Commentary and Debate

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NO DIFFERENTIAL EFFECTS OF CLASSROOM ETHNIC COMPOSITION ON NATIVE AND IMMIGRANT FRIENDSHIP SEGREGATION: COMMENT ON SMITH ET AL., 2016[1]

INTRODUCTION

Increasing ethnic diversity across Western countries has raised critical questions about how societies can overcome social segregation, or the tendency for ethnic groups to stick to themselves in their social relations. Segregation has been argued to breed negative attitudes toward ethnic outgroups (e.g., Allport 1954), while simultaneously perpetuating native-immigrant inequalities in education and employment (e.g., Massey and Denton 1993; Quillian 2014; Leszczensky and Stark 2019). Such concerns have engendered a search for policies and institutions to counteract segregation, with schools and classrooms as the frequent focus of these efforts. One central question in this literature asks, How does the ethnic composition of a class shape the formation of social relations within and across ethnic lines?

[1] This work is the result of the authors' collaboration in the Systematizing Confidence in Open Research and Evidence (SCORE) project, a large-scale replication project in the social sciences. The results presented in this comment do not include the hypothesis selected by SCORE for reanalysis and represent an independent extension of our work. We would like to thank Sanne Smith for sharing the code of the original analysis with the SCORE project and for constructively engaging with us in this replication. Direct correspondence to David Kretschmer, Universität Mannheim, Mannheimer Zentrum für Europäische Sozialforschung (MZES), A5, 6, 1 68159 Mannheim, Germany. Email: dkretsch@mail.uni-mannheim.de

 https://doi.org/10.1086/727823

In "Ethnic Composition and Friendship Segregation: Differential Effects for Adolescent Natives and Immigrants" (Smith et al. 2016), Sanne Smith, Daniel McFarland, Frank van Tubergen, and Ineke Maas (henceforth SMTM) report results from a detailed study that addresses this question. Using data on friendship networks in secondary school classes from the Children of Immigrants Longitudinal Survey in Four European Countries (CILS4EU) project (Kalter et al. 2014; Kalter, Kogan, and Dollmann 2019), SMTM examine how the ethnic composition of school classes relates to ethnic homophily—that is, the preference for same- relative to cross-ethnic friends—among native and immigrant adolescents.

The article's key finding is that processes of friendship formation appear to operate differently for natives and immigrants. Among natives, ethnic homophily is high when classroom diversity is high and when the proportion of natives in the classroom is low. SMTM argue that this finding could be explained by classical theories of ethnic threat and competition, which suggest that native students will increasingly withdraw to the ingroup as diversity increases feelings of threat. Among immigrants, by contrast, friendship homophily appears to peak at a medium proportion of natives in the class and at medium diversity, but is lower when diversity and the proportion of natives is either high or low, thereby demonstrating a curvilinear relationship. SMTM conclude that, for immigrants, opportunity-based rather than threat-based mechanisms seem to be at work because the pool of suitable friends from the ethnic ingroup is likely to be largest in moderately diverse classes. The article also includes supplementary analyses that provide corroborating evidence for these differential mechanisms among natives and immigrants.

SMTM's analysis proceeds in two steps. First, exponential random graph models (ERGMs) are employed to estimate ethnic homophily in a large number of adolescent friendship networks. In a second step, meta-analytical techniques are applied to assess the association between these network-level estimates of homophily and indicators of ethnic classroom composition.

In this comment, we show that SMTM's findings on differential effects among native and immigrant students are driven by an error in the ERGM estimation process. ERGMs are simulation-based network models; ensuring the successful execution and convergence of the estimation algorithm is essential to obtaining reliable estimates. Although SMTM devote some effort to model assessment and convergence checks, they nonetheless miss estimation problems in a substantial number of networks that are particularly consequential for estimates of immigrant homophily. In fact, as we demonstrate below, these problematic estimates end up dominating SMTM's meta-analytical results.

When replicating the analyses after accounting for these estimation problems, we reproduce qualitatively similar results as SMTM for native homophily but find no evidence for a curvilinear relationship between classroom diversity and ethnic homophily among immigrants. Instead, immigrant homophily is increasing in the proportion of natives in the classroom, while showing no conclusive relationship to classroom ethnic diversity. Our reanalysis of SMTM's corroborating evidence also points toward parallel patterns of friendship formation for natives and immigrants. Therefore, our findings substantively challenge the notion of differential mechanisms of segregation among natives and immigrants. Applying the theoretical frameworks introduced by SMTM, our results would instead suggest that the friendship choices of both groups are consistent with predictions from threat- and competition-based approaches.

ERG MODELING, ESTIMATION, AND CONVERGENCE

Exponential random graph models (ERGMs; Hunter et al. 2008; Lusher, Koskinen, and Robins 2013) are a well-established approach to modeling structure in cross-sectional networks as well as a standard tool for assessing patterns of segregation and homophily. To estimate model parameters that adequately represent the structure of an empirically observed network, the ERGM algorithm uses simulation techniques based on Markov chain Monte Carlo (MCMC) methods. As is usual in such methods, the obtained ERGM coefficients can be reliably interpreted only after plausibility checks on the resulting model and convergence checks on the Markov chains have been conducted. Depending on the exact statistical software and the method at hand, however, results from models that do not fulfill such plausibility criteria or convergence checks may still yield parameter estimates that appear plausible at face value. However, as these estimates do not adequately represent the characteristics of the underlying networks, they cannot be interpreted in substantive terms.

Problems with model estimation and convergence are particularly likely to arise in data such as those used by SMTM. In the CILS4EU data, network information on adolescent students is collected at the classroom level, and the corresponding friendship networks are small in size, frequently consisting of only 15–25 students. Therefore, the data necessarily provide only limited information for the estimation of complicated network models. This holds true particularly for the estimation of parameters such as immigrant homophily, which rely crucially on specific subsets of the data (in this case, dyads of immigrant students from the *same country of origin*). Given the low number of immigrant students in many classrooms, and the even lower number of coethnics, immigrant homophily coefficients are prime candidates for estimation and convergence problems. Recognizing these issues, SMTM already take several precautions to mitigate problems in the estimation process. For example, they restrict their attention to classes with a minimum number of native, immigrant, male, and female students.[2] In addition, SMTM utilize a measure of *model degeneracy* (described in detail in the article's appendix; pp. 1258–69) to check whether the estimation of any given ERGM has diverged before including it in the metaregression. Furthermore, SMTM exclude networks from the meta-analysis when parameter estimates of homophily or the corresponding standard errors are implausibly high (taking on absolute values >5 in their main specification).

While these precautions already exclude a large number of networks for which ERGM estimation is likely to be problematic, they do not take into account other scenarios in which models may yield nonmeaningful estimates. In fact, our reanalysis uncovers estimation problems—particularly concerning immigrant homophily coefficients—in many networks that are not captured by SMTM's exclusion criteria. Most importantly, there are a substantial number of networks for which immigrant homophily coefficients cannot be estimated *at all* from the data. This occurs in all networks that include only one immigrant student from each represented ethnic group. In such cases, there are no dyads of same-ethnic immigrants who can or cannot be friends such that immigrant homophily cannot be estimated from the data. SMTM's exclusion criteria do not (necessarily) capture these networks, as they only consider whether a network contains a minimum number of immigrant students, not whether these students originate from the same ethnic group. For these networks, it should therefore be impossible to estimate an immigrant homophily coefficient.

Corresponding estimation problems can be circumvented by excluding these networks from the analysis prior to estimation. However, with standard ERGM implementations, it is also possible to first estimate models for these networks (including the nonestimable immigrant homophily coefficient) and then identify nonestimable coefficients with convergence diagnostics after estimation. Here, trace and density plots are suitable to detect characteristic patterns for nonestimable coefficients and to assess convergence more generally. We illustrate this with the density and trace plots in figure 1, which also displays the observed empirical networks that these plots are based on (different shades of gray and different shapes indicate different ethnic groups, with natives indicated with black circles; friendship ties are indicated by arrows). The trace plots (middle row) show the behavior of simulated values from the Markov chain across a part of the estimation process, and the density plots (bottom row) show the distribution of

[2] For details, see Smith et al. 2016, p. 1237, n. 10. The article states that at least two students of each group have to be present for a network to be considered; however, checking SMTM's code shows that only networks with at least *three* members of each group are included. From this point forward, page numbers refer to Smith et al. (2016), the article under discussion, unless otherwise indicated.

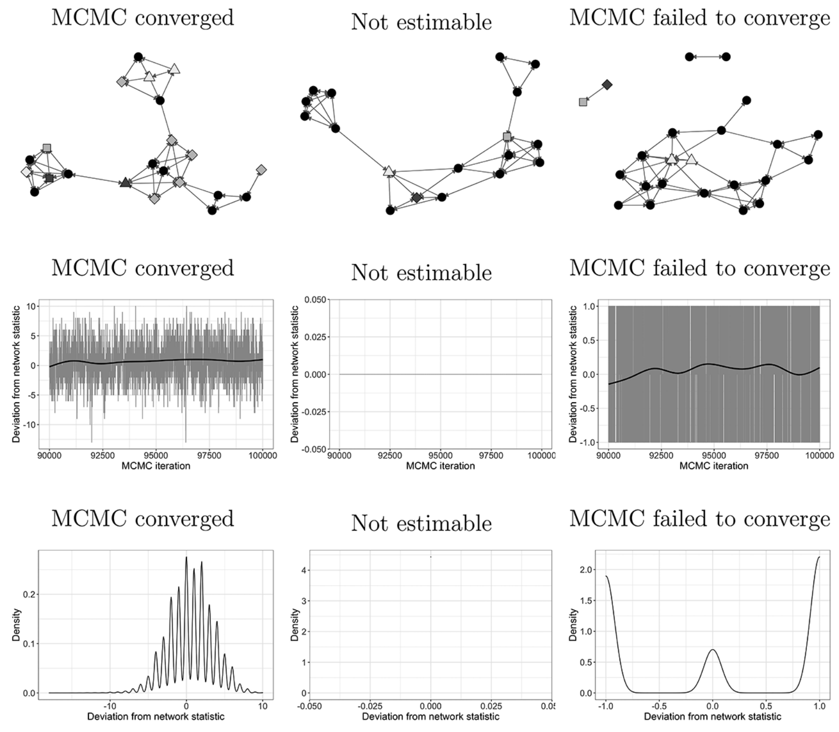


FIG. 1.—Empirical networks (top), trace plots (middle) and density plots (bottom) for converged, nonestimable, and nonconverged MCMC sequences estimating immigrant homophily coefficients in three different classrooms. Different shades of gray and different shapes indicate different ethnic origins, with natives indicated by black circles.

simulated values across the Markov chain.[3] The plots in the left column of figure 1 present results for a well-converging immigrant homophily coefficient: the trace plot shows that the Markov chain varies randomly around a mean value close to zero with little auto-correlation, thus "mixing well." The density plot, in turn, approximates a normal distribution around the mean value.[4]

By contrast, the graphs in the center column display the case of a nonestimable immigrant homophily coefficient. They are thus representative

[3] To be precise, for each iteration step, the Markov chain displays the difference between a simulated network statistic (e.g., the number of same-ethnic friendship ties among immigrants for the estimation of immigrant homophily) and the network statistic observed in the empirical network. On average, the deviation between the value simulated on the basis of the model and the empirically observed value should be close to zero, and the deviations should be symmetrically and approximately normally distributed.

[4] The sawtooth pattern reflects that the simulated network statistic—i.e., the number of same-ethnic friendship ties among immigrants—can only take on integer values.

of the classrooms that cannot provide information on immigrant homophily and therefore should not be included in an analysis of immigrant homophily. Note that, as shown in the top row's center panel, the underlying network contains three immigrant students but no pair of immigrant students among these three are from the same country of origin. In this case, the corresponding MCMC chain in the estimation process is "stuck" at a fixed value of zero, which is the only number of same-ethnic friendships that can be predicted in the absence of multiple immigrants from the same ethnic group. Therefore, the chain is represented by a horizontal line in the trace plot, and the density plot collapses to a point distribution at value zero.

When parameters that cannot be estimated from the data are included in an ERGM, standard implementations of the algorithm in R still report a coefficient for the corresponding parameter. For example, the version we use in the analysis reported (ver. 3.10-4 of the ergm package; see Handcock et al. 2022) reports a fixed value of zero, while some older versions (such as ver. 3.1-0 used by SMTM) report a fixed value of one.[5] This changes however, when more complicated constraints are introduced into the ERGM framework. In the SMTM analysis, for example, a constraint is introduced on the number of friendships students can form because students could nominate at most five best friends in the CILS4EU sociometric questionnaire.[6] Under these conditions, the coefficients produced for parameters that cannot be estimated from the data are no longer limited to a fixed value but vary across networks and are therefore harder to identify from the model output.

Fortunately, the software implementation we use (ver. 3.10-4 of the ergm package) always returns missing standard errors for these nonestimable coefficients such that problematic networks can still be detected via these missing values (or from the trace and density plots shown above). However, SMTM used a version of the ergm package that reports standard error values of approximately zero (usually on the order of 10^{-30}) alongside arbitrary coefficient estimates for nonestimable parameters. Importantly, because SMTM do not identify these problematic networks from these infinitesimal standard errors or trace and density plots, the corresponding (substantively meaningless) homophily coefficients are included in their metaregression. Furthermore,

[5] While this comment was under review, the ergm package received major updates (ver. 4.0 and subsequent versions; Krivitzky et al. 2022). We still report results from ver. 3.10-4 here because using newer versions of the ergm package requires us to more strongly deviate from the SMTM analysis. Still, all our findings also replicate when using comparable analyses based on newer ergm versions (ver. 4.3-1).

[6] Formally, SMTM represent this limit with a constraint to the outdegree of 5 in the specification of the ERGM algorithm.

because the meta-analysis weighs each coefficient by the inverse of its standard error, these coefficients end up dominating SMTM's meta-analytic results.

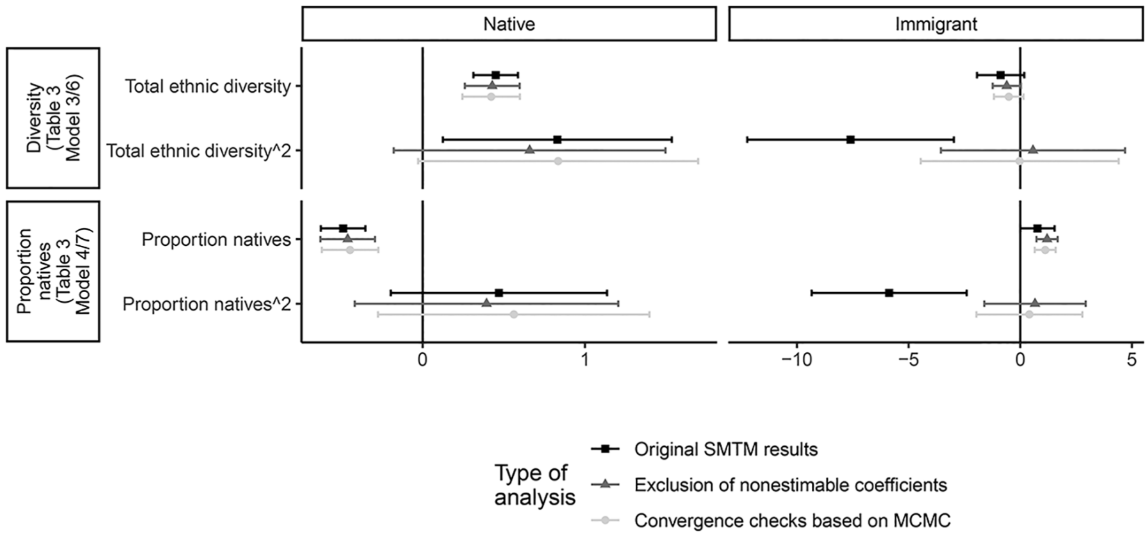
Beyond this fundamental issue of nonestimability, *nonconvergence* of the estimation process can additionally produce unreliable model coefficients. Nonconvergence can take on many different forms, most of which can be diagnosed through trace and density plots as those shown in figure 1. The right column of figure 1 illustrates one type of convergence problem concerning the immigrant homophily coefficient. The underlying network includes two immigrants from the same ethnic group with one unreciprocated tie between them. In an attempt to, on average, produce this number of immigrant same-ethnic ties observed in the network, the estimation algorithm constantly bounces back and forth between either zero or two ties, as seen from the bimodal density plot at the lower right. The low density in the middle of the graph indicates that simulated networks matching the observed network are very rare. Therefore, the ERGM estimation process fails to model the actual structure of the underlying network. These and related convergence problems are particularly likely in networks with a very low number of immigrant students from the same ethnic group.

REPLICATION OF META-ANALYSES

We now illustrate how accounting for estimation and convergence problems affects SMTM's meta-analytic main results. Throughout, we present three sets of results: (i) the original results from SMTM, (ii) results where we exclude nonestimable coefficients, and (iii) results where we additionally exclude coefficients due to convergence problems identified from trace and density plots. We otherwise try and stay as close as possible to SMTM's original study in terms of methodology. In our online appendix, we discuss our methodological choices in detail and demonstrate that differences between our replication and the original analysis indeed originate from the estimation and convergence issues outlined above.

Main results.—SMTM's main evidence for differential effects of classroom composition on native and immigrant homophily assesses how homophily varies with *total ethnic diversity* and the *proportion natives* in the classroom, as well as their squared terms to capture potential nonlinearities. (Models 3 and 4 in table 3 [p. 1247] report results for native homophily, while models 6 and 7 report results for immigrant homophily).[7] Our figure 2 reproduces SMTM's metaregression results and compares those to

[7] The additional covariates in the model include classroom socioeconomic status, class size, and survey country.



Note: Model specification identical to SMTM Table 3, Model 3/6 and 4/7. Full results in Online Appendix, Table A1−A4.

FIG. 2.—Original and reanalysis results for the association between ethnic homophily and total ethnic diversity/proportion natives. Model specification is identical to SMTM table 3, models 3 and 6 and models 4 and 7. Full results are available in the online appendix, tables A1−A4.

our reanalysis.[8] For readability, we limit the graph to the coefficients for indicators of ethnic classroom composition, while full model results are provided in the online appendix.

For natives, our analyses are in line with the original findings: higher ethnic diversity and a lower proportion of natives in the classroom relate to higher ethnic homophily among natives. We do not find a significant quadratic effect for ethnic diversity in our reanalysis, but our point estimates are comparable to the original results and the differences in statistical significance may also be a consequence of the lower number of networks included in our models. Our results are substantively similar regardless of whether we drop nonestimable coefficients only or also exclude networks based on additional convergence checks.

Turning next to immigrant homophily, our findings here differ from SMTM's results. While SMTM find a curvilinear relationship between immigrant homophily and both *total ethnic diversity* and the *proportion natives*, we can reproduce neither of these patterns. While we find a negative point estimate for the linear effect of *total ethnic diversity*, indicating lower immigrant homophily in more diverse classrooms, this association fails to reach standard levels of statistical significance. By contrast, we do find a significant linear relationship of immigrant homophily to *proportion natives*, wherein immigrant homophily increases with the share of native students. Importantly however, quadratic effects are negligible in size and far from statistically significant for both indicators of classroom ethnic composition. Model comparisons between a linear and quadratic specification with both the Akaike and Bayesian information criteria prefer the linear over the quadratic specifications for both variables. We also note that our results are very similar regardless of whether we drop nonestimable coefficients alone or exclude additional networks where we detect convergence issues.

In summary, our reanalysis of SMTM's main models yields substantively similar patterns with respect to native homophily. However, our results do not support a curvilinear relationship between classroom composition and immigrant homophily. Instead, our findings suggest that the curvilinear relation between composition and immigrant homophily reported by SMTM is an artifact of including—and heavily weighting in the meta-analysis—homophily coefficients that cannot be adequately estimated from the network data.[9]

[8] We derive 95% confidence intervals for the SMTM analysis from information on point estimates and standard errors reported in their article, using quantiles of the normal distribution.

[9] We note that a curvilinear relationship for immigrant adolescents is also suggested by figs. 3 and 5 (pp. 1245–46), which provide a descriptive analysis of the relation between homophily and *total ethnic diversity* and *proportion natives*. In our online appendix, we produce corrected graphs showing the linear relationships described here.

Beyond these main analyses, SMTM also present additional models that attempt to provide corroborating evidence for differential threat- and opportunity-based mechanisms underlying patterns of friendship formation for native and immigrant adolescents, respectively. We also reevaluate these models here.

Same-ethnic friendship density.—First, SMTM consider the contribution of same-ethnic friendship density to homophily (p. 1247, table 3, models 5 and 8), arguing that natives should display greater homophily particularly when confronted with dense immigrant networks because they "should feel especially threatened when immigrants form a unified group" (p. 1233). *Immigrant same-ethnic density* is measured as the proportion of immigrants' *realized* same-ethnic friendships among all *possible* same-ethnic friendships. A conceptual issue here relates to the definition of immigrant same-ethnic friendship density when a given classroom does not contain multiple immigrants from the same origin country. In our reanalysis in figure 3 below, we report results for two different ways to account for this problem, either by excluding the corresponding networks from the analysis (thereby treating immigrant same-ethnic density as undefined) or by setting the value of same-ethnic friendship density to zero (as by definition there can be no such friendships).[10]

In their original analysis, SMTM find a large and significant positive effect of immigrant same-ethnic density on native homophily. We cannot replicate this finding in our reanalysis. Instead, we find a much smaller coefficient for *immigrant same-ethnic density* which, although still positive, is far from reaching conventional levels of statistical significance.

For immigrants, SMTM did not find a corresponding effect of *native same-ethnic density*. Our reanalysis reproduces this result, as shown in the right panel of figure 3.

Combined effects of proportion natives and immigrant diversity.—In a final portion of their analysis, SMTM consider the effects of *proportion natives* and *immigrant diversity* simultaneously in a combined metaregression model (table 4, models 1 and 3; p. 1252). The diversity index in these models excludes natives (who are accounted for via the *proportion natives* indicator) and is instead calculated with respect to immigrant students only. Substantively, higher scores on *immigrant diversity* (conditional on the proportion of natives) indicate classrooms with small dispersed minorities, while lower scores denote classes in which one minority group tends to predominate.

[10] Our online appendix discusses these different operationalizations in more detail. Note that the choice of operationalization was not an issue for SMTM because they inadvertently included (some) *self-ties* when calculating the number of possible and realized friendship ties. Because self-ties are by definition ties to the same ethnic group, this ensured that immigrant same-ethnic density was always defined in their analyses.

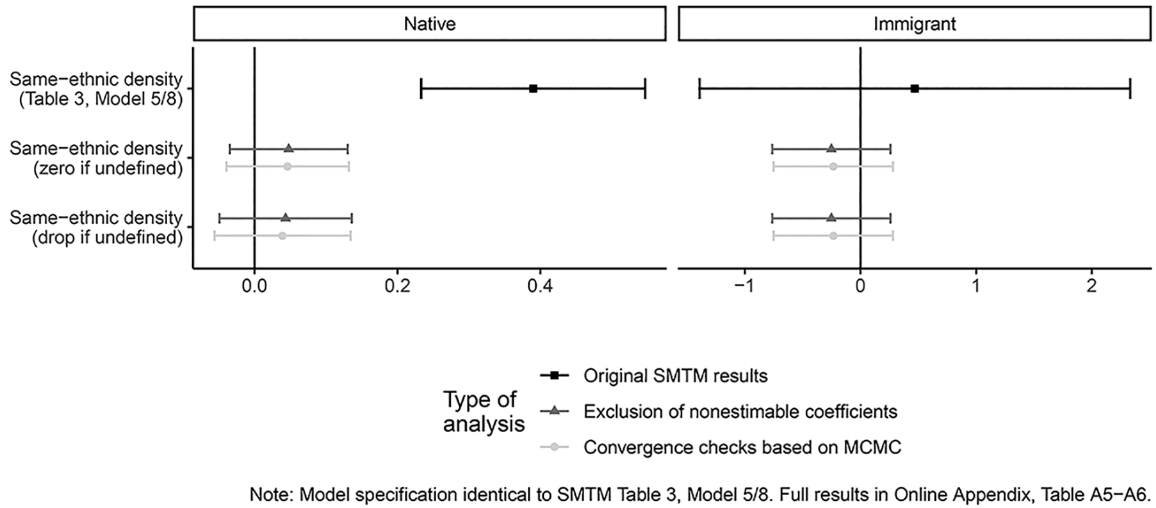


Fig. 3.—Original and reanalysis results for the association between ethnic homophily and same-ethnic friendship density. Model specification is identical to SMTM table 3, models 5 and 8. Full results are available in the online appendix, tables A5−A6.

For natives, SMTM report that both *proportion natives* and *immigrant diversity* contribute to homophily separately, with a higher proportion of natives and higher immigrant diversity being associated with lower homophily (see left panel, fig. 4). This is interpreted as evidence in support of threat-based theories because natives are presumed to be least threatened in classes where immigrants are few in number and dispersed across many national groups. Our reanalysis also finds lower native homophily at a higher share of native students. The additional effect of immigrant diversity is negative as in SMTM's original analysis and similar in size, but no longer statistically significant in our reanalysis.

Among immigrants, SMTM do not detect any relationship between immigrant homophily and *immigrant diversity* once the curvilinear effect of *proportion natives* has been accounted for (right panel, fig. 4). Here as well, our reanalysis offers a different picture: as before, we find no curvilinear relationship for proportion natives, but a positive linear effect, indicating higher immigrant homophily in classrooms with a larger proportion of native students. At the same time, *immigrant diversity*, in contrast to SMTM's results, *is* significantly and positively associated with homophily among immigrant students.[11] Immigrant students' homophily therefore is stronger in classrooms with a more diverse set of immigrants.

CONCLUSION

In this comment, we have replicated the assessment of differential effects of ethnic classroom composition on native and immigrant homophily from SMTM. Our reanalysis identifies a key problem with the original empirical analysis—namely, the inclusion of (heavily weighted) homophily coefficients from network models that carry no substantive meaning, either because coefficients are not estimable in the first place or because the models otherwise fail to converge. To conclude this comment, we summarize some methodological takeaways from this replication before discussing how these issues change the substantive conclusions drawn from the data.

Methodologically, our reanalysis highlights the crucial importance of thorough model checking and diagnostics when examining ERGMs and related network models. Estimation and convergence problems are to be expected

[11] In order to match SMTM's specification, we have included a quadratic term for proportion natives in this analysis even though our reanalysis indicates no quadratic relationship. That said, we note that the immigrant diversity effect is also statistically significant for immigrants when using a linear specification for the effect of proportion natives. Models that furthermore include an interaction effect between proportion natives and immigrant diversity (table 4, models 2 and 4; p. 1252) reproduce these findings and provide, as in SMTM, no evidence of an interaction effect.

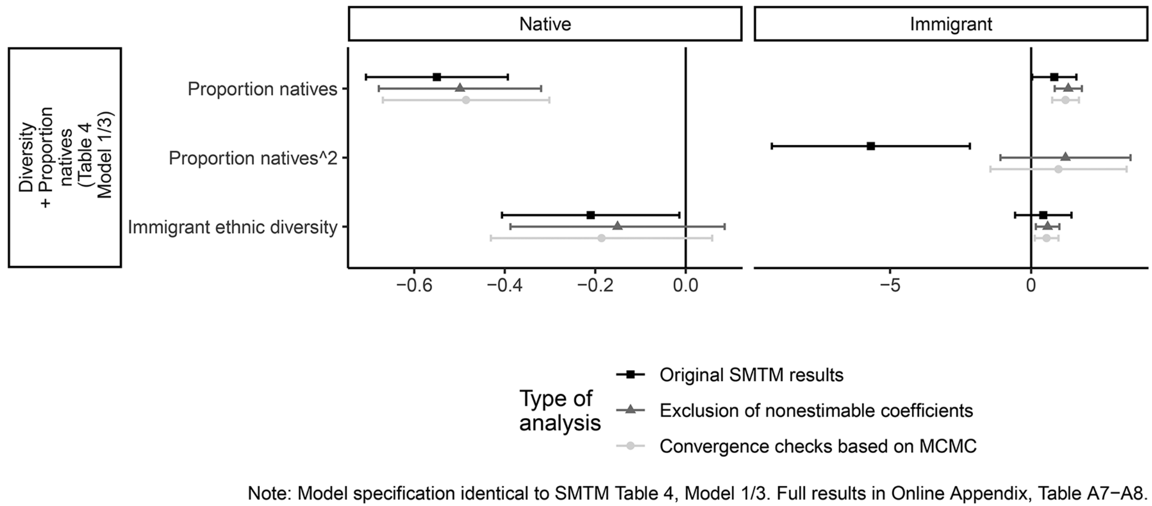


FIG. 4.—Original and reanalysis results for combined effects of immigrant ethnic diversity and proportion natives. Model specification is identical to SMTM table 4, models 1 and 3. Full results are available in the online appendix, tables A7−A8.

especially when, as in the case at hand, networks are small and thus provide limited data for the estimation algorithm. Although the workload involved in conducting plausibility, model, and convergence assessments across a large number of networks (e.g., hundreds of classrooms in the CILS4EU data) is considerable, these efforts are crucial for ensuring the suitability of network estimation results in any subsequent meta-analysis.

In substantive terms, we can at least qualitatively replicate most of the article's results for natives. Specifically, when the native group is relatively small and when ethnic diversity is high, native homophily is particularly strong. Tying this finding back to the conceptual frameworks elaborated by SMTM, this pattern is in line with theories of ethnic threat and competition, according to which natives are threatened by large ethnic out-groups. That said, however, our replication of the corroborative evidence SMTM provide for these mechanisms among natives is less conclusive than their original findings.

For immigrants, our replication results deviate substantially from the patterns originally reported by SMTM. More specifically, SMTM report curvilinear relationships between immigrant homophily and both the proportion natives in a classroom and total ethnic diversity, with immigrant homophily peaking at a medium share of natives and at medium diversity. SMTM interpret these findings as suggestive of an opportunity-based mechanism with immigrants having particularly good opportunities to befriend suitable same-ethnic peers in moderately diverse classes. Our reanalysis, however, identifies these curvilinear relationships as artifacts of including substantively meaningless coefficients in the meta-analytical models. After excluding these networks, we instead find evidence for a monotonic relationship between immigrant homophily and the proportion of natives in class, with immigrant homophily rising in direct proportion to the size of the native group. We also find no conclusive results for the relationship between immigrant homophily and total ethnic diversity.

Relating our findings to SMTMs' theoretical framework, our replication results for immigrants are much more in line with ethnic threat and competition arguments than with opportunity-based mechanisms, given that homophily increases when immigrants face a larger *native* out-group. Indeed, follow-up analyses appear to provide corroborative evidence pointing in this same direction. Here, results from models examining the effects of immigrant diversity are particularly illuminating. It appears that, conditional on the share of natives, immigrant homophily further increases in settings with high immigrant diversity. Arguably, it is particularly in such situations that immigrants may feel threatened since they are divided into small groups that not only compete with the majority, but also amongst each other. These results thus raise the possibility that ethnic threat and competition may operate as unifying mechanisms underlying ethnic homophily among both natives and immigrants.

Naturally, our comment is primarily concerned with correcting the errors in SMTM's original analyses and does not claim to offer the last word on these substantive questions. As SMTM point out, there are good theoretical reasons to expect threat and competition mechanisms to be particularly salient for the majority group, while playing a smaller role in shaping the friendship choices of ethnic minorities. Empirically assessing these mechanisms, in particular with more elaborate network models at the micro level, will continue to challenge scholars given the limited size of most classroom networks in existing data and corresponding estimation problems. Indeed, researchers may need to look for different data or alternative modelling strategies (such as multilevel network models; e.g., Ripley et al. 2022) for more definitive answers to these questions. For the moment, however, staying within the empirical strategy employed by SMTM, we believe the weight of the evidence points in the direction of "No Differential Effects of Classroom Composition on Native and Immigrant Homophily," rather than the "Differential Effects" suggested in the title of SMTM's article.

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