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Networks in the making: Friendship segregation and ethnic homophily☆

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ABSTRACT

Recent work focuses on how homophily (tastes for similarity) can lead to network segregation (the lack of intergroup friendships). Yet studies seldom consider whether and how levels of network segregation could also lead to the trend towards homophily over time. Instead, existing cross-sectional studies argue that intergroup exposure exacerbates homophily. By neglecting longitudinal data on changes to friendships and focusing on intergroup exposure rather than initial intergroup friendships, existing studies are likely to present an overly pessimistic view on the benefits of intergroup contact. Using longitudinal data and stochastic actor-oriented models, I study how levels of initial ethnic network segregation between students in Swedish Classrooms with "native" backgrounds and immigrant-origin students are related to subsequent levels of ethnic homophily. Results show that more initial network segregation in classroom friendship networks is linked to more ethnic homophily in network evolution, which suggests that beyond mere exposure, optimal conditions for contact and actual intergroup friendships are crucial for positive intergroup dynamics, and that their benefits can appear longitudinally.

1. Introduction

The rise of immigration in recent decades has led to concern about the challenges of rising numbers of ethnic minorities for various forms of integration (van der Meer and Tolsma, 2014; Schachter, 2016; Van Tubergen and Smith, 2018). One such concern is that rising numbers of ethnic minorities might increase the salience of ethnicity and thus exacerbate ethnic homophily, which refers to individuals' preference for forming social ties within rather than outside of their ethnic ingroup (McPherson, Smith-Lovin, and Cook, 2001). Several prominent studies find that homophily tends to be larger for groups that are exposed to greater numbers of outgroup members (Currarini et al., 2010; Kossinets and Watts, 2009; McFarland et al., 2014; Moody, 2001; Smith et al., 2016). These studies typically warn that the positive effects of intergroup contact on intergroup relations are not as large as one might expect, because intergroup contact can exacerbate homophily.

Yet studies of the effects of intergroup contact on homophily are limited in several fundamental ways. First, the current reliance on cross-sectional data could conceal the positive effects of contact on intergroup attitudes (Pettigrew and Tropp, 2006), for example because cross-sectional data do not allow us to study the extent of homophily in updates to networks following initial intergroup contact. Second, according to contact theory, it is extended and high-quality contact that improves intergroup attitudes (Eller and Abrams, 2004; Stephan and Rosenfield, 1978), and should thus reduce homophily. So far the insight that the quality of contact matters

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for the consequences of contact (Pettigrew and Tropp, 2006; Wagner et al., 1989) is often absent in studies of homophily, which tend to measure the effects of simple exposure (i.e., being enrolled in the same classroom) rather than high quality contact (i.e. initial friendships between groups).

In recent years, sociologists have advanced increasingly sophisticated methods of inferring the average amounts of homophily in a social network by netting out other relational mechanisms (Goodreau et al., 2009; Kossinets and Watts, 2009; Rivera et al., 2010; Zeng and Xie, 2008). Such studies focus on the effects of homophily on intergroup network segregation, but seldom consider the possible effects of network segregation on homophily. To investigate the implications of network segregation for homophily, I use the case of classroom friendship networks among adolescents. Network scholars often turn to school and classroom settings– such settings are useful because network boundaries are well-defined, and because friendships during this early stage of life can have long-lasting effects (Cotterell, 2007). It is by studying these sorts of networks, that scholars have learned of the ways in which some forms of outgroup exposure (such as being in the same classroom, grade, or school) can exacerbate homophily in social networks (Currarini et al., 2010; Kossinets and Watts, 2009; McFarland et al., 2014; Moody, 2001; Smith et al., 2016).

In this paper, I analyze dynamic friendship networks among 3255 Swedish adolescents embedded in 160 classrooms using the Children of Immigrants Longitudinal Survey of Four European Countries (CILS4EU). The CILS4EU is ideal for my research question because it contains multi-context, sociocentric, and longitudinal data, and because it oversamples contexts in which there are many minorities, which improves the study of homophily. I focus on Swedish classrooms because Sweden has a nontracked school system, where students usually go from subject to subject in school, and from year to year, with the same group of students (i.e., with the same classmates) until they complete their education. To parse homophily out from other relational mechanisms within a context, I use stochastic actor oriented models of network evolution (Leszczensky and Pink, 2015; Ripley et al., 2019; Snijders, van de Bunt, and Steglich, 2010; Stark and Flache, 2012), together with strategies that are used to combine network effects that are estimated across multiple contexts (An, 2015; Snijders and Baerveldt, 2003). Results show that while simple ethnic composition in classrooms does not predict tie evolution, higher levels of initial ethnic network segregation in classroom friendships are positively associated with higher levels of subsequent ethnic homophily in the evolution of these friendships. While further studies are needed to identify a causal effect, the current study shows that more intergroup friendships at the context-level predict lower levels of homophily in how individuals update friendships, which supports the idea that the benefits of contact for intergroup relations typically appear over time and after exposure to high-quality contact.

2. Background

Network segregation between social groups, in which there are relatively few ties between individuals from different social categories, is prevalent in many domains of social life (Byrne, 1971; Kossinets and Watts, 2009; Laumann, 1966; Lazarsfeld and Merton, 1954; Verbrugge, 1977). Race and ethnicity are one of the most salient social dimensions on which network segregation occurs (Kao et al., 2019; McPherson et al., 2001). One factor that contributes to network segregation, is *homophily* – which refers to individuals' tastes for similarity (Wimmer and Lewis, 2010). Ethnic homophily exists because attitudes, customs, tastes, and values, which promote friendships, are often linked to, or even rooted in, ethnicity (Alba, 1990).

In recent years, sociologists have studied homophily as a cause of network segregation. This has pushed forward increasingly advanced methods for studying the contributions of homophily to network segregation net of other explanations for social ties (Goodreau et al., 2009; Rivera et al., 2010; Zeng and Xie, 2008). It goes without saying that homophily is a basis for network segregation, but scholars also know that opportunities for interaction (Khmelkov and Hallinan, 1999; Moody, 2001), as well as reciprocity and transitivity in networks, also generate homophily and produce a great deal of network segregation (Goodreau et al., 2009; Kossinets and Watts, 2009; Wimmer and Lewis, 2010).

Yet despite the rich body of literature on the effects of homophily on network segregation, scholars do not yet understand the flip side of the equation – how network segregation may impact homophily. In other words, although scholars are increasingly adept at analyzing the ecological conditions that shape homophily (Cheng and Xie, 2013; McFarland et al., 2014), there are few studies on how initial network segregation matters for homophily in tie evolution. In this study, I begin to bridge this gap by determining whether initial network segregation predicts homophily in subsequent changes to initial networks.

2.1. Origins of homophily and the effects of intergroup contact

So far, studies on the origins of homophily do not consider network segregation as a possible source of homophily – instead, they focus on the effects of ethnic composition and intergroup exposure (e.g., relative group size, proportion immigrant, diversity indices, etc.). These studies often reveal higher levels of racial homophily in settings where individuals encounter a greater number of outgroup members (Currarini et al., 2010; McFarland et al., 2014; Moody, 2001). For example, studies by Smith et al. (2016) and Goodreau et al. (2009) show that homophily often increases with outgroup exposure, and that levels of homophily are especially linked to proportion minority. These results are usually taken to support "group threat theory" (Moody, 2001:680; Smith et al., 2016:1230) in which the presence of a relatively large outgroup exacerbates a sense of threat (Hewstone and Brown, 1986; Sidanius and Pratto, 1999) and thus increases homophily. They also contradict "contact theory," in which contact with outgroup members generates positive attitudes towards the outgroup (Allport, 1954) and thus decreases homophily.

Existing studies usually measure outgroup exposure in relatively coarse terms (e.g., being enrolled in the same classroom) and rarely use higher quality measures of contact (e.g., information on actual friendships) to study the effects of outgroup exposure. This may prevent researchers from observing the benefits of contact in reducing homophily. The original formulation of contact theory

theorizes that the optimal benefits of contact are conditional on cooperation, common goals, equal status, and institutional support (Allport, 1954). Soon after, scholars further emphasized the importance of the quality and nature of contact (Sherif and Sherif, 1953:221). Since friendships are likely to be high quality types of contact that satisfy the optimal conditions, I hypothesize that intergroup contact within networks rather than simple exposure corresponds with improvements to intergroup attitudes, and thus less homophily. In fact, in their comprehensive meta-analyses, Pettigrew and Tropp (2006) point out that studies using intergroup friendship as a measure of contact find significantly stronger effects of contact on improved intergroup attitudes, compared to studies that use lower quality measures of contact such as mere exposure. However, their insights are infrequently used to study levels of homophily in networks as inferred using relational networks analyses.

2.2. Networks in the making: the need for longitudinal and multi-context analyses

Studies on the effects of outgroup contact on homophily are also limited in their reliance on cross-sectional data. In their discussion on racial homophily, Wimmer and Lewis (2010:636) call for the use of longitudinal data sets in order to advance a less descriptive approach and increase understanding of how networks change over time. Likewise, Snijders and Baerveldt (2003:124) call for the comparison of network formation processes across contexts to test theories of relational behavior and to understand sources of network variation (Smith et al., 2016:1256). Yet an emerging set of longitudinal network studies primarily consider the interplay between friendships and educational outcomes (Raabe, Boda, and Stadtfeld et al., 2019; Stadtfeld et al., 2019), delinquency (Richmond et al., 2018), or health/well-being (Elmer et al., 2017) – fewer studies consider the contextual conditions for the evolution of ethnic homophily. Although a few longitudinal network studies are moving in this direction (Kossinets and Watts, 2009; McFarland et al., 2014), such studies are often single-context (i.e. they include a single large network) and thus do not address the ecological effects of intergroup exposure on homophily.

Longitudinal and multi-context data are essential for analyzing the contextual origins of homophily, and the relationship between homophily and intergroup contact. The positive effects of intergroup contact may require repeated contact over time. Social psychologists have found using longitudinal data that contact is beneficial for intergroup attitudes (Eller and Abrams, 2004; Stephan and Rosenfield, 1978) – it is a logical, albeit untested, extension of their finding that extended contact should also reduce homophily. In order to prevent an overly pessimistic outlook on the implications of intergroup contact for homophily, it is necessary to use not just a measure of high-quality contact, but also longitudinal data.

Longitudinal analyses allow researchers to control for initial networks and base analyses on tie formation and tie dissolution, holding constant initial network-tendencies (McFarland et al., 2014). This is important because some factors may contribute both to outgroup exposure and homophily in initial network structures but have little to do with homophily in evolving networks (how individuals actually approach friendships). So again, while longitudinal social networks analyses are on the rise (Dijkstra et al., 2013; Leszczensky and Pink, 2019; Snijders and Baerveldt, 2003; Stark and Flache, 2012), longitudinal tests of contact theory on any kind of outcome remain relatively rare (Pettigrew and Tropp, 2006). In other words, it remains an open question whether forms of high-quality outgroup exposure, such as desegregated social networks that crosscut social categories, are linked to lower levels of homophily in how individuals update their ties.

2.3. The case of adolescent classroom friendships

To study homophily, sociologists often turn to school and classroom settings – these settings have several benefits for studying the implications of network segregation for subsequent homophily. Not only are schools and classrooms microcosms of broader societies (Coleman, 1961; Cotterell, 2007), they also offer relatively neatly bounded populations within which networks form. Recent studies of classroom friendships have leveraged this beneficial feature to disentangle the opportunities and motivations for friendships (Goodreau et al., 2009; Moody, 2001; Zeng and Xie, 2008). Second, children and adolescents reflect the changing face of societies. Because the rise of immigration to Western Europe – especially to countries such as Sweden – is relatively recent (Castles and Miller, 2013; Heath et al., 2008), the adolescent population contains a greater number of minorities than in the general population. This improves studies of homophily because overly homogenous settings – in which there are no opportunities for inter-ethnic friendships to exist in the first place – do not offer opportunities to observe inter-group relations (Wimmer and Lewis, 2010).

Last but not least, interethnic contact in schools and classrooms provide individuals with early exposure to members of ethnic outgroups (Kruse and Kroneberg, 2019; Leszczensky and Pink, 2019; Smith et al., 2016). Studies suggest that early intergroup friendships can foster subsequent interethnic relationships, such as interethnic marriages, in adulthood (Ellison and Powers, 1994; Emerson et al., 2002; Kao et al., 2019) – yet it is unclear whether those subsequent interethnic dynamics are characterized by greater opportunities for intergroup relationships or lower levels of ethnic homophily. In this paper, I will assess whether initial interethnic friendships in classrooms are linked to lower levels of ethnic homophily in the evolution of classroom friendships.

3. Data and methods

To study the interplay between network integration and homophily, I use the first and second wave of data from the Swedish sample of the Children of Immigrants Longitudinal Survey in Four European Countries (CILS4EU) project (Kalter et al., 2016), which followed adolescents in England, Germany, the Netherlands, and Sweden starting from the school year in which students are between 14 and 15 years old. The CILS4EU began in the 2010–2011 school year, with stratified sampling by region, school type, school size, and percentage of immigrant minority children enrolled. Schools with many minority students were oversampled. The CILS4EU's focus on

the adolescent immigrant population and its oversampling of schools with many minorities is essential to this study.

Within participating schools, a target of two classrooms of 14-year-old students were randomly selected. To study network integration, I use information on classroom friendships, which was collected for all students within selected classrooms by asking them to nominate up to five best friends from a roster of classmates. Since nearly all classmates are surveyed within each classroom, information on inter- and intra-ethnic ties are triangulated, without directly asking students about their friends' ethnicities, a strategy that leads to more accurate answers by reducing social desirability bias (Kao et al., 2019:29). Classroom friendship networks are constructed from nominations using directed ties. The resulting data is sociocentric – this is exactly the sort of data that is required for studying homophily.

I focus on the Swedish subset of the data for both conceptual and technical reasons.[1] Sweden's nontracked education system implies that students are more likely to be exposed to similar school settings in which networks remain relatively stable over time. In the Swedish school system, students rotate with the same group of classmates (akin to a U.S. homeroom) across different subjects as a unit throughout the school day – these classrooms also generally remain a unit from year to year. Classrooms that were not consistently defined across both waves were not included in this study. The analytic sample also excludes classrooms that are too homogenous for homophily to be studied. In line with existing studies, I retain only classrooms with at least 2 ethnic minorities and 2 ethnic majorities, at least 2 boys and 2 girls, at least 10 students, and in which fewer than 10% of friendship nominations are invalid (Smith et al., 2016). A total of 160 Swedish classrooms, containing a total of 3255 students, fit these criteria.[2]

To measure ethnicity, I distinguish between "native" Swedish students as well as between students from different immigrant minority groups. Given the recency of migration to Sweden,[3] I use respondents' own country of birth or the country of birth of their parents to identify respondents with a non-native (immigrant) background. In the handful of cases where respondents' parents come from mixed backgrounds, the respondents' immigrant or maternal background takes precedence (Dollmann et al., 2014). Approximately 60.2% of respondents have a "native" Swedish background. Among the immigrant-origin respondents, 17.5% come from former Yugoslavia, 8.67% from Iraq, 7.3% from Turkey, 3.4% from Lebanon, and the remainder are split between "other Nonwestern" and "other Western" backgrounds. I combine smaller ethnic groups into the "other Nonwestern" and "other Western" categories because specific ethnic groups within these categories rarely meet in the same classroom.[4]

3.1. Analytic strategy

To quantify intergroup network segregation in a given classroom network, the main analyses uses a log odds ratio of a friendship between individuals that share the same ethnicity to a friendship between individuals that differ in ethnicity (Moody, 2001). Network segregation is measured ecologically because extended contact – i.e. intergroup separation within an extended social network – could have an effect on intergroup attitudes that goes beyond personal networks – i.e. an individual's personal breakdown of ingroup versus outgroup ties (Zhou et al., 2019). Moody's index of network segregation for these classroom friendship networks ranges from −0.5 to 2.9 with a mean of 0.4 and standard deviation of 0.5, where values above 0 imply that networks are segregated.[5] In the section after the main results, I repeat the analyses using several additional measures of network segregation.[6]

Fig. 1 illustrates an example of the classroom networks on which these analyses are based. The network in Fig. 1 is fairly typical – natives and ethnic minorities show up as somewhat clustered in the network, but are far from disconnected. The amount of network change in Fig. 1 is also fairly typical in that usually students replace around 1 in 3 of their friends between network waves.[7]

[1] I do not use the data from the other countries – In Dutch schools, the classroom context from the first wave usually does not exist anymore in the second wave due to the institutional rules of the Dutch educational system, which reassigns students to different classrooms, and allows for a large amount of cross-over between academic tracks. The English data is limited by inconsistencies in the way that network data was collected (Kruse and Jacob, 2016). In Germany, early tracking implies that an important subset of the classrooms could not be studied longitudinally - tracks that lead to the lowest qualifications complete their schooling after the first wave of data collection.

[2] Students' overall participation rate in the analytic sample was 85% in the first wave and 78% in the second wave. Sensitivity analyses that restrict the analytic sample to the 112 classrooms with participation rates of at least than 70% in either survey wave led to similar results, as shown in Table A-1 of the Appendix.

[3] Numbers of asylum-seekers and refugees, arriving in Sweden from new origins began to rise in the 1970s. Some of the second-generation immigrants in the current study are likely children of these early arrivals, or a part of subsequent family-reunification migration that occurred in the 1980s and 1990s. Numbers of asylum seekers increased rapidly after 2006, in part due to several acts that expanded on the definition of refugees (Sweden's Ministry for Foreign Affairs, 2006) and loosened requirements necessary to receive asylum (Eger, 2010).

[4] Sensitivity analyses after the main results use alternate strategies for categorizing ethnicity (Table A-1).

[5] In two cases, network segregation is exceptionally high and thus re-coded to the upper cutoff for outliers (three times the standard deviation above the mean) to limit the influence of extreme values. Results were substantively similar when omitting the two outliers from the analyses. Also note that alternate definitions of ethnicity used in sensitivity analyses, as well as alternate measures of network segregation, did not lead to any outliers.

[6] The main analyses are repeated using four measures of network segregation: Moody's index, Newman and Girvan's index, Krackhard and Stern index, and Gupta-Anderson-May index. For more on the different properties of these indices please see Bojanowski and Corten (2014). Sensitivity analyses after the main results also consider native-immigrant network segregation in addition to ethnic network segregation.

[7] While there is substantial network turnover, networks are still stable enough to be considered repeated observations of the same network. Only 4% of networks have a Jaccard index of below 0.2, which is sometimes considered the cutoff below which networks are too unstable (Ripley et al., 2019).

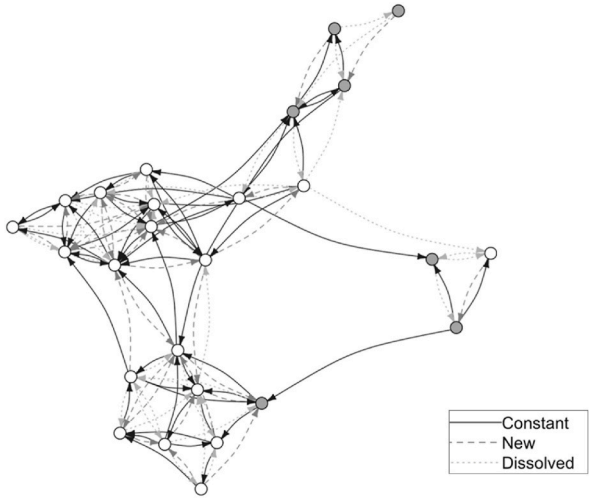

Fig. 1. Example of an Evolving Classroom Friendship Network. *Note.* Gray nodes indicate migrant status.

I also measure average levels of homophily at the network level – this is precisely what enables us to parse out interdependencies between ties and relational mechanisms that contribute to network segregation without being caused by homophily (Kossinets and Watts, 2009; Rivera et al., 2010; Wimmer and Lewis, 2010). While homophily can be understood as preferences by individuals, the aggregation of individual choices results in features of networks that are observable net of other explanations for ties. Specifically, I use stochastic actor-oriented models (SAOMs) of network evolution to model network dynamics (Snijders et al., 2010; Steglich et al., 2010). SAOMs differ from tie-based approaches like ERGMs (Goodreau et al., 2009; Wimmer and Lewis, 2010) because they use actor-based simulations to infer the social mechanisms behind observed tie changes in networks. They also differ from cross-sectional approaches in that they do not assume that the observed network is in a temporary state of equilibrium (Block and Grund, 2014; Snijders et al., 2010). Rather, they explicitly simulate network evolution, accounting for the creation, termination, and stability of ties, by modeling actors' decisions.[8]

Similar to agent-based models, SAOMs assume that network changes are the result of many small changes, called micro-steps, in which a randomly selected actor has a chance to change (create or terminate) an outgoing tie or to keep their network unchanged based on their "objective function," whose specification is parallel to a multinomial logistic regression (such that each effect in the objective function can be interpreted as an increase in log-odds). Model terms in SAOMs refer to different effects or parts of the objective function, and the importance of each effect is estimated from the data. I include effects to capture individual preferences (such as ethnic homophily) and relational mechanisms (Kossinets and Watts, 2009; Rivera et al., 2010; Wimmer and Lewis, 2010), which refer to how agents respond to the structure of the network.

Table 1 summarizes the included model terms: density, reciprocity, transitivity ("the friend of my friend is my friend"), structural degree-related effects (e.g., the extent to which popularity or sociality is self-reinforcing or correlated with each other), sociality covariates (differences in the number of ties that immigrant minorities seek relative to "natives" and for boys compared to girls), popularity effects (differences in the number of nominations received by immigrant status and gender), gender homophily (preference for same-gender friendships), and ethnic homophily (e.g. the extent to which Iraqi-origin students prefer to be friends with other Iraqi-origin students, Swedish-origin students prefer to befriend other Swedish-origin students, etc.). Inclusion of additional covariates (such as homophily on socioeconomic status, interaction effects between the above set of model terms, etc.) did not improve model fit; they are thus omitted both for the sake of parsimony and because the inclusion of too many irrelevant effects lead to issues with convergence (Ripley et al., 2019).

To fit the model, the first data wave serves as a starting point for simulations, and the dependent variables are the changes in the networks that occur between the first and second waves. Missing values for individual attributes were very uncommon (less than 1% of observations were missing ethnicity or gender) and results were not sensitive to whether these values were imputed to the modal category or treated as non-informative in the estimation process (Huisman and Steglich, 2008). Repeated simulations fit the model and computation of each SAOM was carried out using the *RSIENA* 1.2–13 package in R version 3.5.1 (Ripley et al., 2019). Models converged in approximately 89% of cases (for N = 2944 students nested in 143 classrooms) and I do not include the 17 classrooms in

[8] Note that in theory at any level of network segregation, SAOM coefficients cannot be estimated if ties do not change, though in practice this did not occur.

Table 1
Models of friendship formation.

Parameter	Description
Density (density)	Baseline probability of friendships
Reciprocity (recip)	Increased propensity of a reciprocated friendship
Transitivity (gwespFF)	Transitive two-path connecting pairs in one direction ("the friend of my friend is my friend")
Indegree Popularity (inPopSqrt)	A popularity effect that implies that high indegrees get reinforced (high dispersion of indegrees) as defined by the sum of the square roots of indegrees
Outdegree Activity (outActSqrt)	A sociality effect that implies that high outdegrees get reinforced (high dispersion of outdegrees) as defined by the sum of the square roots of the outdegrees
Indegree Activity (inAct)	The extent to which higher indegrees yield higher outdegrees (covariance between in- and out-degrees) as defined by the cross-product of in- and out-degrees
Migrant Ego Effect (egoX migrant)	The extent to which immigrant-origin students make more friends than "natives"
Migrant Alter Effect (altX migrant)	The extent to which immigrant-origin students receive more friendship nominations than "natives"
Ethnic Homophily (sameX ethnicity)	Increased propensity of same-ethnic friendships
Boy Ego Effect (egoX boy)	The extent to which boys make more friends than girls
Boy Alter Effect (altX boy)	The extent to which boys receive more friendship nominations than girls
Gender Homophily (sameX gender)	Increased propensity of same-gender friendships

which there were estimation issues even after using strategies to improve convergence.[9] I further discuss model convergence, as well as goodness of fit diagnostics, following the main results.

After analyzing all class-level networks separately, I combine the results using *RSIENA* meta-analysis in which the outcome is the estimate of ethnic homophily. Such meta-analyses are a rising strategy for the analyses of ecological conditions that covary with network processes (An, 2015; Snijders and Baerveldt, 2003) and can be used whenever the explanations for network ties are adequately captured and networks are comparable (An, 2015; Kruse and Kroneberg, 2019; McFarland et al., 2014; Smith et al., 2016; Snijders and Baerveldt, 2003). Since true levels of homophily differ from classroom to classroom, I use random-effects meta-analyses. These analyses are conducted using the package *metafor* in R version 3.5.1 with the option method = "REML", which is the restricted maximum likelihood estimator and is recommended for use with *RSIENA* models (Viechtbauer, 2005, 2010). All meta-analyses apply weights proportional to the inverse variance of the estimate on the homophily coefficient (down-weighting cases where ethnic homophily is imprecisely estimated).

To analyze the relationship between initial network segregation and subsequent homophily, I include the following classroom-level covariates in meta-analyses: network segregation, mean classroom socioeconomic status as proxied by parental International Socio-Economic Index of Occupational Status (Ganzeboom et al., 1992), classroom size, and proportion of immigrants in the classroom. Note that the individual *RSIENA* models used here already control for the mechanical implications of relative group size through different opportunities for intergroup ties (Block and Grund, 2014). Yet ethnic composition of classrooms may have implications for homophily beyond opportunity structure, and thus the proportion of immigrants is a key control. In addition, controlling for mean classroom socioeconomic status (SES) helps account for differences in both network segregation and homophily that may exist due to differences in SES (Bobo and Licari, 1989). Finally, in larger classroom populations, students have more potential friends to choose from, which makes it easier to satisfy homophilous preferences (Cheng and Xie, 2013; Currarini et al., 2010). If there is a connection between classroom size and network segregation, accounting for network size helps guard against a spurious relation between network segregation and homophily.

4. Results

Table 2 shows an example of an RSIENA model fitted to an example classroom network. The negative sign on outdegree is unsurprising – it reflects that unless other effects contribute to a students' objective function, ties are unlikely. Specifically, the log odds of adding or maintaining a tie is similar to the odds of not adding a tie, for a tie that is not mutual, does not involve transitivity, is not homophilous, etc. The log odds of adding or keeping a reciprocated tie is 1.56 times the odds of adding or keeping a non-reciprocated

[9] Among the 143 classrooms where models converged, convergence is achieved in 80% of cases either immediately or by using repeated estimation using the result from a previous estimation as the initial value for the next estimation. In 20% of cases, convergence was achieved by leaving out the inAct term, which is selected for omission for theoretical and technical reasons. First, the structural degree-related effects related to indegree dispersion (inPop) and outdegree dispersion (outAct) are more theoretically intuitive than their correlation structure (inAct). Second, standard errors on the inAct term were relatively large even in classrooms where its inclusion did not yield issues of convergence. Since structural degree-related effects are typically included in models of friendship networks, I use the full model when possible. Importantly, results are robust to other specifications that improve estimation, including the omission of any subset of the degree-related terms or the omission of the gender covariate terms. Results are also substantively similar when simply omitting the cases where the full model could not be estimated.

Table 2
Model of network change for an example classroom.

	Coef.	SE
Density (outdegree)	−0.66	1.56
Mutual (reciprocity)	1.56**	0.58
GWESP (transitivity)	1.84***	0.44
Indegree Popularity	−0.87*	0.44
Outdegree Activity	−0.15	0.08
Indegree Activity	−0.24	0.60
Homophily		
Ethnic homophily	0.80	0.41
Gender homophily	1.02**	0.42
Covariate		
Ego Migrant (ref: Native)	−0.71	0.47
Alter Migrant (ref: Native)	0.93**	0.36
Ego Boy (ref: Girl)	0.46	0.44
Alter Boy (ref: Girl)	−0.28	0.46

Note. Results of a stochastic actor-oriented model with effects summarized in Table 1. $p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

tie, all else equal. Moving down the table, we see that tie evolution tends to favor "the friends of friends" as well as same-gender ties. The negative sign on indegree indicates that popularity tends to be self-limiting (it is not the case that popular individuals get more popular over time). In this example network, there is evidence of gender homophily but not ethnic homophily, and there is evidence that migrants tend to gain more ties over time than natives in the classroom but no other significant differences in numbers of ties.

Table 2 provides intuition on how the analysis are conducted and how homophily is measured for a specific classroom. However, further analyses are required to determine whether these tendencies exist on average over all classrooms studied here and how these tendencies might depend on ethnic composition and initial network segregation. Fig. 2 summarizes network evolution dynamics across all classrooms (i.e., repeating the analyses shown in Table 2 for a specific classroom over all classrooms in the analytic sample). At the top of Fig. 2, we see a strong tendency in all classrooms for the creation and/or maintenance of ties that lead to reciprocated friendships and that lead individuals to be friends with the friend of a friend. Moving down, there is some evidence of self-limiting properties of the degree dispersion, though note also that these structural degree-related effects were not always precisely estimated.

Fig. 2 also shows how the evolution of friendship ties is linked to gender and immigrant background. The "ego" and "alter" effects show that in the average classroom, there is little effect of gender or immigrant background on the number of ties that individuals seek out or receive. Similarly, the distributions of the estimated ethnic homophily coefficients show that in the average classroom, there is only a little ethnic homophily (values of the ethnic homophily covariates are on average positive but close to 0).[10] There are two nuances to the interpretation of the ethnic homophily coefficient to note here. First, while there is on average relatively little ethnic homophily in how ties are updated and maintained, this does not mean that networks are no longer ethnically segregated after extended exposure. Instead, it means that conditional on initial levels of network segregation, the additional ties that are created or the ties that are dropped on average do not depend much on ethnicity. This serves to reinforce the need for longitudinal analyses, which may offer distinct insights on networks and homophily. Second, ethnic homophily in the evolution of ties is not always small – it contains a large amount of variation between classrooms. For example, while average levels of ethnic homophily tend to be much lower than average levels of gender homophily, there are some classrooms in which ethnic homophily appears to contribute as much to tie evolution as gender homophily. To explain variation in ethnic homophily, I use random effects meta-analyses that include classroom-level covariates, such as network segregation.

Fig. 3 shows the predicted magnitudes of the homophily coefficients for ethnic homophily based on the random effects meta-analyses that regress ethnic homophily on features of classrooms including proportion immigrant, classroom size, mean SES, and network segregation as covariates. Effects are weighted by the inverse variance of the estimate of homophily for each observation and bars are 95% CI on estimated effects. The main result in Fig. 3 is that initial ethnic network segregation is positively associated with subsequent levels of ethnic homophily in friendship updating behavior, and this effect is statistically significant ($p < 0.012$). In classrooms with higher initial levels of network segregation, individuals are significantly more likely to continue preferentially seeking out or maintaining friendships with same-ethnic individuals.

[10] Further studies are necessary to understand why ethnic homophily coefficients are relatively low here. First, the majority of existing studies on ethnic homophily use Add Health rather than data from the Swedish case, though for a notable exception that conducts cross-sectional network analyses of the first wave of the Swedish CILS4EU data, please see Smith et al. (2014; Table 4D). Second, it is possible that ethnic homophily decreases over time, though three or more waves of data are required to fully assess this possibility. The focus of the current study is to analyze several contextual precursors for ethnic homophily in tie evolution, conditional on pre-existing networks (i.e., the focus is on ethnic homophily in tie evolution rather than evolution of ethnic homophily).

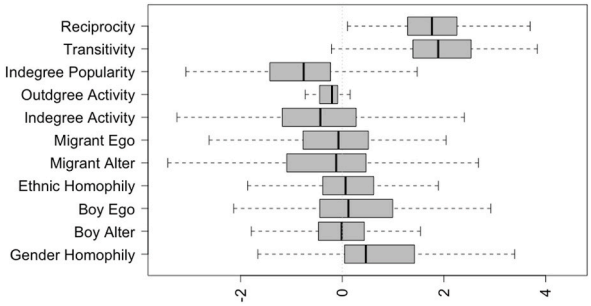

Fig. 2. Distributions of Ethnic Homophily and Other Network Dynamics Across Classrooms Using Stochastic Actor-Oriented Models of Friendship Evolution. *Note*. Summarizing the range, IQR, and mean of coefficient estimates using the stochastic actor-oriented model summarized in Table 1 repeated over 143 classrooms (N = 2,944 students).

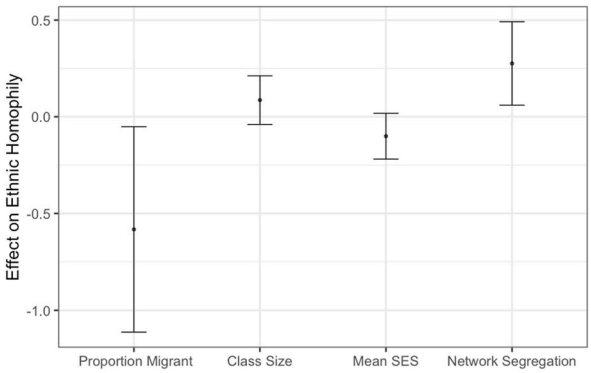

Fig. 3. Effects of Network Segregation and Classroom Characteristics on Ethnic Homophily in Classroom Friendship Networks.
Notes. (1) Effects are based on the regression in Column 1 of Table 3, which regresses the ethnic homophily coefficients (as estimated using stochastic actor-oriented models) on classroom characteristics such as initial network segregation (2) bars are 95% CI

In addition, the results in Fig. 3 show that mean classroom SES and classroom size are negatively and positively associated with ethnic homophily, but neither effect is statistically significant.[11] Note that both classroom size and mean SES are standardized such that a one-unit increase refers to a one standard deviation increase (4.3 students and 8.8 on the International Socio-Economic Index of Occupational Status, respectively). Finally, although the results in Fig. 3 show that the proportion migrant in classrooms is negatively and significantly associated with subsequent ethnic homophily, the sensitivity analyses following the main results are less clear on whether ethnic composition relates to ethnic homophily in tie evolution.

Fig. 4 plots predicted values of ethnic homophily on the y-axis against levels of network segregation on the x-axis. When network segregation is at the high end of its spectrum, ethnic homophily reaches levels that are high enough that they are comparable with average amounts of gender homophily in a classroom. When network segregation is at the low end of this spectrum, there is little to no ethnic homophily. For the most part, classrooms with some amount of initial network segregation (values of network segregation that are greater than 0) also tend to be classrooms in which ties develop in more ethnically homophilous ways.

The models on which the above analyses are based converged well – the distribution of the maximum convergence ratio among the included sample is displayed in Figure A-1 in the Appendix. Values of the maximum convergence ratio under 0.25 are typically used as a criterion for convergence (Ripley et al., 2019).[12] It is possible for models to converge well but still be a poor fit for the observed network, for example if the variables included in the models do not describe the data adequately. To assess whether the variables

[11] Perhaps because classroom sizes here are much smaller than the larger U.S. schools that were used to find a positive association between ethnoracial homophily and school size (Cheng and Xie, 2013; McFarland et al., 2014).

[12] There were 10 cases in which the maximum convergence ratio was between 0.25 and 0.30 indicating reasonable but not excellent convergence. Results were not sensitive to the choice of whether to drop or retain these cases. Supplementary analyses, available on request, also show that none of the main covariates except classroom size were related to convergence. Convergence was significantly worse in smaller classrooms, which is unsurprising because for small classrooms, a single absent student or mistaken nomination may render network data unreliable.

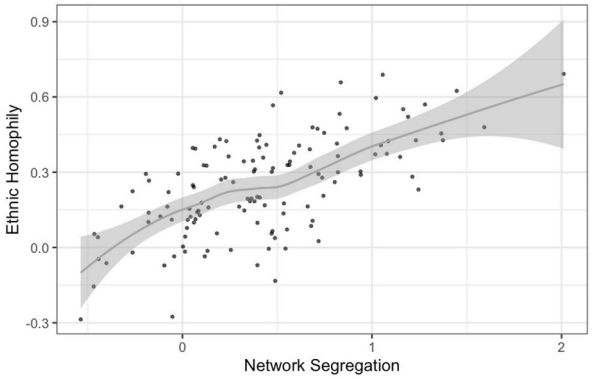

Fig. 4. Initial Network Segregation and Ethnic Homophily in the Evolution of Classroom Friendships. *Note*. Showing predicted effects of initial network segregation on subsequent ethnic homophily coefficient (as estimated using stochastic actor-oriented models), holding all other characteristics of classrooms at average levels.

included in the models describe the data adequately, I analyze the model's ability to reproduce several network properties that were *not* explicitly modeled using a Monte Carlo simulation-based approach (Snijders and Steglich, 2015). Based on the empirical estimates for each classroom, I generate a distribution of networks out of which I use a random sample of 1000 networks to compare characteristics of the simulated networks with the characteristics of the observed data.

Goodness of fit diagnostic results are displayed for all classrooms included in the analyses in the middle row of Figure A-1 in the Appendix. These plots provide evidence of good fit for the actual network changes observed in the data since the Monte Carlo Mahalanobis distance test p-values are usually above 0.05 for the diagnostics considered here: outdegree distribution (the number of friends that people typically nominate), geodesic distance distribution (the average number of friendships required to connect any two classmates), and triad census (the typical classification of all directed triads in the network). To provide further intuition on these diagnostics, I also show an example of a goodness of fit test for a particular diagnostic in an example classroom (bottom row of Figure A-1). Here, the dashed lines and violin plots indicate the distribution of simulated geodesic distances and solid lines indicate levels of the observed geodesic distances in the example network. The solid lines fall comfortably within the dashed lines, which implies good fit and is also reflected in the high p-value.[13]

5. Sensitivity and scope

Table 3 reports the results of the main analyses, which use a familiar measure of network segregation proposed by Moody (2001), in the first column and supplementary results using alternate measures of network segregation in the other columns. Two patterns appear: first, there is relatively weak evidence of an association between simple classroom exposure to immigrant-origin students (proportion migrant) and ethnic homophily; second, there is relatively strong evidence of the main finding that ethnic homophily is

Table 3
Regressions of ethnic homophily on initial network segregation.

	1. Moody	2. N&G	3. K&S	4. GAM
Proportion Migrant	−0.58* (0.27)	−0.45 (0.26)	−0.07 (0.41)	−0.44 (0.27)
Class Size	0.09 (0.06)	0.07 (0.06)	0.09 (0.07)	0.07 (0.06)
Mean SES	−0.10 (0.06)	−0.09 (0.06)	−0.11 (0.06)	−0.10 (0.06)
Network Segregation	0.28* (0.11)	1.13** (0.39)	−0.39 (0.25)	1.35** (0.52)

Note. Regressions of the ethnic homophily coefficient (estimated using stochastic actor-oriented models and weighted by its inverse variance) on classroom characteristics such as initial network segregation, using different measures of initial network segregation including: 1. Moody's index, 2. Newman and Girvan's index, 3. Krackhard and Stern index, 4. Gupta-Anderson-May index.

[13] Here we want p-values to be large because it is desirable that the observed characteristics of the example class are not significantly different from the simulated characteristics.

linked to network segregation. For example, the second column of Table 3 uses Newman and Girvan's assortativity coefficient to measure ethnic network segregation (Newman and Girvan, 2002), and in these analyses, the relationship between initial network segregation and subsequent ethnic homophily becomes even stronger. The third column uses an index of assortativity proposed by Krackhard and Stern (Krackhardt and Stern, 1988), and although the results using this index are no longer statistically significant, this is likely because the Krackhard and Stern index differs from the others in that it is strongly correlated with the proportion migrant in classrooms.[14] Finally, the results in the fourth column, which are based on a measure of within-group mixing proposed by Gupta et al. (1989), again support the main finding of a positive association between initial network segregation and subsequent ethnic homophily.

Network segregation indices that separately capture network segregation for different ethnic groups are beyond the scope of the current study.[15] However, I conduct several supplemental analyses to ensure that the main results are robust to alternate codings of ethnicity, and I also repeat the analyses but consider network segregation between immigrants and "natives" rather than between ethnic groups. The second column in Table A-1 in the appendix repeats the main analyses but breaks down the "other western" and "other nonwestern" ethnic categories using the most geographically granular definition of ethnicity possible. The new results remain consistent with the idea that initial ethnic network segregation in classroom contexts is positively associated with subsequent ethnic homophily in how individuals update their ties. The third column in Table A-1 instead aggregates all origins into just two categories "western" and nonwestern" and the results show that network segregation between natives and immigrants is still positively associated with homophily, suggesting that more aggregate network segregation dynamics are closely related to more aggregated conceptualizations of ethnicity. While there is no objective definition of ethnicity and the most analytically useful coding likely varies depending on data availability and on the substantive question at hand, the results in the sensitivity analyses using the alternate coding of ethnicity continue to support the idea that higher levels of ethnic homophily in tie evolution patterns tend to follow higher levels of initial network segregation.

In this study, I assess the relationship between levels of initial network segregation and subsequent changes to ties, assuming a similar effect of network segregation on both the addition and maintenance of ties. In sensitivity analyses, I further leverage the dynamic data on ties to differentiate between the addition and maintenance of ties in two ways. First, I allow SAOMs to distinguish between tie creation (i.e., interethnic ties are less likely created), and maintenance (i.e., interethnic ties are more likely terminated). Results in the first and third column of Table A-2, which come from the meta-analyses of the two types of homophily (which are estimated using models that includes separate "creation" and "endowment" effects), show that the association between network segregation and ethnic homophily in tie creation retains the same sign as in the previous analyses. The association between network segregation and ethnic homophily in tie maintenance is close to zero and reversed in sign. Standard errors are large throughout, likely because the more complicated model demands too much of the data. Results using OLS regressions (also in Table A-2) also suggest that initial network segregation is linked to the creation, but not termination of ties.[16] Yet admittedly, OLS-based techniques fail to consider other explanations of ties. Thus, while this study suggests that initial network segregation predicts ethnic homophily in tie-updating behavior, further studies are needed to fully distinguish between creation and maintenance of ties.

Finally, note that although the data used in this study were collected prior to the major events and border closures of 2015, the 2010–2011 school years occurred against the backdrop of several shifts in the Swedish immigration scene. While this study will not attempt to identify whether these shifts influenced network segregation in adolescent classroom friendships, it may be helpful to briefly describe several segregation-relevant events that occurred prior to the study to contextualize the environment in which networks formed. For example, just prior to this study in 2009–2010, several reforms to national integration policy were introduced to speed up the introduction of newly arrived immigrants into working and social life (Borevi, 2015). In addition, during the time of the study, certain political groups began campaigning heavily on the perceived problems of immigration. This was perhaps fueled by media coverage of prior events such as the 2009 Malmö riots and the 2010 Rinkeby youth riots, which increased the salience of immigration and the framing of immigration as a problem (Tomson, 2020). Further research is necessary to determine whether these events had implications for adolescent friendships.

6. Discussion and conclusion

Recent studies argue that when individuals are put in social settings with more outgroup members, they become more homophilous, meaning that their tastes for similarity increase (Currarini et al., 2010; Kossinets and Watts, 2009; McFarland et al., 2014; Moody, 2001; Smith et al., 2016). Yet, since these studies of homophily use mere exposure rather than the structure of actual friendships to proxy contact, they are likely to underestimate the positive effects of high-quality types of exposure (Eller and Abrams, 2004; Pettigrew and Tropp, 2006; Stephan and Rosenfield, 1978; Wagner et al., 1989). In addition, by relying on cross-sectional data,

[14] The correlation coefficient is 0.84 as opposed to <0.17 for the other measures. For more on the differences between network segregation measures (such as on treatment of isolates) please see Bojanowski and Corten (2014).

[15] Similarly, ethnicity-specific homophily as an outcome is outside the scope of this study. In exploratory analyses, I use an interaction term in RSIENA models between the migrant status coefficient and the ethnic homophily coefficient, and comparison of the resulting homophily estimates did not yield differential implications of network segregation for the different types of homophily. However, the possibility of differential contextual conditions for different types of homophily is not fully explored here and may be a fruitful topic for future research.

[16] Using separate OLS regressions to predict (A) the ratio between the proportion of same-ethnic ties in t1 that are dropped by t2 and the proportion of inter-ethnic ties in t1 that are dropped by t2 and (B) the ratio between the proportion of same-ethnic dyads which are not tied in t1 that newly formed by t2 and the proportion of inter-ethnic dyads which are not tied in t1 that are newly formed by t2.

existing studies are not able to analyze how individuals choose to sustain ties, drop ties, or form new ties over an extended period of time.

In this study, I use data that allow us to follow many sociocentric classroom friendship networks over two consecutive school years (Kalter et al., 2016). I analyze tie change in each classroom using stochastic actor oriented models (Leszczensky and Pink, 2015; Ripley et al., 2019; Snijders et al., 2010; Stark and Flache, 2012) along with meta-analyses to assess the contextual conditions for homophily (An, 2015; Snijders and Baerveldt, 2003). Results show that simple measures of ethnic composition are poor predictors of homophilous updates to networks. The observation made by prior literature – that the ethnic composition of classrooms can shape homophily within classrooms and schools – may be driven by the cross-sectional association between classroom ethnic composition and levels of ethnic homophily, for instance due to how ties form in unfamiliar social settings.

Moreover, I find that higher levels of initial ethnic segregation in friendships predict higher levels of ethnic homophily in tie-updating behavior. In other words, individuals who are embedded in more integrated social networks tend to become less homophilous over time. This finding helps bridge the gap between (1) knowledge that higher quality contact is a better catalyst for improved attitudes towards outgroups (Allport, 1954; Pettigrew and Tropp, 2006) and (2) recent studies of homophily, which are increasingly able to get at the aggregate attitudes that drive friendship-making with social outgroups (Goodreau et al., 2009; Kossinets and Watts, 2009; Rivera et al., 2010; Zeng and Xie, 2008). Existing studies on the link between homophily and intergroup network segregation have made exciting improvements to our knowledge on the implications of homophily for network segregation, but up to now have not analyzed the implications of network segregation for homophily.

These results imply that it is essential to avoid conflating simple forms of exposure (related to the ethnic composition of social settings) and high-quality forms of social relations. Given that only the latter has direct implications for ethnic homophily, scholars should not use social relations interchangeably with exposure. In addition, when only cross-sectional data on social relations are available, scholars should acknowledge that these relations likely reflect both network segregation patterns that emerge in the short run and dynamics that evolve over longer periods of exposure. Although, on average, ties do not evolve particularly homophiliously, the segregation dynamics that are initially present appear to condition the later extent of homophily – namely, more integrated networks tend to have social relations that continue to evolve in less homophilous ways. These results also illustrate the benefits of dynamic network analyses that condition on initial networks, and thus scholars should increase the availability of panel data that permits the analyses of tie evolution.

Yet if high levels of interethnic friendship contact in classroom contexts can explain low levels of ethnic homophily in how individuals update their ties, this implies that even casual forms of contact between members of different social categories may have the benefit of reducing homophily. To clarify, I find no evidence of direct implications of simple ethnic composition for homophily. However by simply having people of different social categories in the same social setting – such as students of different ethnic backgrounds in the same classroom – there will be mechanically less network segregation due to the contributions of random chance to tie formation (Moody, 2001). My results show that such network integration might reduce levels of homophily in the subsequent evolution of friendships. In other words, even simple exposure may be beneficial through its ability to generate more opportunities for higher quality contact. Similarly, the lack of network ties between different social groups may be more harmful than previously anticipated. For example, future studies might consider the possibility of a negative feedback loop, in which network segregation exacerbates homophily, which contributes to more network segregation over time.

Note that there are at least two mechanisms that could produce a link between initial network segregation and later homophily: first, initial friendships could shape preferences for similarity over time; second, the conditions that encourage initial interethnic friendships could continue to shape individuals' attitudes over time and have a lasting benefit in reducing ethnic homophily. It is probable that both mechanisms are at play – both support my argument that the optimal conditions for contact are crucial and that their benefits also appear longitudinally. While a causal argument is beyond the scope of this study, future research could move closer to such an argument by analyzing the implications of network segregation for homophily among individuals who are newcomers in classrooms. Such research would require many more observations of networks (to generate enough newcomers to study) and ideally a third wave of data that contains information on network segregation within newcomers' prior classrooms.

Finally, while this study builds on and addresses recent studies of homophily that get at tastes for similarity net other relational explanations of ties, there are several limitations to this approach. Namely, this strategy can mask conditions in which network segregation has different implications for different individuals' homophily. On average, the there is a positive association between initial network segregation in contexts and subsequent homophily, but network segregation may matter more for some individuals' homophily than others, which is a possibility that future research should explore. In addition, given the importance of network integration, more work must be done on the question of what kinds of policies encourage friendship integration beyond classroom composition. As levels of immigration continue to rise in Sweden, Western Europe, and beyond, networks play an increasingly important role in shaping attitudes towards social differences.

Appendix

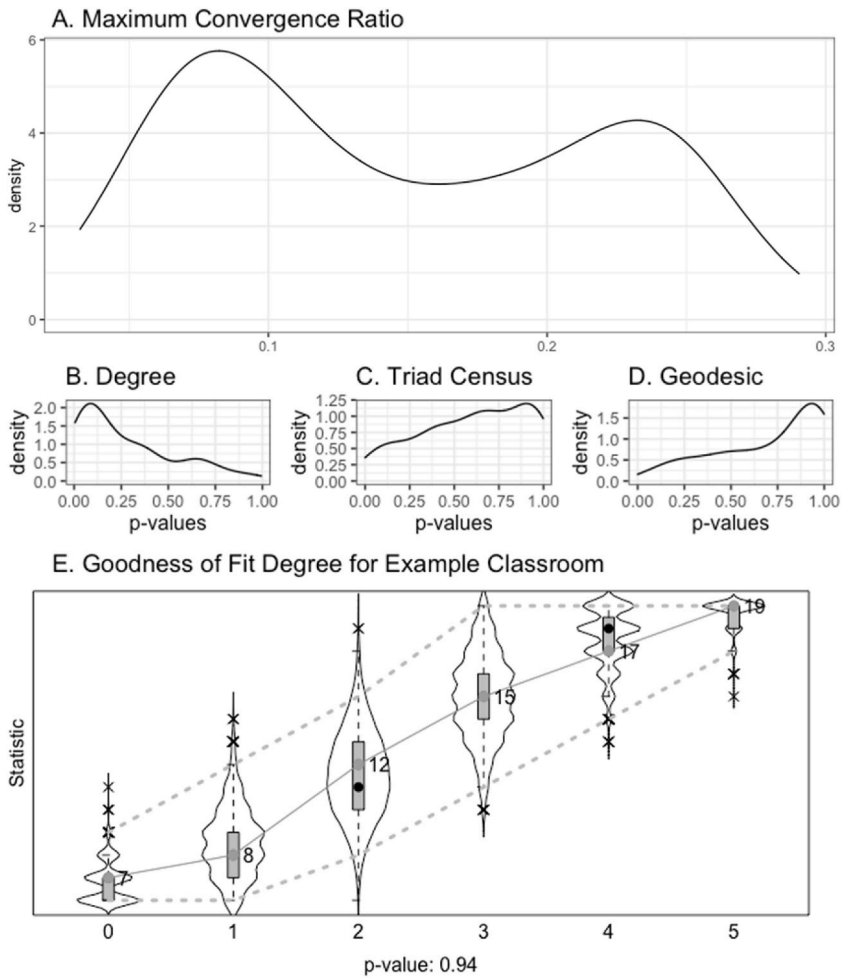

Figure A-1. Convergence and Goodness of Fit Diagnostics.

Table A-1
Predicting ethnic homophily.

	Main results		Disaggregating ethnic groups		Aggregating ethnic groups		Restrictive sample	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ethnic Network Segregation								
Moody's Index	0.28*	–	0.23*	–	0.11		0.27*	–
	(0.11)		(0.11)		(0.12)		(0.13)	
N&G's Index	–	1.13**	–	0.87**	–	0.67	–	0.92*
		(0.38)		(0.31)		(0.52)		(0.45)
Native-Immigrant Network Segregation								
Moody's Index	0.27**	–	0.19	–	0.26*	–	0.25*	–
	(0.11)		(0.10)		(0.13)		(0.12)	
N&G's Index	–	0.62*	–	0.50	–	0.64*	–	0.65
		(0.27)		(0.26)		(0.32)		(0.33)

Notes: (1) Predicting ethnic homophily coefficient using initial network segregation, classroom size, mean SES, and proportion migrant (2) N&G refers to Newman and Girvan's index (3) The disaggregation vs aggregation of ethnic groups refers to whether all countries of origin are treated as separate ethnic groups whenever possible, even less common countries of origin, or whether ethnicity is aggregated into two broad categories – "western" and "nonwestern" (4) The restrictive sample repeats the analyses using the definition of ethnicity in the main results but only using the subset of classrooms where the participation rate was more than 70% in both waves.

Table A-2
Implications of Network Segregation for Ethnic Homophily in Tie-Creation and Tie-Maintenance.

	Tie-Creation Homophily		Tie-Maintenance Homophily	
	(1) RSIENA	(2) OLS	(3) RSIENA	(4) OLS
Network Segregation	0.55 (0.37)	0.52** (0.19)	−0.02 (0.25)	−0.16 (0.22)
Proportion Migrant	−0.74 (1.19)	−0.07 (0.48)	−0.06 (0.73)	0.13 (0.53)
Mean SES	−0.33 (0.25)	−0.01 (0.01)	0.12 (0.16)	0.02 (0.01)
Class Size	0.15 (0.28)	0.04 (0.03)	−0.15 (0.18)	−0.04 (0.03)

Notes: (1) and (3) meta-analyses of RSIENA models that include separate endowment and creation effects; (2) OLS regression of proportion same-ethnic ties that are dropped to proportion inter-ethnic ties that are dropped; (4) OLS regression of the proportion of potential inter-ethnic ties that are created to the proportion of potential same-ethnic ties that are created.

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