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Research Paper

Destabilizing segregation in friendship networks with farsighted agents

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ABSTRACT

We consider a model of friendship network formation based on de Marti and Zenou (2017) where individuals belong to two different communities and costs of forming links depend on community memberships. Once there are myopic and farsighted individuals in both communities, many inefficient friendship networks such as segregation, partial integration or partial assimilation become destabilized. In the case of low intra-community costs, either (for high inter-community costs) the network where the smaller community ends up being assimilated into the dominant community or (for low inter-community costs) the network where both communities are fully integrated is both stable and strongly efficient. In the case of intermediate intra-community costs, star networks with a myopic individual in the center are both stable and strongly efficient.

1. Introduction

Social networks or friendship networks are important in obtaining information on goods and services, like product information or information about job opportunities. Individuals are often regrouped into communities based on their ethnicity, religion, income, education, etc. (see e.g. de Marti and Zenou, 2017). Beside belonging to different communities, individuals often differ in their degree of farsightedness, i.e., their ability to forecast how others will react to the decisions they take. Indeed, recent experiments on network formation provide evidence in favor of a mixed population consisting of both myopic and (limited) farsighted individuals (see Kirchsteiger et al., 2016; Teteryatnikova and Tremewan, 2020). The degree of farsightedness and the depth of reasoning are often correlated with other relevant attributes such as education, income, age, etc. (see Mauersberger and Nagel, 2018).

The aim of this paper is to provide a theoretical study of how different degrees of farsightedness affect the formation of friendship relationships when individuals can belong to various communities.[1] It is important to understand what happens when myopic individuals interact with farsighted individuals since, in general, some networks that are stable when all players are myopic could now be destabilized once individuals are mixed. In particular, we are interested in addressing the following set of questions. What are the friendship network structures that may endogenously arise once individuals belonging to two different communities can be either

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[1] Jackson (2008) and Goyal (2007) provide a comprehensive introduction to the theory of social and economic networks. Mauleon and Vannetelbosch (2016) give an overview of the solution concepts for solving network formation games. In Bramoullé et al. (2016), one can find the recent developments on the economics of networks.

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myopic or farsighted in forming links? When do we observe integration, segregation or (partial) assimilation? Does farsightedness help to bridge communities and to integrate societies? Do myopic individuals end up assimilated to the dominant community? Are individual incentives to link adequate from a social welfare point of view? Does it improve efficiency if some individuals become farsighted? And if yes, whom?

To answer these questions we consider a model of network formation based on de Marti and Zenou (2017) where individuals belong to two different communities. Communities may be defined along social categories such as ethnicity, religion, education, income, etc. In contrast to de Marti and Zenou (2017) where all individuals were myopic, we now allow the possibility of having a mixed population composed of both myopic and farsighted individuals. Myopic or farsighted individuals decide with whom they want to form a link, according to a utility function that weights the costs and benefits of each connection. Farsighted individuals are able to anticipate that once they add or delete some links, other individuals could add or delete links afterwards. Benefits of a friendship connection decrease with distance in the network, while the cost of a link depends on the type of individuals involved. Two individuals from the same community face a low linking cost, while the cost of forming a friendship relationship between two individuals from different communities decreases with the rate of exposure of each of them to the other community.

We adopt the notion of myopic-farsighted stable set to determine the friendship networks that emerge when some individuals are myopic while others are farsighted.[2] A myopic-farsighted stable set is the set of networks satisfying internal and external stability with respect to the notion of myopic-farsighted improving path. That is, a set of networks is a myopic-farsighted stable set if there is no myopic-farsighted improving path between networks within the set and there is a myopic-farsighted improving path from any network outside the set to some network within the set. A myopic-farsighted improving path is simply a sequence of networks that can emerge when farsighted individuals form or delete links based on the improvement the end network offers relative to the current network while myopic individuals form or delete links based on the improvement the resulting network offers relative to the current network. A network is said to be stable if it belongs to some myopic-farsighted stable set.

When all individuals are myopic, many inefficient friendship networks such as segregation, partial integration or partial assimilation can be stable. In addition, other inefficient asymmetric network configurations can also be stable. For instance, the network in which both communities are fully intra-connected and where there is only one bridge link can be stabilized. Thus, a tension between efficiency and stability may occur since inefficient or even Pareto-dominated networks, like segregation, partial integration or partial assimilation, can arise.

What happens when the population is composed of both myopic and farsighted individuals and intra-community costs are low? We first show that, if farsighted individuals in the dominant community are relatively numerous and inter-community costs are large enough, then a friendship network where individuals of the small community are fully assimilated into the dominant community is both stable and strongly efficient. Precisely, a singleton set consisting of the network where the smaller community is assimilated into the dominant one is a myopic-farsighted stable set. In a friendship network where the small community is fully assimilated into the dominant community, each individual belonging to the dominant community is linked to all individuals in both communities while each individual belonging to the small community is only linked to all individuals in the dominant community.

The complete segregation, partial integration or partial assimilation are destabilized because farsighted individuals, while they do not have immediate incentives to add or delete links, anticipate that once they do so, other individuals will continue adding or deleting links leading to a friendship network where the small community is assimilated into the larger one. First, farsighted individuals in the dominant community push farsighted individuals in the small community into a friendship network where farsighted individuals in the small community are worse off compared to what they obtain when they are fully assimilated into the dominant community. Next, farsighted individuals in the dominant community lure the myopic individuals in the small community with the prospect of forming a friendship network where the dominant community is fully assimilated into the smaller one. From such friendship network, farsighted individuals in the dominant community are able to induce a switch towards the opposite fully assimilated network, the friendship network where the small community is fully assimilated into the dominant community, where they achieve their best outcome. The fewer farsighted individuals in the small community are, the more likely this friendship network will arise. In the limit, when all individuals in the small community tend to be myopic, a singleton set consisting of the network where the smaller community is assimilated into the dominant one is the unique myopic-farsighted stable set.

In addition, we are able to provide the lower bound on the relative number of farsighted individuals in the dominant community relative to the number of individuals in the small community so that the friendship network where the smaller community ends up being assimilated into the dominant community is stable. Thus, turning myopic individuals into farsighted ones, especially in the dominant community, could be very helpful in avoiding (Pareto-) inefficient friendship networks like segregation, partial integration or partial assimilation.

Notice that, for large inter-community costs, if all individuals in the small community become farsighted while there are both myopic and farsighted individuals in the dominant community and the smaller community is not too small relatively to the other one, then a friendship network where individuals in the dominant community are fully assimilated into the small community could be stabilized and it Pareto dominates the complete segregated network. For small inter-community costs, the complete integrated network remains stable whatever the number of farsighted and myopic individuals within the population and it is efficient.

In the case of intermediate intra-community costs, we show that a mixed population of farsighted and myopic individuals again solve the tension between stability and efficiency. Many friendship networks are stable when all individuals are myopic, but once

[2] Herings et al. (2020) were first to define the myopic-farsighted stable set for two-sided matching problems. This notion is extended to R&D network formation with pairwise deviations in Mauleon et al. (2023) and to general network formation problems in Luo et al. (2021).

there are enough farsighted individuals, independently to which community they belong, then a star network with a myopic individual in the center is going to arise and is efficient.

We now turn to the related literature. There is an extensive literature using network models to explain the fact that individuals are more likely to be linked to individuals who have similar characteristics. Currarini et al. (2009) develop a dynamic random matching model with a population formed by groups of different sizes and show that segregation in social networks results from the decisions of the individuals involved and/or from the ways in which individuals meet and interact. In equilibrium, individuals' behavior is totally homogeneous within the same group of individuals. Bramoullé et al. (2012) develop a model of dynamic matching with both random meetings and network-based search. They show that majority and minority groups have different patterns of interactions and that relative homophily in the network is strongest when groups have equal size, and vanishes as groups have increasingly unequal sizes.[3]

Despite strong empirical evidence, few models of network formation with differentiated communities have studied the impact of social networks on the long-run integration outcome of minorities. Jackson and Rogers (2005) extend the Jackson and Wolinsky (1996) connection model by including two communities and assuming that the cost of linking two individuals from different communities is exogenous and independent of the behavior of the two individuals involved in the link. Johnson and Gilles (2000) add a geographical dimension to Jackson and Wolinsky (1996) connection model assuming that the cost of a link is proportional to the geographical distance between two individuals. As already mentioned, de Marti and Zenou (2017) model is a variation of the connection model where the cost of a link is endogenous and depends on the neighborhood structure of the two individuals involved in the link.

We go further the related literature by considering the impact of a mixed population along two dimensions (community membership and degree of farsightedness) on the stability of friendship networks. That is, we analyze how the presence of farsighted individuals can affect the long-run integration outcome and under which circumstances this can lead to either a segregated society or an integrated society or a society where one community is assimilated into the other one. By doing so, we stabilize the efficient network structure where the smaller community ends up being assimilated into the larger community.[4] Our analysis can be interpreted as a medium term analysis since the next generations of assimilated individuals are likely to end up being fully integrated.

Another strand of the literature studies the role of social networks in the assimilation of immigrants, a hot debate in the United States and in Europe. There is strong evidence showing that family, peers and communities affect assimilation decisions (see e.g. Bisin et al., 2016). In particular, there may be a conflict between an individual's assimilation choice and that of her peers and between an individual's assimilation choice and that of her family and community. Verdier and Zenou (2017) study the role of the immigrant network in the assimilation process of ethnic minorities. They show that, in an exogenous network, the more central minority individuals are located in the social network, the more they assimilate to the majority culture. By endogenizing the network structure, they show when the ethnic minority will integrate or not into the majority group.[5]

Assimilation of immigrants in Western Europe and North America is a social process motivated and guided by cultural beliefs, formal rules, informal norms, and social networks. Class inequality interacts with parental immigrant culture in maintaining ethnic and religious identities among the second generation, separating them from natives (Drouhot and Nee, 2019). Studies done in Germany, the United Kingdom, and the Netherlands suggest that the main predictors of contacts with native majority among immigrants are generational status and educational attainment (see Damstra and Tillie, 2016; Martinovic, 2013; Van Tubergen, 2015).[6] If perceived opportunities are more extensive in the mainstream than in ethnic enclaves, the purposive action of immigrants and their children will try to optimize returns to investment in human and cultural capital in the mainstream society, even in the face of opposition to their assimilation by members of the majority and minority groups (Nee and Alba, 2013). So, highly educated immigrants that can anticipate economic and social opportunities in the host country will maintain higher levels of social contacts with host country ethnics.

The paper is organized as follows. In Section 2 we present our model based on de Marti and Zenou (2017) model of friendship networks with two communities. In Section 3 we introduce the concept of myopic-farsighted stable sets. In Section 4 we provide a characterization of the myopic-farsighted stable sets when intra-community costs are low. In Section 5 we consider the case where intra-community costs are intermediate. In Section 6 we look at the tension between stability and efficiency. In Section 7 we conclude.

2. Friendship networks with two communities

We consider a model of friendship networks based on de Marti and Zenou (2017) where individuals belong to two different communities.[7] Individuals benefit from direct and indirect connections to others, which can be interpreted as positive externalities.

[3] Golub and Jackson (2012) study how the speed of learning and best-response processes depends on homophily. Pin and Rogers (2016) provide a survey on stochastic network formation and homophily. Mele (2017) proposes a dynamic model of network formation that combines strategic and random networks features.

[4] Using data from the German Socio-Economic panel for the period 1996 to 2011, Facchini et al. (2015) find that first generation migrants who have a German friend are more similar to German natives than migrants who do not. In addition, the educational achievement is positively related to the likelihood of forming friendships with majority group members. Similarly, from data of the European Community Household Panel (1994–2001), De Palo et al. (2007) find that more educated migrants tend to socialize more intensively with the majority community.

[5] Verdier and Zenou (2018) study the population dynamics of cultural traits emphasizing different facets of the impact of forward looking cultural leaders in the process of cultural assimilation of minority communities.

[6] Using original survey data on Turkish immigrants in Germany, France, and The Netherlands, Ersanilli and Koopmans (2011) show that Turks of the in-between generation are more highly educated (and those currently employed) report higher levels of social contact with host country ethnics. Based on the European Community Household panel (ECHP), De Palo et al. (2007) show that more educated migrants tend to relate somewhat less with their close neighborhood, but quite intensively with the broader community.

[7] See also Bjerre-Nielsen (2020) for a related model of network formation with multiple types.

These benefits decay with distance between individuals and the cost of forming links may depend on community memberships. The novelty is that individuals can now be either farsighted or myopic when deciding about the friendship links they want to form. In de Marti and Zenou (2017) all individuals were supposed to be myopic.

The set of individuals is denoted by $N = N^M \cup N^F$, where N^M is the set of myopic individuals and N^F is the set of farsighted individuals. Let n be the total number of individuals and $n^M \geq 0$ ($n^F = n - n^M \geq 0$) be the number of myopic (farsighted) individuals. Moreover, the population is divided into two communities $N = N^B \cup N^G$, where N^B is the *blue* community and N^G is the *green* community. Each individual belongs to one of the two communities and the type of individual i is denoted as $\tau(i) \in \{N^B, N^G\}$. We have $n = n^B + n^G$, where n^B and n^G denote, respectively, the number of N^B individuals and the number of N^G individuals in the population. Let $n^{M,B}$ and $n^{F,B}$ be, respectively, the number of myopic and farsighted individuals in the blue community, with $n^B = n^{M,B} + n^{F,B}$. Let $n^{M,G}$ and $n^{F,G}$ be, respectively, the number of myopic and farsighted individuals in the green community, with $n^G = n^{M,G} + n^{F,G}$. Notice that $n^M = n^{M,B} + n^{M,G}$, $n^F = n^{F,B} + n^{F,G}$ and $n = n^M + n^F$. Without loss of generality, the green community is the largest one and there are at least two individuals in each community: $1 < n^B \leq n^G$.

A friendship network g is a list of which pairs of individuals are linked to each other and $ij \in g$ indicates that i and j are linked under g. The complete network on the set of individuals $S \subseteq N$ is denoted by g^S and is equal to the set of all subsets of S of size 2. It follows in particular that the empty network is denoted by $g^{\emptyset}$. The set of all possible networks on N is denoted by $\mathcal{G}$ and consists of all subsets of g^N. The network obtained by adding link ij to an existing network g is denoted $g + ij$ and the network that results from deleting link ij from an existing network g is denoted $g - ij$. Let $N(g) = \{i \mid \text{there is } j \text{ such that } ij \in g\}$ be the set of individuals who have at least one link in the network g. Let $N_i(g) = \{j \in N \mid ij \in g\}$ be the set of neighbors (or friends) of individual i in g.[8] Let $n_i(g) = \#(N_i(g))$ be the number of neighbors (or friends) of individual i in g. A path in a network g between i and j is a sequence of individuals $i_1, \ldots, i_K$ such that $i_k i_{k+1} \in g$ for each $k \in \{1, \ldots, K-1\}$ with $i_1 = i$ and $i_K = j$. A network g is connected if for all $i \in N$ and $j \in N \setminus \{i\}$, there exists a path in g connecting i and j. A non-empty sub-network $h \subseteq g$ is a component of g, if for all $i \in N(h)$ and $j \in N(h) \setminus \{i\}$, there exists a path in h connecting i and j, and for any $i \in N(h)$ and $j \in N(g)$, $ij \in g$ implies $ij \in h$. A star network is a network such that there exists some individual i (the center) who is linked to every other individual $j \neq i$ (the peripherals) and that contains no other links (i.e. g is such that $N_i(g) = N \setminus \{i\}$ and $N_j(g) = \{i\}$ for all $j \in N \setminus \{i\}$).

A network utility function (or payoff function) is a mapping $U_i : \mathcal{G} \to \mathbb{R}$ that assigns to each network g a utility $U_i(g)$ for each individual $i \in N$. A network $g \in \mathcal{G}$ is strongly efficient if $\sum_{i \in N} U_i(g) \geq \sum_{i \in N} U_i(g')$ for all $g' \in \mathcal{G}$. A network $g \in \mathcal{G}$ Pareto dominates a network $g' \in \mathcal{G}$ relative to U if $U_i(g) \geq U_i(g')$ for all $i \in N$, with strict inequality for at least one $i \in N$. A network $g \in \mathcal{G}$ is Pareto efficient relative to U if it is not Pareto dominated, and a network $g \in \mathcal{G}$ is Pareto dominant if it Pareto dominates any other network.

Preferences are given by

$$U_i(g) = \sum_{j \neq i} \delta^{t(i,j)} - \sum_{j \in N_i(g)} c_{ij}(g),$$

where $t(ij)$ is the number of links in the shortest path between i and j (setting $t(ij) = \infty$ if there is no path between i and j), $0 < \delta < 1$ is the benefit from a connection that decreases with the distance of the relationship, and $c_{ij}(g) > 0$ is the cost for individual i of maintaining a direct link with j. The cost of forming one link may vary as a function of the type of individuals connected by such link. Following de Marti and Zenou (2017), given a network g such that $0 < n_i^{\tau(i)}(g) < n_i(g)$, the rate of exposure of individual i to her own community $\tau(i)$ is equal to

$$e_i^{\tau(i)}(g) = \frac{n_i^{\tau(i)}(g)}{n_i(g) - 1} \tag{1}$$

where $n_i^{\tau(i)}(g)$ is the number of i's same-type friends in network g while $n_i(g)$ is the total number of i's friends in network g. For $n_i(g) = 0$, we simply assume that $e_i^{\tau(i)}(g) = 0$.

Let c and C be strictly positive parameters, $c > 0$ and $C > 0$.[9] The cost for individual i of maintaining a link with j, $c_{ij}(g)$, depends on whether i and j belong or not to the same community:

$$c_{ij}(g) = \begin{cases} c & \text{if } \tau(i) = \tau(j) \\ c + e_i^{\tau(i)}(g) \cdot e_j^{\tau(j)}(g) \cdot C & \text{if } \tau(i) \neq \tau(j). \end{cases}$$

Such cost function assumes that it is less costly to interact with someone of the same type (intra-community cost) than with someone of a different type (inter-community cost). Notice that C is not present in the cost of a link between individuals of the same community. But, C becomes an additional cost when two individuals from different communities, having links with individuals of their own community, form a link between them. For instance, if a green individual has only green friends, then it will be more costly for her to interact with a blue individual that has mostly blue friends. However, the more similar the friendship composition of two individuals of different types, the easier it is for them to interact. If at least i or j has no friends of the same type (i.e., $e_i^{\tau(i)} = 0$ or $e_j^{\tau(j)} = 0$), then it is equally costly for them to interact with someone of the opposite type as with someone of the same

[8] Throughout the paper we use the notation $\subseteq$ for weak inclusion and $\subsetneq$ for strict inclusion. Finally, # will refer to the notion of cardinality.

[9] For $C = 0$ the model of de Marti and Zenou (2017) reverts to the connections model introduced by Jackson and Wolinsky (1996).

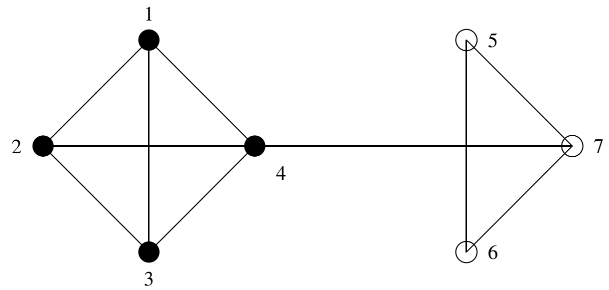


Fig. 1. A bridge link between both communities. Greens are represented by solid circles while blues are represented by circles.

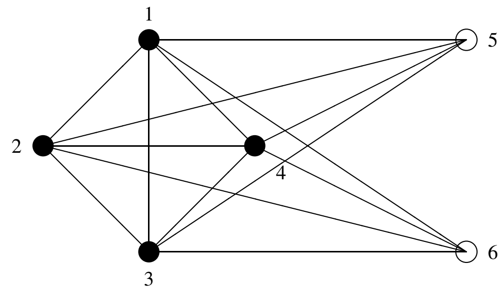


Fig. 2. The blue community is fully assimilated within the green community.

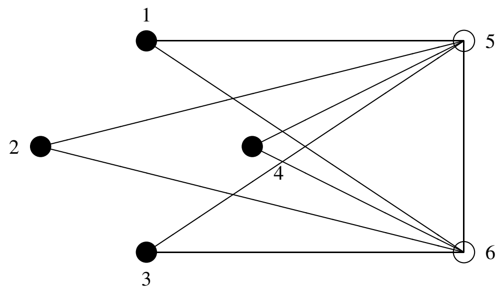


Fig. 3. The green community is fully assimilated within the blue community.

type (i.e., the cost is c in both cases).[10] In Fig. 1 we depict a friendship network among seven individuals and two communities ($N^G = \{1,2,3,4\}$, $N^B = \{5,6,7\}$) with a bridge link between both communities. Green individuals are represented by solid circles while blue individuals are represented by circles. For instance, green individual 4's payoff is equal to $4\delta + 2\delta^2 - 4c - C$ since $e_4^{\tau(4)} = 3/(4-1) = 1$ and $e_7^{\tau(7)} = 2/(3-1) = 1$.

We now describe some prominent network configurations in the case of friendship networks with communities. Let $g_{\text{assi,green}}$ denote the network where all members of the blue community are fully assimilated to the dominant (or larger) green community. That is, each green individual is linked to all other (green and blue) individuals while each blue individual is only linked to all green individuals. Formally, $g_{\text{assi,green}} = g^{N^G} \cup \{ij \mid i \in N^G, j \in N^B\}$. In $g_{\text{assi,green}}$, a green individual obtains $(n-1)(\delta - c)$ as utility, while a blue obtains $(n^G)(\delta - c) + (n^B - 1)\delta^2$ as utility. In Fig. 2 we depict $g_{\text{assi,green}}$ for $N^G = \{1,2,3,4\}$ and $N^B = \{5,6\}$. Similarly, let $g_{\text{assi,blue}}$ denote the network where all members of the green community are fully assimilated to the smaller blue community. That is, each blue individual is linked to all other (green and blue) individuals while each green individual is only linked to all blue individuals. Formally, $g_{\text{assi,blue}} = g^{N^B} \cup \{ij \mid i \in N^B, j \in N^G\}$. In $g_{\text{assi,blue}}$, a blue individual obtains $(n-1)(\delta - c)$ as utility, while a green obtains $(n^B)(\delta - c) + (n^G - 1)\delta^2$ as utility. In Fig. 3 we depict $g_{\text{assi,blue}}$ for $N^G = \{1,2,3,4\}$ and $N^B = \{5,6\}$. Let g_{int} denote the complete integrated network where both communities are fully intra-connected and fully inter-connected: $g_{\text{int}} = g^N$ and is depicted in Fig. 4. In g_{int}, a green individual and a blue individual obtain, respectively,

$$(n-1)(\delta - c) - n^B \frac{n^G - 1}{n-2} \frac{n^B - 1}{n-2} C \text{ and } (n-1)(\delta - c) - n^G \frac{n^B - 1}{n-2} \frac{n^G - 1}{n-2} C$$

[10] In the definition of the rate of exposure (see the expression (1)), we subtract 1 in the denominator because, when computing the cost of a given bridge link between communities, this bridge link is not included in the computation of the cost. What is relevant for the cost is the rate of exposure according to the rest of the connections of each of the two individuals involved in the bridge link.

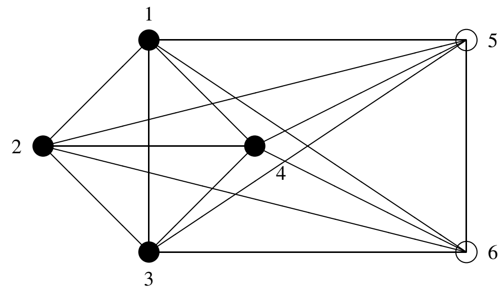


Fig. 4. Both communities are fully integrated.

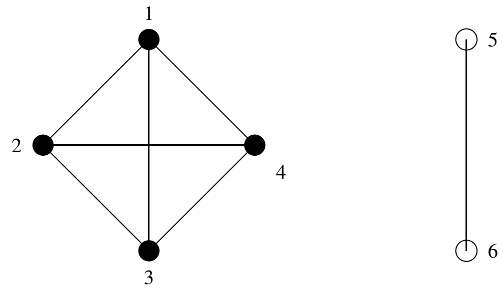


Fig. 5. Both communities are segregated.

as utility. Let g_{seg} denote the complete segregated network where both communities are fully intra-connected but isolated of each other: $g_{\text{seg}} = g^{N^G} \cup g^{N^B}$ and is depicted in Fig. 5. In g_{seg}, a green individual obtains $(n^G - 1)(\delta - c)$ as utility, while a blue obtains $(n^B - 1)(\delta - c)$ as utility.

de Marti and Zenou (2017) adopt the notion of pairwise stability, introduced by Jackson and Wolinsky (1996), to study the networks that will be formed at equilibrium. A network is pairwise stable if no individual benefits from deleting a link and no two individuals benefit from adding a link between them. Formally, a network $g \in \mathcal{G}$ is pairwise stable if (i) for all $ij \in g$, $U_i(g) \geq U_i(g - ij)$ and $U_j(g) \geq U_j(g - ij)$, (ii) for all $ij \notin g$, if $U_i(g) < U_i(g + ij)$ then $U_j(g) > U_j(g + ij)$. Pairwise stability presumes that individuals are myopic: they do not anticipate that other individuals may react to their changes.

Many different network configurations can be pairwise stable depending on the exact intra- and inter-community costs. Consider first the case where intra-community costs are low, i.e. $c < \delta - \delta^2$. Proposition 1 in de Marti and Zenou (2017) shows that:

(i) The complete integrated network g_{int} is pairwise stable when inter-community costs are small;
(ii) The complete segregated network g_{seg} is pairwise stable when inter-community costs are large.

For intermediate inter-community costs, g_{int} and g_{seg} can be simultaneously pairwise stable. In addition, Proposition 2 in de Marti and Zenou (2017) shows that the following networks are pairwise stable when inter-community costs are intermediate:

(iii) The network $\widetilde{g_1}$ in which both communities are fully intra-connected and where there is only one bridge link (see Fig. 1);
(iv) The network $\widetilde{g_2}$ in which both communities are fully intra-connected, where each blue individual has one and only one bridge link, and where each green individual has at most one bridge link;
(v) The network $\widetilde{g_3}$ in which both communities are fully intra-connected and with a unique blue individual connected with all green individuals.

In addition, one can show that networks involving assimilation or partial assimilation are pairwise stable when inter-community costs are large (see Proposition A.1 in Appendix A.1):

(vi) The network $g_{\text{assi,green}}$ where all the blue community is fully assimilated to the green community;
(vii) The network $g_{\text{assi,blue}}$ where all the green community is fully assimilated to the blue community;
(viii) The network $g_{\text{passi,green}}$ where some blue individuals are assimilated to the green individuals and all other blue individuals are intra-connected and segregated;
(ix) The network $g_{\text{passi,blue}}$ where some green individuals are assimilated to the blue individuals and all other green individuals are intra-connected and segregated.

Notice that other asymmetric networks can also be pairwise stable. For instance, the network in which both communities are fully intra-connected and in which one green individual is linked to all blue individuals.

In Section 4 we show that, once the population includes not only myopic individuals but also farsighted individuals who are able to anticipate that when they add or delete some links, other individuals could add or delete links afterwards, then the networks involving segregation such as g_{seg}, $g_{\text{passi,green}}$ and $g_{\text{passi,blue}}$ are going to be destabilized. Similarly for $\widetilde{g_1}$, $\widetilde{g_2}$ and $\widetilde{g_3}$.

Consider now the case where intra-community costs are intermediate, i.e. $\delta - \delta^2 < c < \delta$. Proposition 3 in de Marti and Zenou (2017) shows that:

(i) The bipartite network g_{bi} in which all green individuals are linked to all blue individuals and in which all blue individuals are linked to all green individuals is pairwise stable.

In addition, Proposition 5 in de Marti and Zenou (2017) shows that segregation and partial integration can be pairwise stable:

(ii) The network $\widetilde{g_4}$ with two disconnected star-shaped communities is pairwise stable when inter-community costs are large;
(iii) The network $\widetilde{g_5}$ where the star-shaped communities are connected through their central individuals is pairwise stable when inter-community costs are large;
(iv) The network $\widetilde{g_6}$ where each peripheral individual in the star-shaped community has one bridge link with the other peripheral individual, whereas central individuals have no bridge links, is pairwise stable when inter-community costs are intermediate;
(v) The network $\widetilde{g_7}$ where the central individuals in both star-shaped communities are linked to each other, and all peripherals individuals from both communities are linked to each other, is pairwise stable when inter-community costs are small.

In Section 5 we show that, once the population includes not only myopic individuals but also farsighted individuals, then the networks such as g_{bi}, $\widetilde{g_4}$, $\widetilde{g_5}$, $\widetilde{g_6}$ and $\widetilde{g_7}$ are going to be destabilized.

3. Myopic-farsighted stable sets

We adopt the notion of myopic-farsighted stable set introduced by Herings et al. (2020) for two-sided matching problems and by Luo et al. (2021) for network formation games to determine the networks that are stable when some individuals are myopic while others are farsighted.[11] A set of networks G is said to be a myopic-farsighted stable set if it satisfies the following two types of stability. Internal stability: No network in G is dominated by any other network in G. External stability: Every network not in G is dominated by some network in G. A network g' is said to be dominated by a network g if there is a myopic-farsighted improving path from g' to g.

A myopic-farsighted improving path is a sequence of distinct networks that can emerge when farsighted individuals form or delete links based on the improvement the end network offers relative to the current network while myopic individuals form or delete links based on the improvement the resulting network offers relative to the current network. Since we only allow for pairwise deviations, each network in the sequence differs from the previous one in that either a new link is formed between two individuals or an existing link is deleted. If a link is deleted, then it must be that either a myopic individual prefers the resulting network to the current network or a farsighted individual prefers the end network to the current network. If a link is added between some myopic individual i and some farsighted individual j, then the myopic individual i must prefer the resulting network to the current network and the farsighted individual j must prefer the end network to the current network.[12]

Definition 1. A myopic-farsighted improving path from a network g to a network g' is a finite sequence of distinct networks $g_1, \dots, g_K$ with $g_1 = g$ and $g_K = g'$ such that for any $k \in \{1, \dots, K-1\}$ either

(i) $g_{k+1} = g_k - ij$ for some ij such that $U_i(g_{k+1}) > U_i(g_k)$ and $i \in N^M$ or $U_j(g_K) > U_j(g_k)$ and $j \in N^F$; or
(ii) $g_{k+1} = g_k + ij$ for some ij such that $U_i(g_{k+1}) > U_i(g_k)$ and $U_j(g_{k+1}) \geq U_j(g_k)$ if $i, j \in N^M$, or $U_i(g_K) > U_i(g_k)$ and $U_j(g_K) \geq U_j(g_k)$ if $i, j \in N^F$, or $U_i(g_{k+1}) \geq U_i(g_k)$ and $U_j(g_K) \geq U_j(g_k)$ (with one inequality holding strictly) if $i \in N^M, j \in N^F$.

If there exists a myopic-farsighted improving path from a network g to a network g', then we write $g \to g'$. The set of all networks that can be reached from a network $g \in \mathcal{G}$ by a myopic-farsighted improving path is denoted by $\phi(g)$, $\phi(g) = \{g' \in \mathcal{G} \mid g \to g'\}$. When all individuals are myopic, our notion of myopic-farsighted improving path reverts to Jackson and Watts (2002) notion of improving path. When all individuals are farsighted, our notion of myopic-farsighted improving path reverts to Jackson (2008) and Herings et al. (2009) notion of farsighted improving path. A set of networks G is a myopic-farsighted stable set if the following two conditions hold. Internal stability: for any two networks g and g' in the myopic-farsighted stable set G there is no myopic-farsighted improving path from g to g' (and vice versa). External stability: for every network g outside the myopic-farsighted stable set G there is a

[11] See Chwe (1994), Herings et al. (2009), Mauleon et al. (2011), Ray and Vohra (2015, 2019), Roketskiy (2018) for definitions of the farsighted stable set when individuals are farsighted. Alternative notions of farsightedness for network formation are suggested by Dutta et al. (2005), Dutta and Vohra (2017), Herings et al. (2004, 2019), Page et al. (2005), Page and Wooders (2009) among others.

[12] Along a myopic-farsighted improving path, myopic players do not care whether other players are myopic or farsighted. They behave as if all players are myopic and they compare their resulting network's payoff to their current network's payoff for taking a decision. However, farsighted players know exactly who is farsighted and who is myopic and they compare their end network's payoff to their current network's payoff for taking a decision.

myopic-farsighted improving path leading to some network g' in the myopic-farsighted stable set G (i.e. there is $g' \in G$ such that $g \to g'$).

Definition 2. A set of networks $G \subseteq \mathcal{G}$ is a myopic-farsighted stable set if: **(IS)** for every $g, g' \in G$, it holds that $g' \notin \phi(g)$; and **(ES)** for every $g \in \mathcal{G} \setminus G$, it holds that $\phi(g) \cap G \neq \emptyset$.

A friendship network g is said to be stable if it belongs to some myopic-farsighted stable set. When all individuals are farsighted, the myopic-farsighted stable set is simply the farsighted stable set as defined in Herings et al. (2009) or Ray and Vohra (2015). When all individuals are myopic, the myopic-farsighted stable set boils down to the pairwise CP vNM set as defined in Herings et al. (2017) for two-sided matching problems.[13] Luo et al. (2021) characterize the myopic-farsighted stable set when all individuals are myopic (i.e. $N = N^M$): a set of networks is a myopic-farsighted stable set if and only if it consists of all pairwise stable networks and one network from each closed cycle.[14]

4. Low intra-community costs

When all individuals are myopic each myopic-farsighted stable set contains all pairwise networks. Hence, many inefficient friendship networks can be stabilized when both communities are composed of only myopic individuals. We now investigate what happens when the population is mixed in terms of their degree of farsightedness.

We consider the following three cases: (1) all individuals in both communities are mixed; (2) all individuals in the small blue community are farsighted; (3) all individuals in both communities are farsighted.

4.1. Farsighted and myopic agents in both communities

Suppose first that some individuals are farsighted while others are myopic in both communities. We show that if there are enough farsighted individuals in the dominant green community relatively to the size of the small blue community, then a friendship network where individuals of the small blue community are fully assimilated into the large green community is stable. In addition, friendship networks involving (partial) segregation or partial assimilation become destabilized.

Let $\widehat{C}$ be the lower bound on the inter-community cost parameter C such that, if there are enough farsighted individuals in the green community, $\{g_{\text{assi,green}}\}$ is a myopic-farsighted stable set whatever the number of farsighted or myopic individuals within the blue community. Formally,

$$\widehat{C} = (\delta - \delta^2 - c)\frac{(n^{F,G} + n^{M,B} - 2)^2(n^{F,G} + n^{M,B} - 3)}{n^{F,G}(n^{F,G} - 1)^2} \cdot \min\{1, n^{M,B}\}.$$

It is the lower bound on C such that a myopic blue individual has incentives to cut a link with another myopic blue individual in the complete component between farsighted green individuals and myopic blue individuals, i.e. $g^{(N^F \cap N^G) \cup (N^M \cap N^B)}$. Let $\underline{n}^G$ be given by

$$\underline{n}^G = (n^B - 1)\frac{(\delta - \delta^2 - c)}{(\delta - c)}.$$

It is the lower bound on the number of farsighted green individuals such that a farsighted blue individual prefers being fully assimilated into the green community than being unconnected from farsighted green individuals: for $i \in N^{F,B}$,

$$(n^B - 1)(\delta - c) + n^{M,G}(\delta - c) < n^G(\delta - c) + (n^B - 1)\delta^2$$

or,

$$(n^B - 1)(\delta - c) < n^{F,G}(\delta - c) + (n^B - 1)\delta^2$$

if and only if $n^{F,G} > \underline{n}^G$. Notice that $\underline{n}^G < n^B \leq n^G$.

Proposition 1 shows that if the number of farsighted individuals in the green community is large enough ($n^{F,G} > \underline{n}^G$) and inter-community costs are large enough ($C > \widehat{C}$), then the set $G = \{g_{\text{assi,green}}\}$ is a myopic-farsighted stable set.

Proposition 1. *Assume low intra-community costs, $c < \delta - \delta^2$, and inter-community costs, $C > \widehat{C}$. If $n^{F,G} > \underline{n}^G$, then the set $G = \{g_{assi,green}\}$, where $g_{assi,green} = g^{N^G} \cup \{ij \mid i \in N^G, j \in N^B\}$, is a myopic-farsighted stable set.*

All the proofs not in the main text can be found in Appendix B. In the proof of Proposition 1, we construct a myopic-farsighted improving path from any $g \neq g_{\text{assi,green}}$ leading to $g_{\text{assi,green}}$ along which farsighted green individuals first delete all their links to push

[13] The pairwise CP vNM set follows the approach by Page and Wooders (2009) who define the stable set with respect to path dominance, i.e. the transitive closure of ϕ.

[14] Notice that we do not require the consent of community members when adding or deleting links. Caulier et al. (2013) propose the concept of contractual stability to predict the networks that are going to emerge at equilibrium when the consent of coalition partners is needed for adding or deleting links.

farsighted blue individuals in a situation where they are worst off compared to what they obtain when they are fully assimilated into the green community. Next, farsighted blue individuals who are looking forward towards $g_{\text{assi,green}}$ delete all their links to reach a network where only the links (if any) between myopic blue individuals remain. Next, myopic blue individuals link to each other and to all farsighted green individuals. In fact, farsighted green individuals are luring myopic blue individuals with the prospect of a friendship network where green individuals are assimilated into the community of blue myopic individuals. Next, farsighted green individuals who are looking forward towards $g_{\text{assi,green}}$ build all the links between them to reach the network $g^{(N^F\cap N^G)\cup(N^M\cap N^B)}$ where farsighted green individuals and myopic blue individuals are fully integrated to each other. Next, myopic blue individuals delete all the links between them. They have incentives to do so since $C > \widehat{C}$ where $\widehat{C}$ is the lower bound on C so that myopic blue individuals have incentives to delete successively the links between them in $g^{(N^F\cap N^G)\cup(N^M\cap N^B)}$. Finally, farsighted blue individuals build the missing links with farsighted green individuals to form $g_{\text{assi,green}}$. Hence, we have that $\phi(g)\cap\{g_{\text{assi,green}}\}\neq\emptyset$ for all $g\neq g_{\text{assi,green}}$ and $G=\{g_{\text{assi,green}}\}$ satisfies (**ES**). Since $G=\{g_{\text{assi,green}}\}$ is a singleton set, it satisfies (**IS**) in Definition 2.

If there are more farsighted green individuals than myopic and farsighted blue individuals, then the condition $n^{F,G} > \underline{n}^G$ holds, and the friendship network $g_{\text{assi,green}}$ where blue individuals are assimilated into the dominant green community is stable. Since g_{seg}, $\widetilde{g}_1$, $\widetilde{g}_2$, $g_{\text{passi,green}}$ and $g_{\text{passi,blue}}$ are Pareto-dominated by $g_{\text{assi,green}}$, we have that $\phi(g_{\text{assi,green}})\cap\{g_{\text{seg}},\widetilde{g}_1,\widetilde{g}_2,g_{\text{passi,green}},g_{\text{passi,blue}}\}=\emptyset$. Hence, these Pareto-dominated networks are now destabilized.

Remark 1. Assume low intra-community costs, $c<\delta-\delta^2$, and inter-community costs, $C>\widehat{C}$. If $n^{F,G}>\underline{n}^G$ then the singleton set $G=\{g\}$ with $g\in\{g_{\text{seg}},\widetilde{g}_1,\widetilde{g}_2,g_{\text{passi,green}},g_{\text{passi,blue}}\}$ is never a myopic-farsighted stable set.

Suppose now that all blue individuals are myopic ($N^B\cap N^F=\emptyset$ and $n^{M,B}=n^B$). The next corollary shows that if there are enough farsighted individuals in the dominant group (green community) while all individuals in the other group (blue community) are myopic and $C>\widehat{C}$, then the friendship network where the blue individuals end up assimilated into the dominant green community will arise since $\{g_{\text{assi,green}}\}$ is the unique myopic-farsighted stable set.

Corollary 1. *Assume low intra-community costs, $c<\delta-\delta^2$, and inter-community costs, $C>\widehat{C}$. If $n^{F,G}>\underline{n}^G$ and $N^M=N^B$, then the set $G=\{g_{\textit{assi,green}}\}$, where $g_{\textit{assi,green}}=g^{N^G}\cup\{ij \mid i\in N^G, j\in N^B\}$, is the unique myopic-farsighted stable set.*

Proof. From Proposition 1 we have that $G=\{g_{\text{assi,green}}\}$ satisfies both (**IS**) and (**ES**). Farsighted and myopic green individuals obtain their highest possible payoff in $g_{\text{assi,green}}$ and myopic blue individuals have no incentive to delete any link nor to add a new link since $C>\widehat{C}$ and $c<\delta-\delta^2$.[15] Since $N^M=N^B$ it follows that $\phi(g_{\text{assi,green}})=\emptyset$. So, since $\phi(g)\cap\{g_{\text{assi,green}}\}\neq\emptyset$ for all $g\neq g_{\text{assi,green}}$ and $\phi(g_{\text{assi,green}})=\emptyset$, the set $G=\{g_{\text{assi,green}}\}$ is the unique myopic-farsighted stable set (any other set would violate (**IS**) and/or (**ES**)). □

4.2. The smaller community is farsighted

Suppose now that all individuals in the small blue community are farsighted. We first show that if inter-community costs are large enough and the blue community is not too small relatively to the green community, then a friendship network where individuals of the large green community are fully assimilated into the small blue community becomes stable.

Let $\widetilde{C}$ be the lower bound on the inter-community cost parameter C such that, in the case of low intra-community costs, $g_{\text{assi,blue}}$ is a myopic-farsighted stable set whatever the number of farsighted or myopic individuals within the green community. Formally,

$$\widetilde{C}=(\delta-\delta^2-c)\frac{(n^{F,B}+n^{M,G}-2)^2(n^{F,B}+n^{M,G}-3)}{n^{F,B}(n^{F,B}-1)^2}\cdot\min\{1,n^{M,G}\}.$$

It is the lower bound on C such that a myopic green individual has incentives to cut a link with another myopic green individual in the complete component between farsighted blue individuals and myopic green individuals, i.e. $g^{(N^F\cap N^B)\cup(N^M\cap N^G)}$.

Let $\underline{n}^B$ be given by

$$\underline{n}^B=(n^G-1)\frac{(\delta-\delta^2-c)}{(\delta-c)}\cdot\min\{1,n^{F,G}\}.$$

It is the lower bound on the size of the blue community such that a farsighted green individual prefers being fully assimilated into the blue community than being segregated from it. That is, for $i\in N^{F,G}$, $U_i(g_{\text{seg}})<U_i(g_{\text{assi,blue}})$ if and only if $n^B>\underline{n}^B$.

Proposition 2 shows that if there are enough individuals in the blue community relatively to the green one ($n^B>\underline{n}^B$) and inter-community costs are large enough ($C>\widetilde{C}$), then the set $G=\{g_{\text{assi,blue}}\}$ is a myopic-farsighted stable set since from any network $g\neq g_{\text{assi,blue}}$ there is a myopic-farsighted improving path leading to $g_{\text{assi,blue}}$. In the proof of Proposition 2 we construct such myopic-farsighted improving path. This myopic-farsighted improving path is similar to the one for Proposition 1 by switching blue individuals

[15] Proposition 1 in de Marti and Zenou (2017) shows that g_{int} is pairwise stable if and only if $C<\overline{C}_1$ where $\overline{C}_1=\frac{(n-2)^2(n-3)}{n^G(n^G-1)^2}(\delta-\delta^2-c)$ is the lower bound on C such that a myopic blue individual has incentives to cut a link with another blue individual in g_{int}. When $N^G=N^F$ and $N^B=N^M$, $\widehat{C}$ is equal to $\overline{C}_1$.

for green ones and vice versa. The major difference is that now the blue community has to be large enough relatively to the green community ($n^B > \underline{n}^B$) to ensure that farsighted green individuals are worst off once all blue individuals delete their links compared to what they obtain when they are fully assimilated into the blue community.[16]

Proposition 2. *Assume low intra-community costs, $c < \delta - \delta^2$, and inter-community costs, $C > \widetilde{C}$. Assume all individuals in the blue community are farsighted, $N^B \subseteq N^F$. If $n^B > \underline{n}^B$, then the set $G = \{g_{assi,blue}\}$, where $g_{assi,blue} = g^{N^B} \cup \{ij \mid i \in N^G, j \in N^B\}$, is a myopic-farsighted stable set.*

Suppose now that all green individuals are myopic ($N^G \cap N^F = \emptyset$ and $n^{M,G} = n^G$). Then, $\widetilde{C}$ is equal to $\overline{C}_2$, where $\overline{C}_2$ is the lower bound on C such that a myopic green individual has incentives to cut a link with another green individual in the complete integrated network, and it is given by

$$\overline{C}_2 = \frac{(n-2)^2(n-3)}{n^B(n^B-1)^2}(\delta - \delta^2 - c).$$

Thus, if $C > \overline{C}_2$, each myopic green individual has an incentive to delete some link to another green individual in the complete integrated network g_{int}, i.e. g^N.

The next corollary shows that if the dominant group (green community) is myopic while the other group (blue community) is farsighted and $C > \overline{C}_2$, then the friendship network where the green individuals end up assimilated into the small blue community will arise for sure since $\{g_{\text{assi,blue}}\}$ is the unique myopic-farsighted stable set.

Corollary 2. *Assume low intra-community costs, $c < \delta - \delta^2$, and inter-community costs, $C > \overline{C}_2$. Assume all individuals in the green community are myopic, $N^M = N^G$, and all individuals in the blue community are farsighted, $N^F = N^B$. Then, the set $G = \{g_{assi,blue}\}$, where $g_{assi,blue} = g^{N^B} \cup \{ij \mid i \in N^G, j \in N^B\}$, is the unique myopic-farsighted stable set.*

Proof. From Proposition 2 we have that $G = \{g_{\text{assi,blue}}\}$ satisfies both (**IS**) and (**ES**). Farsighted blue individuals obtain their highest possible payoff in $g_{\text{assi,blue}}$ and myopic green individuals have no incentive to delete any link nor to add a new link since $C > \overline{C}_2$ and $c < \delta - \delta^2$. Since $N^M = N^G$ it follows that $\phi(g_{\text{assi,blue}}) = \emptyset$. So, since $\phi(g) \cap \{g_{\text{assi,blue}}\} \neq \emptyset$ for all $g \neq g_{\text{assi,blue}}$ and $\phi(g_{\text{assi,blue}}) = \emptyset$, the set $G = \{g_{\text{assi,blue}}\}$ is the unique myopic-farsighted stable set (any other set would violate (**IS**) and/or (**ES**)). □

4.3. Both communities are farsighted

Suppose now that all individuals in both communities are farsighted, $N^{F,G} = N^G$ and $N^{F,B} = N^B$. Since $\widehat{C} = 0$ and $\widetilde{C} = 0$ when $n^{M,G} = 0$ and $n^{M,B} = 0$, it follows from Proposition 1 and Proposition 2 that:

(i) The set $\{g_{\text{assi,green}}\}$, where $g_{\text{assi,green}} = g^{N^G} \cup \{ij \mid i \in N^G, j \in N^B\}$, is a myopic-farsighted stable set for any inter-community costs $C > 0$;
(ii) The set $\{g_{\text{assi,blue}}\}$, where $g_{\text{assi,blue}} = g^{N^B} \cup \{ij \mid i \in N^G, j \in N^B\}$, is a myopic-farsighted stable set for any inter-community costs $C > 0$ if and only if the blue community is not too small relatively to the green one.

In the case all individuals are farsighted, Dutta and Vohra (2017) propose two related solution concepts: the rational expectations farsighted stable set (REFS) and the strong rational expectations farsighted stable set (SREFS) where they restrict coalitions (or pairs in our case) to hold common, history independent expectations that incorporate maximality regarding the continuation path. REFS and SREFS coincide with a farsighted stable set when the latter consists of networks with a single payoff (Theorem 1 of Dutta and Vohra, 2017). Thus, $G = \{g_{\text{assi,green}}\}$ is also a REFS and SREFS for any inter-community costs $C > 0$.[17] Similarly, for $G = \{g_{\text{assi,blue}}\}$.

If the blue community is relatively small (i.e. $n^B \leq \underline{n}^B$), then the set $\{g_{\text{assi,blue}}\}$ is never a myopic-farsighted stable set because $\phi(g_{\text{seg}}) \cap \{g_{\text{assi,blue}}\} = \emptyset$. Moreover, the set $\{g_{\text{seg}}\}$ is never a myopic-farsighted stable set because $\phi(g_{\text{assi,green}}) \cap \{g_{\text{seg}}\} = \emptyset$. Finally, the set $\{g_{\text{passi,blue}}\}$ is never a myopic-farsighted stable set since $\phi(g_{\text{assi,blue}}) \cap \{g_{\text{passi,blue}}\} = \emptyset$ for $n^B > \underline{n}^B$ and $\phi(g_{\text{seg}}) \cap \{g_{\text{passi,blue}}\} = \emptyset$ for $n^B \leq \underline{n}^B$.

Remark 2. Assume low intra-community costs, $c < \delta - \delta^2$, and inter-community costs, $C > 0$. Assume all individuals are farsighted, $N^F = N$.

(**i**) The set $G = \{g_{\text{assi,green}}\}$ is always a myopic-farsighted stable set.

[16] Notice that $\widetilde{C}$ is the counterpart of $\widehat{C}$ so that, for $C > \widetilde{C}$, once we reach the network $g^{(N^F \cap N^B) \cup (N^M \cap N^G)}$ along the myopic-farsighted improving path leading to $\{g_{\text{assi,blue}}\}$, myopic green individuals have incentives to delete successively all the links between them.

[17] See also Ray and Vohra (2019). A similar argument holds if we impose maximality constraints for a mixed population composed of farsighted and myopic individuals. Hence, friendship networks that belong to singleton myopic-farsighted stable sets are robust to alternative concepts, and so, they are more likely to arise.

(**ii**) The set $G = \{g_{\text{assi,blue}}\}$ is a myopic-farsighted stable set if and only if $n^B > \underline{n}^B$.
(**iii**) The set $G = \{g_{\text{seg}}\}$ is never a myopic-farsighted stable set.
(**iv**) The set $G = \{g_{\text{passi,green}}\}$ is never a myopic-farsighted stable set.
(**v**) The set $G = \{g_{\text{passi,blue}}\}$ is never a myopic-farsighted stable set.

Thus, the complete segregated network g_{seg}, the partially segregated networks $g_{\text{passi,green}}$ and $g_{\text{passi,blue}}$, and the friendship network $g_{\text{assi,blue}}$ in which all green individuals are fully assimilated into a too small blue community are destabilized when the whole population is farsighted.

5. Intermediate intra-community costs

We now consider situations where intra-community costs are intermediate, i.e. $\delta - \delta^2 < c < \delta$. So, it becomes more expensive to build links with individuals from the same community. We denote by g^{*i} the star network where individual i is the center of the star.

We next show that, if the whole population is mixed, independently of the distribution of myopic and farsighted individuals in the two communities, then a star network encompassing all individuals from both communities with some myopic individual in the center is going to arise.

Let $\gamma \in [0,1]$ be given by

$$\gamma = \min\left[\frac{n^B - 1}{n^{F,G} + n^B - 2}, \frac{n^G - 1}{n^{F,B} + n^G - 2}\right] \text{ if } n^{F,G} \neq 0 \text{ and } n^{F,B} \neq 0$$

and $\gamma = 1$ otherwise. When $n^{F,G} \neq 0$ and $n^{F,B} \neq 0$, γ is equal to the minimum between the rate of exposure of a farsighted blue individual in the center of a star component encompassing all farsighted green individuals and all myopic or farsighted blue individuals and the rate of exposure of a farsighted green individual in the center of a star component encompassing all farsighted blue individuals and all myopic or farsighted green individuals.[18]

Proposition 3. *Assume intermediate intra-community costs, $\delta - \delta^2 < c < \delta$, $N^F \neq \emptyset$ and $N^M \neq \emptyset$. If $c + \gamma C < (\delta - \delta^2)(1 + \delta(n^F - 1))$, then the set $G^* = \{g^{*i} \mid i \in N^M\}$ is the unique myopic-farsighted stable set.*

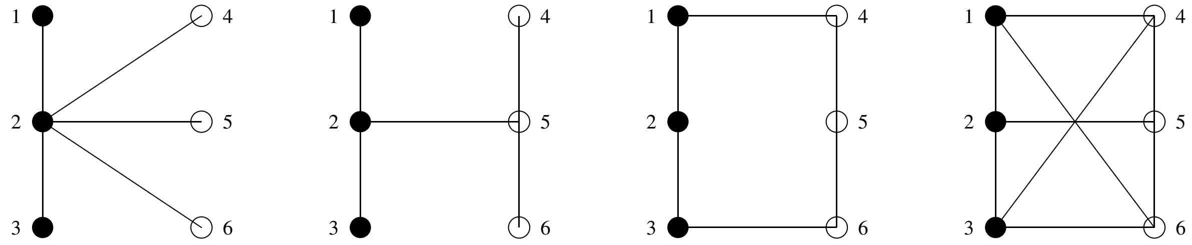
The set of star networks encompassing all individuals from both communities with some myopic individual in the center of the star satisfies the internal stability condition because myopic green and blue individuals who are peripherals have no incentive to delete their single link. The center who is myopic has also no incentive to delete one link. Finally, farsighted green and blue individuals do not have incentives to add or delete their single link because they are all peripherals in all networks in G^* and obtain the same payoff in all these networks.

We then prove external stability by building a myopic-farsighted improving path from any network g outside G^* to some network $g^{*i} \in G^*$ where farsighted green and blue individuals obtain their highest possible payoff. Along this path, farsighted green and blue individuals first delete all their links successively until they reach a network where they have no link and myopic individuals only keep the links to myopic individuals they had in g. Next, farsighted green and blue individuals who are looking forward to some $g^{*i} \in G^*$ build a star network among them. Looking forward to some $g^{*i} \in G^*$, the farsighted individual j^F in the center of the star among all the farsighted individuals adds first a link to some myopic individual, say 1^M, and then adds a link successively to the myopic individuals who are neighbors of 1^M until we reach a network where individual j^F is linked to individual 1^M and all her neighbors, and all other farsighted green and blue individuals. The myopic individuals are better off by adding these links given the sufficient condition on the inter-community cost. Then, the myopic individuals who are neighbors of individual 1^M and have just added a link to the farsighted individual j^F delete their link successively with individual 1^M. They have incentives to do so because of the intermediate intra-community costs. Looking forward to some $g^{*i} \in G^*$, the farsighted individual j^F repeat this process until we reach a network where there is no myopic individual linked directly to the myopic neighbors of individual j^F. Next, individual j^F adds a link to some myopic individual belonging to another component (if any) and proceeds as above until we end up with a star network g^{*j} encompassing all individuals with individual j^F in the center. From g^{*j}, individual j^F deletes all her links successively to reach the empty network. From the empty network, myopic and farsighted individuals have both incentives to add links successively to build some star network $g^{*i} \in G^*$ where some myopic individual $i \in N^M$ is in the center.

Proposition 3 tells us that only star networks encompassing all individuals from both communities with some myopic individual in the center of the star are stable.[19] Hence, friendship networks that were pairwise stable like the bipartite network g_{bi} in which all green individuals are linked to all blue individuals and in which all blue individuals are linked to all green individuals are now destabilized. Similarly, other networks that involve partial integration and were pairwise stable like the networks $\widetilde{g}_5$, $\widetilde{g}_6$ and $\widetilde{g}_7$ are now destabilized. In Fig. 6 we depict these different networks as well as a star network with player 2, who is a myopic green individual, in the center.

[18] The greatest rate of exposure of a myopic green (blue) individual, who contemplates adding a link to a farsighted blue (green) individual in the center of the star component encompassing all farsighted green (blue) individuals and all myopic or farsighted blue (green) individuals is equal to 1.

[19] Notice that $G^* = \{g^{*i} \mid i \in N^M\}$ is not only the unique myopic-farsighted stable set but (i) there is no myopic-farsighted improving emanating from each star network $g \in G^{\star}$ and (ii) from each $g' \notin G^{\star}$ there is a myopic-farsighted improving path leading to each $g \in G^{\star}$. Hence, star networks with some myopic individual in the center are robust predictions.



g^{*2} with $2 \in N^M$ $\widetilde{g}_5$ $\widetilde{g}_6$ $\widetilde{g}_7$

Fig. 6. Stable and unstable friendship networks when the population is composed of both farsighted and myopic individuals and intra-community costs are intermediate.

Once all individuals become farsighted (i.e. $N = N^F$), for $\delta - \delta^2 < c < \delta$ and for $C > 0$, every set consisting of a star network encompassing all individuals is a myopic-farsighted stable set

Proposition 4. *Assume intermediate intra-community costs, $\delta - \delta^2 < c < \delta$, and all individuals farsighted, $N = N^F$. If g is a star network then $\{g\}$ is a myopic-farsighted stable set.*

Proof. Since each set is a singleton set, internal stability (**IS**) is satisfied. (**ES**) Take any network $g \neq g^{*i}$, we need to show that $\phi(g) \ni g^{*i}$. **(i)** Suppose $g \neq g^{*j}$ $(j \neq i)$. From g, looking forward to g^{*i} (where they obtain their highest possible payoff), farsighted individuals ($\neq i$) delete all their links successively to reach the empty network. From $g^{\emptyset}$, farsighted individuals have incentives (since $\delta > c$) to add links successively to build the star network g^{*i} with individual i in the center. **(ii)** Suppose $g = g^{*j}$ $(j \neq i)$. From g, looking forward to g^{*i}, the farsighted individual j deletes all her links successively to reach the empty network. From $g^{\emptyset}$, farsighted individuals have incentives (since $\delta > c$) to add links successively to build the star network g^{*i} with individual i in the center. □

While every set consisting of a star network is a myopic-farsighted stable set, there may be other myopic-farsighted stable sets when the whole population is farsighted.

6. Stability versus efficiency

6.1. Low intra-community costs

Suppose that intra-community costs are low, i.e. $c < \delta - \delta^2$. Since, $n^G \geq n^B$, the network $g_{\text{assi,green}}$ is always better than the network $g_{\text{assi,blue}}$ in terms of strong efficiency (i.e. sum of utilities of all individuals). Comparing the network $g_{\text{assi,green}}$ with the complete integrated network g_{int}, we have that the network $g_{\text{assi,green}}$ is better than the complete integrated network g_{int} in terms of strong efficiency if and only if

$$C > \frac{(n-2)^2}{2n^G(n^G-1)}(\delta - \delta^2 - c) = C^*.$$

In addition, the network $g_{\text{assi,green}}$ is always better than the complete segregated network g_{seg} in terms of strong efficiency. In terms of Pareto efficiency, the network $g_{\text{assi,green}}$ always Pareto dominates the complete segregated network g_{seg}, while it only Pareto dominates the complete integrated network g_{int} if

$$C \geq \frac{(n-2)^2}{n^G(n^G-1)}(\delta - \delta^2 - c) = C^{**},$$

where $C^{**} > C^*$. Finally, the network $g_{\text{assi,blue}}$ Pareto dominates the complete integrated network g_{int} if

$$C \geq \frac{(n-2)^2}{n^B(n^B-1)}(\delta - \delta^2 - c) = C^{***},$$

where $C^{***} \geq C^{**} > C^*$.

Remark 3. Assume low intra-community costs, $c < \delta - \delta^2$. The complete segregated network g_{seg} is never strongly efficient and is Pareto dominated for any value of C. In terms of strong efficiency,

(i) if $C < C^*$, the complete integrated network g_{int} is better than the complete segregated network g_{seg} and the networks with assimilation $g_{\text{assi,green}}$ or $g_{\text{assi,blue}}$;

(ii) if $C > C^*$, the network $g_{\text{assi,green}}$ in which all blue individuals are fully assimilated into the dominant green community is better than the complete integrated network g_{int}, the complete segregated network g_{seg} and the network $g_{\text{assi,blue}}$ in which all green individuals are fully assimilated into the smaller blue community.

In terms of Pareto efficiency, if $C \geq C^{**}$, the network $g_{\text{assi,green}}$ Pareto dominates the complete integrated network g_{int}, and if $C \geq C^{***} \geq C^{**}$, the network $g_{\text{assi,blue}}$ Pareto dominates the complete integrated network g_{int}. The network $g_{\text{assi,green}}$ always Pareto dominates the complete segregated network g_{seg}, and if $n^B > \underline{n}^B$, the network $g_{\text{assi,blue}}$ Pareto dominates the complete segregated network g_{seg}.

Remark that the network $g_{\text{assi,green}}$ always Pareto dominates the network $g_{\text{passi,green}}$ whatever C. Hence, the networks with partial assimilation, $g_{\text{passi,green}}$ and $g_{\text{passi,blue}}$, are never strongly efficient. Similarly, for the partially integrated networks $\widetilde{g}_1$ and $\widetilde{g}_2$. In general, whether a network is strongly efficient or not depends on C. The formation of a link between two individuals from two different communities (the same community) has a positive (negative) exposure effect for both individuals involved in the link because the decrease (increase) in the rate of exposure of each of these individuals to their own community reduces (increases) their inter-community costs that are proportional to C. When C is very small, the difference between inter- and intra-community costs is negligible and it is as if the entire population belongs to a single community. Then, the complete integrated network g_{int} is strongly efficient. When C is large enough, inter-community costs exceed benefits derived from connecting to the other community, and the network $g_{\text{assi,green}}$ in which all blue individuals are fully assimilated into the dominant green community is strongly efficient.[20]

Is there a tension between stability and efficiency when C is larger than $\widehat{C}$?[21] When the whole population is myopic, a conflict between stability and efficiency may occur since many inefficient networks are stable: the complete segregated network g_{seg} as well as networks involving partial integration ($\widetilde{g}_1$, $\widetilde{g}_2$ and $\widetilde{g}_3$) or partial assimilation ($g_{\text{passi,green}}$ and $g_{\text{passi,blue}}$) can be pairwise stable.

However, once there are enough farsighted individuals in the dominant green community relatively to the size of the smaller community, $n^{F,G} > \underline{n}^G$, the tension between stability and efficiency vanishes. Indeed, the network $g_{\text{assi,green}}$ in which all blue individuals are fully assimilated into the dominant green community is likely to emerge since $\{g_{\text{assi,green}}\}$ is a myopic-farsighted stable set and $g_{\text{assi,green}}$ is not only better than $g_{\text{assi,blue}}$, g_{seg}, g_{int}, $g_{\text{passi,green}}$, $g_{\text{passi,blue}}$, $\widetilde{g}_1$ and $\widetilde{g}_2$ in terms of strong efficiency but it also Pareto dominates g_{seg}, g_{int}, $g_{\text{passi,green}}$, $\widetilde{g}_1$ and $\widetilde{g}_2$. Thus, turning myopic players into farsighted players within the dominant community may improve efficiency by destabilizing inefficient and/or Pareto dominated networks.

Remark that when C is larger than $\widetilde{C}$ and all blue individuals are farsighted and sufficiently numerous ($n^B > \underline{n}^B$), then the network $g_{\text{assi,blue}}$ becomes stable. Although the network $g_{\text{assi,green}}$ is better than the network $g_{\text{assi,blue}}$ in terms of strong efficiency, the network $g_{\text{assi,blue}}$ Pareto dominates the complete segregated network g_{seg}.

6.2. Intermediate intra-community costs

Remember that, for $C = 0$, de Marti and Zenou (2017) friendship model reverts to Jackson and Wolinsky (1996) connections model where a star network is strongly efficient for $\delta - \delta^2 < c < \delta$ (and $C = 0$). Hence, such star network is also strongly efficient for $\delta - \delta^2 < c < \delta$ and $C > 0$.

Remark 4. Assume intermediate intra-community costs, $\delta - \delta^2 < c < \delta$. A star network is strongly efficient.

When intra-community costs are intermediate and the population is formed by myopic and farsighted individuals, the set of star networks with a myopic individual at the center of the star is the unique myopic-farsighted stable set and each star network is strongly efficient. Thus, provided that the population is mixed, there is no tension between stability and efficiency.

7. Conclusion

de Marti and Zenou (2017) have considered a model of friendship network formation where individuals are myopic and belong to two different communities (greens and blues). When all individuals are myopic many inefficient friendship networks, like segregation, partial integration or partial assimilation, can be pairwise stable, and so, a tension between efficiency and stability may occur. We have added a second heterogeneity dimension: individuals can be either myopic or farsighted.

Once there are myopic and farsighted individuals in both communities, many inefficient friendship networks that were stable when the whole population was myopic such as segregation, partial integration or partial assimilation are now destabilized.

- In the case of low intra-community costs and large inter-community costs, the network where the smaller community ends up being assimilated into the dominant community is likely to arise since it is both stable and strongly efficient.
  Segregation is destabilized because farsighted individuals, while they do not have immediate incentives to add or delete links, anticipate that once they do so, other individuals will continue adding or deleting links leading to a friendship network where

[20] In $g_{\text{assi,green}}$ all blue individuals have no intra-community links, and so they are considered as if they were green individuals and they do not incur inter-community costs.

[21] Notice that $C^* < C^{**} \leq \overline{C}_1 \leq \overline{C}_2$, $C^{**} \leq C^{***} \leq \overline{C}_2$, $C^{**} \leq \widehat{C}$ and $C^{***} \leq \widetilde{C}$.

the small community is assimilated into the dominant one. In the long term, the offspring of assimilated individuals are likely to end up adopting characteristics and behaviors of the dominant community leading to a fully integrated society.[22]

- In the case of low intra-community costs and low inter-community costs, the network where both communities are fully integrated is both stable and strongly efficient.
- In the case of intermediate intra-community costs, a star network encompassing both communities with a myopic individual in the center of the star is going to arise for sure and is strongly efficient.

So, once the population is mixed in terms of farsightedness and myopia, the tension between stability and efficiency tends to vanish.

The degree of farsightedness of an individual is likely to be correlated with her level of education or grades at school. Hence, for future research it would be interesting to confront our theoretical predictions with empirical or experimental data. Segregation should mostly occur when both communities are low educated. When one community is high educated (i.e. a community with a large number of high educated individuals) while the other community is low educated (i.e. a community with a low number of high educated individuals), the individuals belonging to the less educated community are likely to end up assimilated into the high educated community, and even more likely if they are high educated individuals. Put it differently, it is more likely that the community with relatively less educated individuals will end up being (at least partially) assimilated into the other community, and this is even more true if there are more high educated in the dominant community and the dominant group is relatively larger than the other community. In addition, our results suggest that policies promoting mixing individuals and turning myopic individuals into farsighted ones (especially in the dominant community) could be helpful in avoiding (Pareto-) inefficient situations.

Thus, if the education level and the capacity of perceiving economic and social opportunities are good proxies of the degree of farsightedness of the individuals, policies that promote education in both the native and the immigrant community[23] and policies that facilitate social interactions among individuals from different communities could be helpful in avoiding segregation.[24]

Declaration of competing interest

The authors declare that they have no relevant or material financial interests that relate to the research described in the paper.

Data availability

No data was used for the research described in the article.

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Appendix A

A.1. Assimilation and pairwise stability

Friendship networks where one community is fully or partially assimilated to the other community can be pairwise stable when intra-community costs are low.

Proposition A.1. *Assume low intra-community costs, $c < \delta - \delta^2$.*

(**i**) *The network $g_{assi,green} = g^{N^G} \cup \{ij \mid i \in N^G, j \in N^B\}$ where all the blue community is fully assimilated to the green community is pairwise stable if and only if*

$$C > \frac{(n-2)}{(n^G-1)}(\delta - \delta^2 - c);$$

[22] When adding or deleting links, individuals know perfectly the links other individuals do have. Recently, Foerster et al. (2021) propose a solution concept for network formation games where individuals can form two types of links: public links observed by everyone and shadow links generally not observed by others. Then, it could happen that, some individuals overestimate others' connections and hence under-connect (relative to stable networks under correct beliefs), while others underestimate connections and hence over-connect.

[23] Smith (2003) shows that each new Latino generation in the US has been able to close the schooling gap with native whites which then has been translated into generational progress in incomes and economic status.

[24] Using data on adolescents in the United States, Boucher et al. (2023) find that policies that facilitate socialization can backfire for students from low-education families because they increase homophily and reduce the education investment of their parents. In contrast, policies that facilitate social interactions between kids from different backgrounds can be effective in reducing the education gap between children from low- and high-educated families.

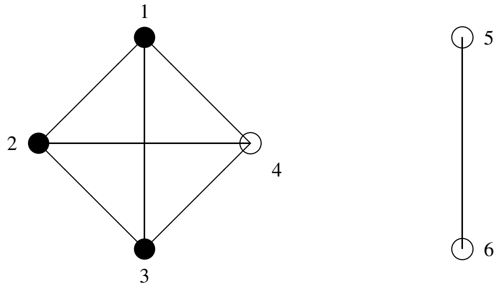

Fig. A.1. One blue individual is assimilated to the green community while the rest of blue individuals are segregated.

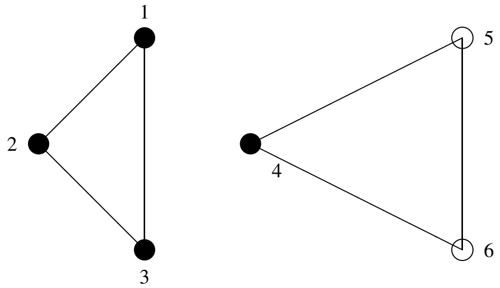

Fig. A.2. One green individual is assimilated to the blue community while the other green individuals are segregated.

(ii) *The network* $g_{assi,blue} = g^{N^B} \cup \{ij \mid i \in N^B, j \in N^G\}$ *where all the green community is fully assimilated to the blue community is pairwise stable if and only if*

$$C > \frac{(n-2)}{(n^B-1)}(\delta - \delta^2 - c);$$

(iii) *Take any* $N^{B_1} \subsetneq N^B$ *such that* $1 \le n^{B_1} \le n^B - 2$. *The network* $g_{passi,green} = g^{N^G} \cup g^{N^B \setminus N^{B_1}} \cup \{ij \mid i \in N^G, j \in N^{B_1}\}$ *where* n^{B_1} *blue individuals are assimilated to the green individuals and all other blue individuals are intra-connected and segregated is pairwise stable if and only if*

$$C > \frac{(n^G + n^{B_1} - 1)}{(n^G-1)}\left(\delta - \delta^2 - c + (n^B - n^{B_1})\delta^2\right);$$

(iv) *Take any* $N^{G_1} \subsetneq N^G$ *such that* $1 \le n^{G_1} \le n^G - 2$. *The network* $g_{passi,blue} = g^{N^B} \cup g^{N^G \setminus N^{G_1}} \cup \{ij \mid i \in N^B, j \in N^{G_1}\}$ *where* n^{G_1} *green individuals are assimilated to the blue individuals and all other green individuals are intra-connected and segregated is pairwise stable if and only if*

$$C > \begin{cases} \hat{C}_1 & \text{if } n^{G_1} \le \frac{1}{2}(n^G - n^B); \\ \hat{C}_2 & \text{if } n^{G_1} > \frac{1}{2}(n^G - n^B); \end{cases}$$

where

$$\hat{C}_1 = \max\left\{ \frac{(n^B + n^{G_1} - 1)}{(n^B-1)}\left(\delta - \delta^2 - c + (n^B + n^{G_1})\delta^2\right), \frac{(n^B + n^{G_1} - 2)}{(n^B-1)}\left(\delta - \delta^2 - c + (n^G - n^{G_1})\delta^2\right) \right\};$$

$$\hat{C}_2 = \frac{(n^B + n^{G_1} - 1)}{(n^B-1)}\left(\delta - \delta^2 - c + (n^G - n^{G_1})\delta^2\right).$$

In Fig. A.1 (A.2) we depict a network where one blue (green) individual is assimilated to the green (blue) community, while the rest of blue (green) individuals are isolated.

Appendix. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jebo.2024.03.012.

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