_{i,1}$	$W_{i,2}$	Y_i
	Yugoslavia	$1-W_{i,1}$	$1-W_{i,2}$	$1-Y_i$
		X_i	$1-X_i$	

Notes: A 2x2 ecological inference table representing vote choice (rows) and linguistic group affiliation (columns) in the Carinthian plebiscite. X_i and Y_i are known proportions for each community i ; $W_{i,1}$ and $W_{i,2}$ are unknown proportions which we explore in ecological inference. Note that the notation used throughout this paper has been adopted from Imai, Lu, and Strauss (2007, 2011).

Table 1 may be set-up to the entire referendum zone, but, as indicated above, we have obtained sufficient local data to construct parallel tables for each individual electoral community $i = 1, \dots, 51$. While the marginals (the shares of the two linguistic groups, and the votes received for the Austrian and the Yugoslavian option, i.e., X_i and Y_i) are known, the key goal of any ecological inference model or technique is to obtain reliable estimates for the unknown parameters $W_{i,1}$ and $W_{i,2}$. Substantively, $W_{i,1}$ is the share of linguistic Germans that select Austria, and $W_{i,2}$ is the share of linguistic Slovenes that choose Austria. Once these quantities are known, of course $1 - W_{i,1}$ and $1 - W_{i,2}$ are also fixed for each local community i .

In logical and statistical analyses, a number of alternative or complimentary methods have been suggested to fill in the unknown quantities of interest. The logical “methods of bounds” may be used to uncover deterministic, but most

often very wide boundaries that are guaranteed to cover $W_{i,1}$ and $W_{i,2}$. Parametric models, ecological regression, often labeled “Goodman’s regression,” provide alternative statistical attempts to identify $W_{i,1}$ and $W_{i,2}$. Eventually, the seminal contribution by King (1997) integrated these two previously alternative and isolated approaches into a common statistical framework, derived appropriate estimation techniques and thoroughly tested the novel framework with an extensive set of empirical applications.

6.1 Logical Bounds

Duncan and Davis (1953) were the first to provide a logical approach to the ecological inference problem. Their model requires no specific statistical assumptions and provides deterministic, but wide bounds for the quantities of interest. Consider, for instance, the town of Ferlach/ Borovlje: from the electoral returns we know that among $N = 1,703$ valid votes, 72.5 percent voted for Austria and the remaining 27.5 percent opted for Yugoslavia; from the 1910 census we also learn that 89.8 percent spoke German and only 10.2 percent spoke Slovenian in everyday conversation. Unfortunately, these marginals do not tell us very much about the electoral behavior of the local Slovenian minority, and the share of them voting for Austria may lie anywhere from zero to one hundred percent ($W_{i,1} \in [0, 1]$). However, for Ferlach/ Borovlje we know somewhat more about vote choice among the German-speaking majority. Since the vote share for Austria significantly falls behind the share of ethnic Germans, a notable portion must have cast a vote for Yugoslavia. The method of bounds thus reveals that the share of German-speakers who selected Austria *must* lie in the interval from 69.4 to 80.8 percent ($W_{i,1} \in [0.694, 0.808]$). The true value of $W_{i,1}$ will be at its lower limit when all Slovenians cast a vote for Austria (i.e., $W_{i,2} = 1$), it will be at the upper limit when none of them do ($W_{i,2} = 0$).

More generally, links of the marginals (X_i and Y_i) with the quantities of interest ($W_{i,1}$ and $W_{i,2}$) are formalized by a simple algebraic equation. Note that this expression lacks an error term and thus provides deterministic bounds:

$$Y_i = W_{i,1}X_i + W_{i,2}(1 - X_i); \forall i = 1, 2, \dots, n; \text{ with } Y_i, X_i, W_{i,1}, W_{i,2} \in [0, 1]$$

As demonstrated by King (1997, 301–3), deterministic Duncan/ Davis bounds for the vote shares $W_{i,1}$ and $W_{i,2}$ may be easily derived by the following equations:

$$W_{i,1} \in \left[\max\left(0, \frac{X_i + Y_i - 1}{X_i}\right), \min\left(1, \frac{Y_i}{X_i}\right) \right]$$

$$W_{i,1} \in \left[\max\left(0, \frac{Y_i - X_i}{1 - X_i}\right), \min\left(1, \frac{Y_i}{1 - X_i}\right) \right]$$

By definition, these equations imply that we have complete knowledge about the four cells in Table 1 ($W_{i,1}, W_{i,2}, 1 - W_{i,1}, 1 - W_{i,2}$) once we observe any

single one. Solving the above equation for $W_{i,1}$, therefore yields a linear relation among the shares of the German ($W_{i,1}$) and the Slovene language groups ($W_{i,2}$) that support Austria. Note that the first fraction term (in parenthesis) represents the intercept of the linear association, while the second term (also in parentheses) captures its (negative) slope of the linear association:

$$W_{i,1} = \left(\frac{Y_i}{1 - X_i} \right) - \left(\frac{X_i}{1 - X_i} \right) W_{i,2}$$

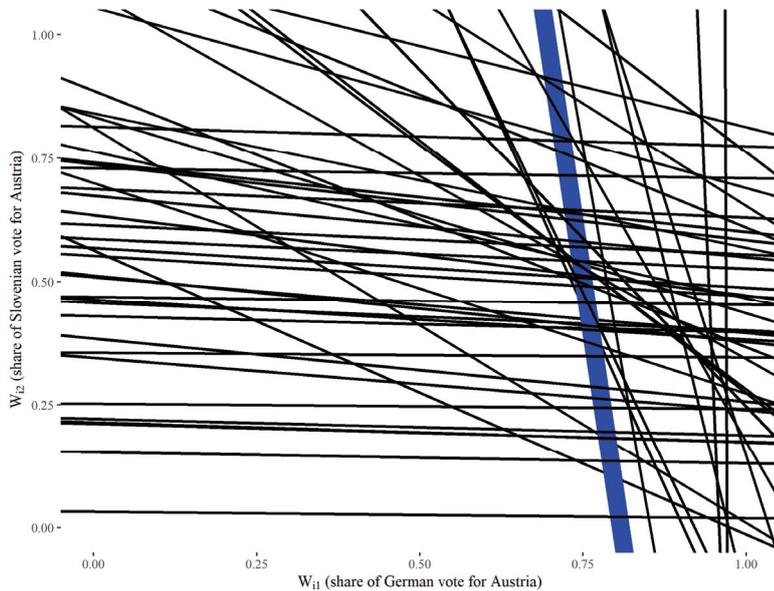
The above equation provides sufficient information so as to construct a “tomography plot” of the ecological inference problem that covers all of the 51 local communities in Zone I. Each line in Figure 4 has been calculated from the local marginals for each of the 51 communities at hand and represents potential associations of $W_{i,1}$ and $W_{i,2}$. In any case, both values are related by a simple linear equation, and the true values are guaranteed to fall somewhere on the specific lines. To see this more clearly, we have used a thicker blue line to represent the previously discussed example of Ferlach/ Borovlje: the range of the Slovenian vote for Austria, on the y-axis, is as wide as possible and only limited by the margins of the scale ($0 \leq W_{i,2} \leq 1$). However, the German vote for Austria, on the x-axis, is restricted to a much more narrow interval which only covers a small part of the overall scale range ($0.694 < W_{i,1} < 0.808$).

Generally, steep lines, which run parallel to the y-axis, as in the case of Ferlach/ Borovlje, tell us a lot about the German voter segment, but little about the Slovenian one. Vice versa, flat lines, which run parallel to the x-axis, enable us to define narrow, informative bounds for the Slovenian vote, but wide, non-informative bounds for the German vote. Short diagonals at the bottom-left or top-right of the figure are most informative and provide narrow bounds for each of the vote shares $W_{i,1}$ and $W_{i,2}$. Eventually, (almost) exact diagonals ranging from top-left to bottom-right tell us nothing (or very little) about a specific community. Instead of searching for the true values of $W_{i,1}$ and $W_{i,2}$ somewhere within the entire unit square, we now know that the true values are much more restricted and fall somewhere on the respective tomography line for any local community i .

The practical value of Duncan/ Davis bounds depends on the specifics of the data and distributions at hand. Applied to the Carinthian plebiscite, these logical restrictions on the parameter space provide rich and useful information. Particularly, both the ethno-linguistic composition and the electoral returns vary considerably from one community to the other. In addition, both variables quite often approach the scale margins when these areas are either characterized by a lopsided composition of the German or Slovenian linguistic group or local referendum returns overwhelmingly favor either the Austrian or the Yugoslavian vote. Even a brief inspection of Figure 4 clearly reveals that most community-level tomography lines at least substantively restrict the vote shares for one of the groups thereby providing information for the other group, as

well. The deterministic Duncan/ Davis bounds therefore supply necessary information for a successful application of the ecological inference framework.

Figure 4: Duncan/ Davis Bounds in a Tomography Plot



Notes: Each of these lines represents one of the 51 local communities of Zone I. The dataset is presented and summarized in Appendix A. Intercepts and the downward slopes may be exactly calculated from the marginals, and W_{i1} and W_{i2} are guaranteed to lie somewhere on these lines. For illustrative purposes, the community of Ferlach/ Borovlje, discussed above, is highlighted by the thick blue thicker line.

Eventually, logical bounds calculated for each of the 51 local communities may also be aggregated so as to obtain deterministic bounds on W_1 and W_2 for the entire referendum zone. However, if we run these computations, we also see that the Duncan/ Davis bounds are still too wide to allow for any substantively meaningful interpretation. If we are inclined to accept the validity of the referendum returns and the 1910 census, which is certainly more doubtful, at least 49.42% and a maximum of 95.87% of the Germans voted for Austria ($W_1 \in [0.4942, 0.9587]$). Bounds for the share of Slovenian voters that also supported the Austrian option are more narrowly defined and vary between 41.82% and 63.53% ($W_2 \in [0.4182, 0.6353]$). Therefore, the choice for Austria was only possible due to the support of 10,628 to 16,146 Slovenian voters. But, as indicated above, there are also good reasons not to trust the data gathered by the Austro-Hungarian census. When the number and share of linguistic Slovenians is systematically depressed, the above intervals are biased downwardly and provide lower bounds rather than a realistic assessment.

6.2 Employing Non-Parametric Statistical Models

Imai, Lu, and Strauss (2007, 2011) show that ecological inference is essentially a *coarse data* problem: this label applies when key quantities of interest are neither entirely missing nor fully observed. For the referendum dataset, knowledge of the marginal distributions enables us to calculate Duncan/ Davis bounds, but we do not directly observe the key quantities of interest $W_{i,1}$ and $W_{i,2}$. Building upon the coarse data framework by Heitjan and Rubin (1991), ecological inference may be decomposed into three distinct subissues:

- 1) Contextual effects occur when $W_{i,1}$ and $W_{i,2}$ are correlated with observed or unobserved contextual variables;
- 2) distributional effects arise when parametric models are mis-specified and do not capture the true underlying distribution of the coarsened variables;
- 3) aggregation problems due to the loss of information by focusing exclusively on higher-level entities.

Common parametric models, including the seminal specifications by King (1997) and Wakefield (2004), usually assume the data to be CAR (coarsened at random). Therefore, $W_i^* = [\text{logit}(W_{i,1}), \text{logit}(W_{i,2})]$ is defined by

$$W_i^* | \mu, \Sigma \stackrel{i.i.d.}{\sim} \mathcal{N}(\mu, \Sigma)$$

Note that μ is a 2x1 vector of population means and Σ a 2x2 positive definite variance matrix. This simplistic specification also rests on the idea that there are no measured or unmeasured contextual effects which impact on $W_{i,1}$ and $W_{i,2}$, and this assumption is usually quite unrealistic. Concerning the empirical application in this paper, the Carinthian plebiscite, we have briefly scrolled through a whole catalogue of alternative explanations, cultural links, economic self-interest, ideological or political convictions, which may either concomitantly or adversely affect both ethno-linguistic groups. It is thus pivotal for our analysis to relax assumptions of no contextual effect, and Imai, Lu, and Strauss (2007) suggest two alternative perspectives. The first is to collect additional covariates Z_i and to treat the data as CCAR (conditionally coarsened at random). The second is a NCAR (not coarsened at random) model that attempts to capture contextual effects directly without additional observed covariates Z_i .

In order to address the second issue, likely distributional effects, Imai, Lu, and Strauss (2007, 48-50) recommend to switch to more flexible and general Bayesian non-parametric models that are based on Dirichlet process priors. With the term “non-parametric,” we imply that no *a priori* distributional assumptions are made and that in-sample predictions comply with the Duncan/ Davis bounds defined above:

$$\begin{aligned} W_i^* | \mu_i, \Sigma_i &\sim \mathcal{N}(\mu_i, \Sigma_i), \\ \mu_i, \Sigma_i | G &\sim G \\ G | \alpha &\sim \mathcal{D}(G_0, \alpha), \\ \alpha &\sim G(a_0, b_0). \end{aligned}$$

$$\mu_i | \Sigma_i \sim \mathcal{N}\left(\mu_0, \frac{\Sigma_i}{\tau_0^2}\right); \Sigma_i \sim \text{InvWish}(v_0, S_0^{-1}).$$

7. Turning Prejudiced Guesses into Unbiased Inference

The joint consideration of Duncan/ Davis bounds and some key elements of ecological regression enables us to now turn towards the key goal of this paper, i.e., to obtain meaningful and precise estimates for the shares of ethnic German or Slovenian citizens that voted for Austria ($W_{i,1}$ and $W_{i,2}$, respectively) both in each of the 51 communities and across the entire Zone I.

We apply Bayesian non-parametric models that relax the assumption of no correlation/ no contextual effects so as to obtain unbiased and precise posteriors for $W_{i,1}$ and $W_{i,2}$. These models are fit via MCMC simulation and the Gibbs sampler as implemented in the “eco” package (Imai, Lu, and Strauss 2011; Lu 2017). Technically, we set diffuse priors, run a total of 300,000 iterations per chain, but discard the first 100,000 draws as a burn-in period, and only evaluate every 200th iteration (i.e., we employ a thinning interval of 200). We also run multiple chains in order to check for proper mixing and overlap and compute a battery of statistical tests for convergence of the MCMC process. Construction and simulation of the Bayesian models at hand pass all conventional tests that guard against autocorrelation within chains, non-stationarity of chains, and mismatch across different chains with overdispersed starting values (cf. key model diagnostics in Appendix B).

Table 2: Filling In the Blanks

		ethno-linguistic group		
		German	Slovenian	
vote	Austria	$W_1 =$ (64.81%); 76.09% ; (86.39)	$W_2 =$ (46.25%); 51.06% ; (56.33%)	59.04%; 22.025
choice	Yugoslavia	$1 - W_1 =$ (13.61%); 23.91% ; (35.19%)	$1 - W_2 =$ (43.67%); 48.84% ; (53.75%)	40,96%; 15,279
		31.4%; 11,713	68.6%; 25,591	

Notes: The Table fills in the gaps and summarizes Bayesian posterior distributions for the entire referendum Zone I. The bold numbers represent the posterior means for the share of German-language voters that opted for Austria (W_1) and for Slovene-language voters that chose Yugoslavia. The numbers in brackets indicate the 95% Bayesian HPD intervals.

With these methodological foundations in mind, we now turn to the key substantive findings of our study. Table 2 presents summaries of the posterior densities for the key quantities of interest, the overall counts/ shares of German and of Slovenian voters that cast votes for Austria or for Yugoslavia. The results clearly indicate that previous guesses have severely misjudged and dis-

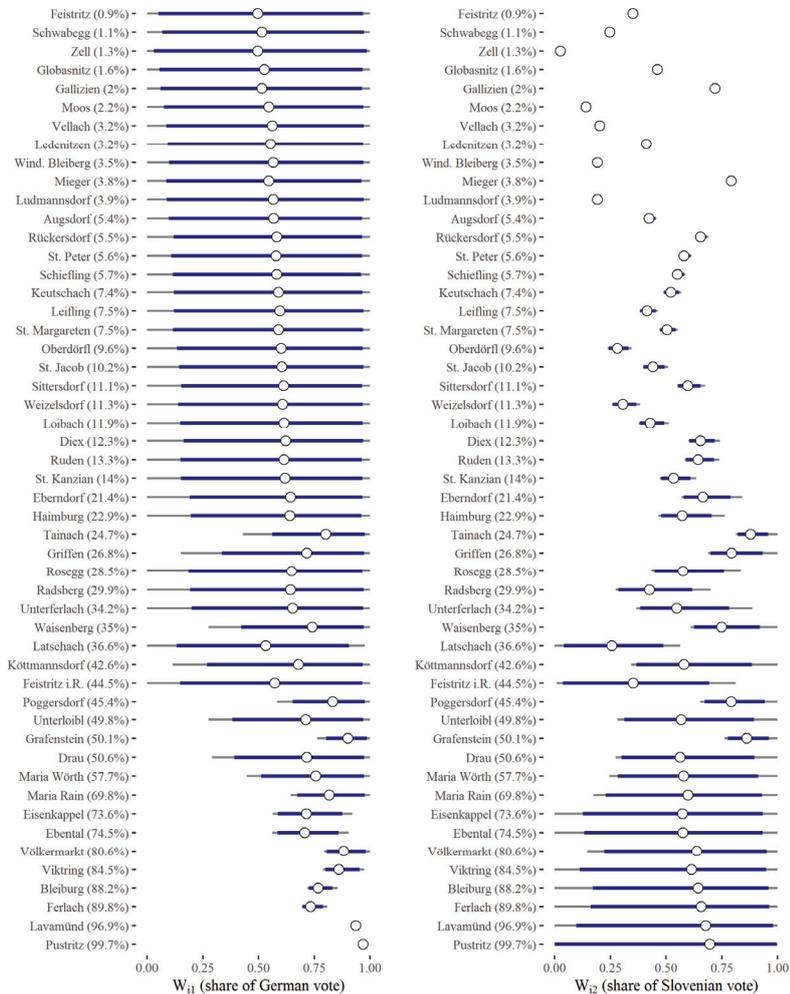
torted the impact and salience of ethno-linguistic cleavages for vote choice in the Carinthian plebiscite. We find that more than half of the Slovenian voters opted to join Austria (the upper-right cell; $W_2 = 51.06\%$), and the 95% highest probability density region (HPD) ranges from 46.25% to 56.33%. Converted to raw counts, this implies that more than 13,000 Slovenian voters selected Austria. Likewise, previous accounts have severely and persistently overrepresented the share and number of ethnic Germans who were ready to join the German-Austrian rump state. Actually, only somewhat more than three quarters of them selected this option (the upper-left cell; $W_1 = 76.09\%$), while the other quarter chose to run with Yugoslavia. The 95% Bayesian HPD interval ranges from 64.81% up to 86.39%.

Self-reported linguistic group membership clearly impacts on vote choice in the referendum. Linguistic Germans are more likely to vote for Austria than linguistic Slovenians and vice versa. However, the gulf between both groups is not nearly as deep as previously claimed, and the German and Slovenian groups merely differ by some 25 percentage points. Effectively, the raw number of voters who supported Austria was higher in the Slovenian than in the German camp. Below the line, these findings do emphasize the key role of German and Slovenian group identities. Yet, in contrast to the prejudice by parochial and nationalist accounts ethnic identity was far from being a deterministic and mechanical predictor, and many other aspects probably co-determined vote choice in the referendum. Finally, as indicated before, the Austro-Hungarian census was designed to underrepresent linguistic minority groups. Our estimates are therefore biased downwardly and only apply as lower limits. Unfortunately, we only know the direction, but not the overall magnitude of this bias.

In the next step, we re-project the results from the common ecological inference model presented above towards the 51 electoral communities at hand, i.e., we derive in-sample predictions to substantiate or validate our results. Figure 5 presents some key information on each of these local entities. The grey bars show deterministic Duncan/ Davis bounds. As discussed before, these ranges are not statistical measures, they do not rely on any distributional assumptions, and the true values of $W_{i,1}$ and $W_{i,2}$ are, as long as we do not deal with measurement bias or error, guaranteed to fall within these ranges. The blue bars identify the 95% Bayesian highest probability density (HPD) of our non-parametric ecological inference model. These blue intervals thus cover 95% of the MCMC iterations after burn-in.

Finally, the white dots denote the posterior means, i.e., our best and most likely estimates for the share of German-speaking voters $W_{i,1}$ and Slovene-speaking voters $W_{i,2}$ that favor to joining the new Austrian republic.

Figure 5: Duncan/ Davis Bounds and In-Sample Predictions for 51 Local Communities in Referendum Zone I



Notes: In the left-hand panel, $W_{i,1}$ indicates the share of the German-speaking voters in each community i that cast a vote to join Austria, in the right-hand panel, $W_{i,2}$ indicates the share of the Slovene-speaking voters in each community i that cast a vote to join Austria. The labels identify local communities; in brackets we note the share of linguistic Germans. The grey bars indicate deterministic Duncan/ Davis bounds; the blue bars show the 95% Bayesian HPD intervals; the points denote the posterior means of the local $W_{i,1}$ or, respectively, $W_{i,2}$.

The grey Duncan/ Davis bounds and the blue Bayesian HPD intervals illustrate that both logical bounds and the results from our Bayesian non-parametric models become more precise for ethnic groups which are in an explicit majori-

ty position. In Figure 5 we have arranged the 51 communities in Zone I according to their share of German-speaking inhabitants with lower shares at the top and higher shares at the bottom. Some simple inspection of both subpanels reveals that we obtain more precise inferences on the share of German-speaking voters that support Austria $W_{i,1}$ within predominantly German communities, while we are in a better position to narrow down the intervals for $W_{i,2}$ in communities which are dominated by the Slovenian group (and vice versa).

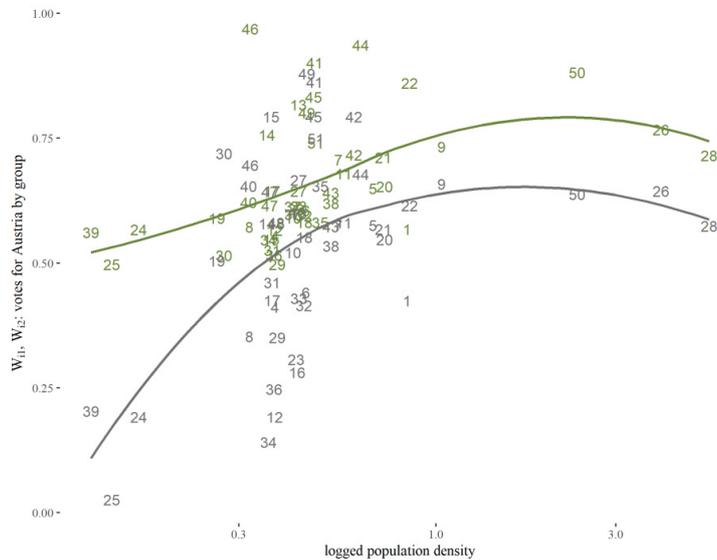
Below the line, we find that self-declared conversational languages, our proxy to distinguish “Germans” and “Slovenes,” certainly had an impact on vote choice in the Carinthian plebiscite: someone who indicates that they speak German is comparatively more likely to vote for Austria than someone who speaks Slovenian. But this impact is certainly not deterministic: more than half of those who were considered Slovenian speakers by the census cast a vote to join the German-Austrian Republic, and just a bit more than 75 percent of those who were reported as speaking German did so as well. These inferences substantially differ from guesses which are published in the literature: not merely 10,000 Slovenes supported Austria, but more than 13,000. Effectively, the roughly 22,000 voters that opted for Austria were composed of as many as 13,000 “Slovenes” (about 60%) and only 9,000 “Germans” (roughly 40%).

Provided that vote choice in the Carinthian plebiscite cannot sufficiently be explained by ethnic or linguistic group affiliations, we need to at least briefly hint at some alternative explanations. While the list of likely causes laid out above is long and complex, the empirical material at hand is limited and restrictive. To probe deeper into likely socioeconomic underpinnings of vote choice, we utilize data on the number of inhabitants per square kilometer to derive a simple indicator of local population density within each community i . The underlying rationale is that population density may be utilized as a gross indicator of economic structures as well. Low levels often indicate the presence of family farming, while higher densities often imply the emergence of craft producers or small industry.

Figure 6 explores the links of population density with the shares of German- and Slovene-speaking voters ($W_{i,1}$ and $W_{i,2}$, respectively). Note that the green values/ smoother indicate the electoral behavior of the German population segment, the grey provide similar evidence for the Slovenian segment. Generally, both $W_{i,1}$ and $W_{i,2}$ increase with population density so that, regardless of affiliation with one or the other group, an individual voter is more likely to cast a vote for Austria when she is living in and embedded to the social and economic contexts of some larger village or town.

This also implies that $W_{i,1}$ and $W_{i,2}$ are clearly correlated and supports our utilization of a non-parametric ecological inference model which is able to handle these issues.

Figure 6: Vote Choice and Population Density



Notes: The green points/ smoother denote the share of linguistic Germans ($W_{i,1}$), the grey the share of linguistic Slovenes voting for Austria ($W_{i,2}$).

That said, these gross findings summarized in Figure 6 provide some empirical backing for the socioeconomic arguments advanced by Moritsch (1981, 2002): In small villages that are characterized by the lowest levels of population density and mostly inhabited by farmers who indicate to speaking Slovenian, joining Austria is not a very popular choice. With increasing levels of population density we assume with Moritsch (1981) that economic structures gradually shift from mere subsistence towards market-oriented farming. In these cases, the share of eligible voters who cast a vote in favor of Austria increases either slowly ($W_{i,1}$; the green line indicating linguistic Germans) or even rapidly ($W_{i,2}$; the grey line indicating linguistic Slovenes). Ultimately, in the more densely populated towns which are supposedly dominated by craftsmanship and petty industry, this effect levels off and the share of votes for Austria often falls behind the share of the German-speaking population. One possible explanation would indeed be that market-oriented farmers gravitated towards the markets in Austria and the nearby capital Klagenfurt, while those who worked in smallscale industry often saw better chances in Yugoslavia. But to demonstrate this with some empirical validity, further research needs to be done that advances the agenda by Moritsch (1981) and systematically explores localized social structure and the geographic organization of economic exchange processes.

Previous accounts are biased by a deterministic fixation on the ethno-linguistic conflict dimension and result in the bizarre notion that all “Germans” want to vote for Austria, unless tricked or threatened by the Yugoslavian civil or military administration or the church (cf. Fräss-Ehrfeld 2010; Wutte 1922, 1943). The “other” side believes that all “Slovenes” must naturally support Yugoslavia, unless misled by social democrats (cf. Pleterski 1970, 2002; Pleterski and Druškoví 1983). Instead, any meaningful perspective implies to adopting an unprejudiced, multidimensional perspective. While we cannot hope to evaluate the full catalogue of potential explanations for this historical case, the ecological inference models clearly point to the significance of unmodelled variables. Further research needs to be done to pursue and empirically review the economic and party-political arguments at hand.

8. Implications and Perspectives

Historical social science can provide meaningful insights into historical events. The initial starting point of this paper was to evaluate and, if necessary, correct analyses of the 1920 Carinthian plebiscite which put a dominant, if not exclusive emphasis on ethnic and/ or linguistic dimension of electoral choice. By applying a Bayesian, non-parametric ecological inference model, we show that the nationalist lens adopted by Carinthian (and also some Yugoslavian/ Slovenian) authors yields distorted perspectives on the electoral returns and their likely causal determinants.

The “Carinthian” literature has not cared much about the motives of electoral choice and mainly copied guesses initially published by the German-nationalist ideologue Wutte (1922, 1943). However, our analysis reveals that not 10,000 Slovenian citizens, but rather 13,000 selected to join the new Austrian republic. More than half of the linguistic Slovenes thus supported the choice for Austria, and this segment provided almost 60 percent of the overall votes cast in favor of Austria. Vice versa, support among the ethnic Germans was nowhere, as previously insinuated, close to 100 percent, but rather at 75 percent. And this also implies that the referendum was the focal point of a bitter struggle among nationalist electorates, but instead defined by much simpler, more careful, and more pragmatic considerations of civil liberties, political rights, and economic well-being.

So far, we have demonstrated the limits of the ethnic argument. Further research will be necessary to not merely refute canonized and bitterly defended prejudice, but to review alternative explanations in an empirical-systematic research program. Unfortunately, ethnic, socioeconomic, religious, and event-based accounts often tend to be collinear: these predictors regularly overlap and, given the rather comparatively low number of observations, i.e., electoral communities, cannot always be systematically confined.

A feasible way forward could be provided by the more systematic analysis of community-level electoral returns which may help to shed some additional light on localized political preferences. The political consequences of the socialdemocratic endorsement for Austria are, especially for Slovenian historiography, a pivotal issue and should be submitted to more and more systematic research efforts. But there are also a number of roadblocks ahead. Conceptually, local, state, and nation-wide elections in Carinthia have frequently been neglected and characterized by low turnout and high levels of electoral volatility, are organized by majoritarian electoral systems and heavily personalized. Empirically, documentation of these electoral contests is often incomplete. Therefore, further steps ahead will certainly require fine-grained documentary effort.

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Appendix

Find the replication files here: Guido Tiemann (2020): "Kärnten" = Austria, "Koroška" = Yugoslavia? A Novel Perspective on the 1920 Carinthian Plebiscite. GESIS Data Archive, Cologne. doi: [10.7802/2109](https://doi.org/10.7802/2109).

A. Key Data of the Carinthian Plebiscite

Table 3 summarizes the key data at hand. The results of the referendum are taken from Wutte (1922, 194-5) and Wutte (1943, 471-2). An identical tabular summary has been copied by Wadl (2019, 178-9). The dataset reports the number of enfranchised citizens, the absolute and relative frequencies of votes cast for Austria and for Yugoslavia. We have recalculated the vote shares based on the raw count of voters supporting either option and thereby corrected some minor mis-

calculations and rounding errors. We have also computed some simple consistency checks and detected implausible data for the electoral communities of Drau/ Drava and Lavamünd/ Labot. For both units, the sum of votes for Austria and Yugoslavia that has been noted by the sources cited above exceeds the number of eligible voters by four (or, respectively, by eight when we also consider that in either district four additional votes were noted as missing or invalid).

Within the Rosegg/ Rôcek district (A), Drau/ Drava (2) and Latschach/ Loče (3) did not fully match the respective administrative communities, because the borders of Zone I cut through their territories. The Latschach/ Loče community also included the Eastern part of Finkenstein/ Bekštanj. Within the Bleiburg/ Pliberk district (C), the electoral community Lavamünd/ Labot (44) comprised of parts of Kienberg/ Ojstrica, Lavamünd/ Labot, and Legerbuch.

Moreover, we have also verified the figures on ethno-linguistic composition of the electoral communities as assessed by the Austro-Hungarian census of 1910. Wutte (1922, 194-5) merely reports relative frequencies for both linguistic groups, the second edition (Wutte 1943) and the more recent publication by Wadl (2019) adopt these numbers and, thus, their errors and limitations. We draw upon the official census data at the community level which have been compiled in the "Spezialortsrepertorium von Kärnten" (Zentralkommission 1918). These detailed holdings provide the number of local citizens and the size of the ethno-linguistic groups within these communities. In addition, the data include basic demographics such as the number of local citizens and the territorial magnitude of the community in sq. kilometers which enable us to distinguish rural areas from small towns in Zone I. There is also some information on the share of religious denominations, the proximity to the public railway network, and the shares of male and female inhabitants.

Table 3: Community-Level Data on Ethno-Linguistic Composition and Vote Choice in the 1920 Cainthian Plebiscite

No.	Dist.	Community		Pop. dens.	Demographics				pev	vat	Wutte (1922, 1943)		
		Name (Ger.)	Name (Slov.)		g_g	g_s	g_g (%)	g_s (%)			vshs	v _{at} (%)	v _{shs} (%)
1	A	Augsdorf	Loga vas	0.84	85	1221	5.40	94.60	651	262	344	43.23	56.77
2	A	Drau	Drava				50.60	49.40	3891	252	141	64.12	35.88
3	A	Latschach	Loče				36.60	63.40	663	228	410	35.74	64.26
4	A	Ledenitzen	Ledince	0.37	37	1132	3.20	96.80	591	233	327	41.61	58.39
5	A	Rosegg	Roček	0.68	173	433	28.50	71.50	321	189	128	59.62	40.38
6	A	St. Jacob	Šentjakob	0.45	360	3176	10.20	89.80	1893	816	968	45.74	54.26
7	B	Ebental	Žrelec	0.55	635	654	74.50	25.50	245	165	80	67.35	32.65
8	B	Feistritz i.R.	Bistrica v Rožu	0.32	715	893	44.50	55.50	947	410	500	45.05	54.95
9	B	Ferlach	Borovlje	1.03	2825	322	89.80	10.20	1708	1235	468	72.52	27.48
10	B	Keutschach	Hodiše	0.42	85	1081	7.40	92.60	598	304	274	52.60	47.40
11	B	Köttmannsdorf	Kotmara vas	0.57	614	828	42.60	57.40	794	449	272	62.27	37.73
12	B	Ludmannsdorf	Bilčovs	0.37	30	725	3.90	96.10	438	86	331	20.62	79.38
13	B	Maria Rain	Žihpolje	0.43	732	317	69.80	30.20	607	428	142	75.09	24.91
14	B	Maria Wörth	Otok	0.36	366	264	57.70	42.30	375	248	116	68.13	31.87
15	B	Mieger	Medgorje	0.36	37	932	3.80	96.20	522	383	106	78.32	21.68

16	B	Oberdörfel	Zgornja Vesca	0.43	35	349	9.60	90.40	214	63	139	31.19	68.81
17	B	Radsberg	Radiše	0.37	213	498	29.90	70.10	383	181	188	49.05	50.95
18	B	Schiefling	Škofiče	0.45	73	1198	5.70	94.30	664	354	286	55.31	44.69
19	B	St. Margareten	Šmarjeta	0.26	87	1065	7.50	92.50	607	291	279	51.05	48.95
20	B	Unterferlach	Medborovnica	0.73	375	721	34.20	65.80	558	315	225	58.33	41.67
21	B	Unterloibl	Podljubelj	0.72	785	789	49.80	50.20	916	558	315	63.92	36.08
22	B	Viktring	Vetrinj	0.85	1294	237	84.50	15.50	910	703	152	82.22	17.78
23	B	Weizelsdorf	Svetna vas	0.43	101	794	11.30	88.70	516	166	321	34.09	65.91
24	B	Wind. Bleiberg	Slovenji Plajberk	0.16	27	749	3.50	96.50	375	71	276	20.46	79.54
25	B	Zell	Sele	0.14	13	1014	1.30	98.70	566	17	511	3.22	96.78
26	C	Bleiburg	Pliberk	3.95	927	124	88.20	11.80	562	414	136	75.27	24.73
27	C	Eberndorf	Dobrla vas	0.43	599	2196	21.40	78.60	1625	985	505	66.11	33.89
28	C	Eisenkappel	Železna Kapla	5.30	847	303	73.60	26.40	612	381	181	67.79	32.21
29	C	Feistritz	Bistrica pri Pliberku	0.38	18	1841	0.90	99.10	1070	355	653	35.22	64.78
30	C	Gallizien	Galicija	0.27	21	1029	2.00	98.00	559	391	156	71.48	28.52
31	C	Globasnitz	Globasnica	0.37	21	1264	1.60	98.40	708	314	366	46.18	53.82
32	C	Leifling	Libeliče	0.45	160	1783	7.50	92.50	704	290	387	42.84	57.16
33	C	Loibach	Libuče	0.43	153	1607	11.90	88.10	681	286	348	45.11	54.89
34	C	Moos	Blato	0.36	32	1451	2.20	97.80	807	115	650	15.03	84.97

35	C	Rückersdorf	Rikarja vas	0.49	98	1687	5.50	94.50	997	607	327	64.99	35.01
36	C	Schwabegg	Žvabek	0.37	5	440	1.10	98.90	260	61	183	25.00	75.00
37	C	Sittersdorf	Žitara vas	0.42	170	1360	11.10	88.90	796	474	317	59.92	40.08
38	C	St. Kanzian	Škocjan	0.53	166	1019	14.00	86.00	701	358	298	54.57	45.43
39	C	Vellach	Bela	0.12	85	2676	3.20	96.80	1507	281	1029	21.45	78.55
40	D	Diex	Djekše	0.32	197	1404	12.30	87.70	904	507	273	65.00	35.00
41	D	Grafenstein	Grabštanj	0.48	922	918	50.10	49.90	968	832	112	88.14	11.86
42	D	Griffen	Grebij	0.61	841	2344	26.80	73.20	1786	1290	380	77.25	22.75
43	D	Haimburg	Vovbre	0.53	344	1158	22.90	77.10	795	443	310	58.83	41.17
44	D	Lavamünd	Labot	0.63	1476	63	96.90	3.10	7681	717	55	92.88	7.12
45	D	Poggersdorf	Pokrče	0.47	600	859	45.40	54.60	726	574	134	81.07	18.93
46	D	Pustritz	Pustritz	0.32	1122	3	99.70	0.30	674	634	21	96.79	3.21
47	D	Ruden	Ruda	0.36	204	1330	13.30	86.70	823	505	285	63.92	36.08
48	D	St. Peter	Šentpeter	0.38	63	1063	5.60	94.40	627	347	251	58.03	41.97
49	D	Tainach	Tinje	0.45	147	449	24.70	75.30	324	269	44	85.94	14.06
50	D	Völkermarkt	Velikovec	2.37	2079	518	80.60	19.40	1424	1154	229	83.44	16.56
51	D	Waisenberg	Važenberk	0.48	1003	1861	35.00	65.00	1423	1026	349	74.62	25.38

Notes: Key columns of our dataset adopted from Zentralkommission 1918; Wutte 1922, 1943. Note that the data prepared by Wutte suffers from some inconsistencies. Notably, in the newly established electoral districts of Drau/ Drava and Lavamünd/ Labot (1) the number of votes for Austria, Yugoslavia, and the invalid votes/ abstentions exceed (!) the number of persons entitled to vote.

We provide a brief definition and overview of the variables listed in Table 3:

Table 4: Variables, Definitions, and Sources for the Community-Level Data in Table 3

Variable	Description
No.	Running no. to identify and label community;
Dist.	Regional districts of Rosegg/ Rožek (A.), Ferlach/ Borovlje (B.), Bleiburg/ Pliberk (C.), and Völkermarkt/ Velikovec (D.);
Name (Ger.)	Name of administrative community (German);
Name (Slov.)	Name of administrative community (Slovenian);
Pop. dens.	Population density; inhabitants/ km^2 ; Zentralkommission 1918;
g_g	Number of linguistic Germans; Zentralkommission 1918;
g_s	Number of linguistic Slovenes; Zentralkommission 1918;
g_g (%)	Share of linguistic Germans; corrected numbers from Wutte, 1943;
g_s (%)	Share of linguistic Slovenes; corrected numbers from Wutte, 1943;
pev	Number of persons entitled to vote; Wutte, 1943;
v_{at}	Absolute number of votes for Austria; Wutte, 1943;
v_{shs}	Absolute number of votes for Yugoslavia; Wutte, 1943;
v_{at} (%)	Vote share for Austria; Wutte, 1943;
v_{shs} (%)	Vote share for Yugoslavia; Wutte, 1943.

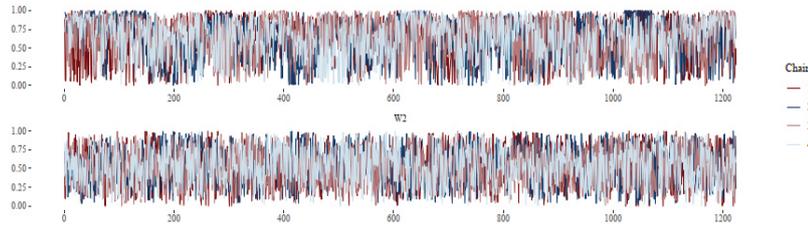
This appendix provides some graphical and numerical tests for the convergence and the mixing of the diverse chains specified in the MCMC estimation/ simulation routines. Focussing on the non-parametric models which have been laid out and explained above, we cannot evaluate any model parameters, but instead focus upon chains of out-of-sample predictions for our key quantities W_1 and W_2 .

Figure 7 displays trace plots, i.e., time series of posteriors produced by non-parametric Gibbs samplers/ the MCMC process for each of the two key quantities W_1 and W_2 . Note that the displayed chains are based on four chains, each with $N = 500,000$ iterations of a non-parametric ecological inference model and an initial burn-in of $N = 250,000$ iterations. So as to address potential autocorrelation or non-linearities, we apply a thinning interval, record and evaluate only every 200th run of the MCMC process. Some brief inspection of Figure 7 immediately reveals that each of the four chains (identified by different colors) appears to be stationary for both W_1 and W_2 , and, in addition, mixing/ overlap of chains with different sets of initial values is quick and substantial.

In addition to these visual diagnostics, we have also computed an array of numerical tests which probe stationarity and mixing. Table 5 compiles a summary of these alternative test statistics. We first address stationarity of the four chains by the Geweke convergence diagnostics. This implies a simple t-test for the equality of means in the first (by default 10%) and last parts (by default 50%) of each chain. The Geweke test returns a z-score which should be strictly below 1 for any chain, and the values in the first two columns of Table 5 indeed confirm the convergence of the MCMC processes for both the predictions of W_1 and W_2 . The complementary Heidelberger-Welsch diagnostics tests the null hypothesis that the sampled values are taken from a stationary distribution; it is

initially applied to the whole chain and then to the first 10%, 20%, etc. until either the null hypothesis is accepted (“success”) or more than 50 % of the chain are discarded (“failure”).

Figure 7: Trace Plot of W_1 and W_2



Notes: Graphical MCMC diagnostics, trace plots, for a Bayesian non-parametric ecological inference model, simulated with the eco package (Imai, Lu, and Strauss 2011; Lu 2017). We specify four chains, each with an initial burn-in of $N = 250,000$ iterations, but different starting values; we save $N = 250,000$ iterations per chain for further analysis and apply a thinning interval of 200.

Table 5: MCMC Diagnostics, Geweke, Heidelberg-Welsch, and Gelman Tests

	Geweke Test		H-W Test		Gelman Test	
	W_1	W_2	W_1	W_2	W_1	W_2
Chain 1	-0.36	0.54	0.58	0.46	1.00	1.00
Chain 2	0.40	-1.50	0.33	0.14	1.00	1.00
Chain 3	0.31	0.64	0.36	0.66	1.00	1.00
Chain 4	-0.65	0.11	0.46	0.87	1.00	1.00

Notes: MCMC diagnostics for a Bayesian non-parametric ecological inference model, simulated with the “eco” package (Imai, Lu, and Strauss 2011; Lu 2017). For the Geweke test, we show z-scores, for the Heidelberger-Welsch diagnostics, we display 95% error intervals, for the Gelman test, we report the Gelman-Rubin statistic R_c (cf. Gelman and Rubin 1992).

In the subsequent step, we advance from analyses within each of the four chains to formal tests that evaluate the overlap across these chains. The two rightmost columns of Table 5 display the upper limits of the Gelman-Rubin diagnostic and assesses the average within-chains and between chains variance with large differences indicating non-convergence. Both for W_1 and W_2 , the values of the Gelman-Rubin test statistic R_c are effectively one and below the upper limit of the computed confidence interval $R_u[W_1] = 1$ and $R_u[W_2] = 1.01$, respectively. We can thus conclude that the four chains have properly converged and mixed.

Ultimately, the test statistics in Table 6 address autocorrelation issues. By definition, each MCMC process is affected by autocorrelation, but excessive levels of and persistent trends in ρ indicate slow mixing. The parameters ρ clearly confirm that, after burn-in, the simulation processes for both W_1 and W_2 are stationary series.

Table 6: MCMC Diagnostics, Autocorrelation Tests

	Autocorrelation Test	
	$\rho[W_1]$	$\rho[W_2]$
Lag 0	1.0000000	1.0000000
Lag 10,000	0.17733235	0.01044720
Lag 50,000	0.18319582	0.03287475
Lag 100,000	0.15991755	0.02285381
Lag 500,000	-0.01507015	-0.02054920

Notes: The test statistics characterize the autocorrelation coefficients ρ of W_1 and W_2 and the respective auto-correlation functions.

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