A belief-based theory of homophily*

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Abstract

Homophily, the tendency of individuals to interact with similar others, is an obvious impediment to creating a more diverse and inclusive society. Existing models, which explain homophily by positing homophilous preferences, cannot say whether this leads to a welfare loss. We therefore develop a theory of homophily that does not rely on preferences. Rather, it builds on the dual process account of Theory of Mind in psychology. The framework allows us to assess the welfare consequences of policies aimed at enhancing diversity. Moreover, it delivers novel comparative statics that emphasize the interplay of cultural and economic factors.

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1. Introduction

Diversity policies are professed to improve welfare for everyone, by giving people access to new information, different viewpoints and more resources. However, implementing such policies often involves restricting individual choice. Consider the question of whether students should be assigned to dormitories at random, or whether they should be free to select their roommate. Many students have a preference for choosing their own roommate and use Facebook or roommate-pairing websites (Johnson, 2011), yet some universities continue to assign roommates at random, arguing that "it is important for all new students to meet new people, expand their interests, [and] broaden their understanding of different regions and culture" (New York University, 2014).[1] Likewise, following a merger, companies often introduce "social controls," such as job rotation, to create a joint culture (Larsson and Lubatkin, 2001). To weigh the cost and benefits of such policies, we develop a theory of homophily. Unlike much of the existing literature, we do not assume that players have a direct preference for associating with similar others. Rather, we explain these preferences by showing that people can gain by interacting with similar others if that reduces strategic uncertainty. This makes it possible to assess the welfare consequences of policy interventions aimed at increasing diversity. Moreover, it allows us to explain why homophily is observed in some cases, but not in others.

Our starting point is that to understand people's tendency to interact with similar others, we need to unpack the black box of cultural identity. Following Kreps (1990), we view culture as a means to reduce strategic uncertainty. When there is uncertainty about what action is appropriate, cultural rules can act as focal principles. As a metaphor for situations that are characterized by strategic uncertainty, we consider (pure) coordination games. There are two groups. When members of the same group interact, their payoffs are given by:

	s^1	s^2
s^1	1,1	0,0
s^2	0,0	1,1

Such games are rife with strategic uncertainty: the payoff structure provides little guidance. However, there may be a focal point, which may depend on the context in which the game is played. Players from the same group share a similar cultural code, and may successfully coordinate by jointly inferring the focal point from the context of the game. When players interact with a member of the other group, there is no shared cultural background and thus

[1] Similarly, in the majority decision in the Supreme Court case Grutter v. Bollinger (2003), Justice Sandra Day O'Connor held that states have a compelling interest in "obtaining the educational benefits that flow from a diverse student body."

more strategic uncertainty. On the other hand, players may benefit from interacting with players from the other group if they have complementary skills, or if teams composed of players from different groups are more creative or have superior problem solving abilities (e.g., Page, 2007). To model this, suppose that if a player interacts with a member of the other group, then payoffs are given by:

	s^1	s^2
s^1	V,V	0,0
s^2	0,0	V,V

where $V \geq 1$; all payoffs are commonly known.

To model players' behavior, we build on the dual process account of Theory of Mind in psychology.[2] The dual process account of Theory of Mind posits that an individual can form an instinctive understanding of another person's beliefs, by putting himself in the other's position, and then adapt his views through reasoning. To capture this, we assume that each player has some initial (random) impulse telling him which action is appropriate. A player's first reaction is to follow his impulse. After some introspection, the player realizes that he may act on instinct and so, his opponent may also act on instinct. In addition, the impulse of the opponent may be similar to his own. This means that impulses can be used as input to form initial beliefs. But if the player thinks a little more, he realizes that his opponent may have gone through a similar reasoning process, leading the player to revise his initial beliefs. This process continues to higher orders. The limit of this procedure, where players go through the entire reasoning process in their mind before making a decision, defines an *introspective equilibrium*.

A key assumption is that players find it easier to project themselves into the role of players that are similar to them, in line with neurological and behavioral evidence (de Vignemont and Singer, 2006; Jackson and Xing, 2014). In the context of our model, this is because players with a shared cultural background may have similar ideas about which action is appropriate in a given context. Formally, players' initial impulses are (imperfectly) correlated within groups and independent across groups. So, if impulses are highly correlated, players from the same group are likely to agree on which action is focal in a particular context.

Our first result shows that in the unique introspective equilibrium, each player follows his initial impulse. So, the naive response of following one's initial impulse is optimal under the

[2]See Epley and Waytz (2010) for a survey. The dual process account of Theory of Mind relies on a rapid instinctive process and a slower cognitive process. As such, it is structurally similar to the two-systems account of decision-making under uncertainty, as popularized by Kahneman (2011). The foundations of dual process theory go back to the work of the psychologist William James (1890/1983). See Section 2 for an extended discussion.

infinite process of reasoning through higher-order beliefs. This holds even if impulses are noisy and people from different subcultures have uncorrelated impulses. It now follows that players coordinate more effectively if they belong to same group. If skill complementarities are only weak (i.e., V close to 1), then this provides an incentive to choose activities that enhance the chances of meeting similar people.[3] On the other hand, if skill complementarities are strong, then players may want to choose activities that increases the chance that they interact with players from the other group, even if that means they face more strategic uncertainty.

To analyze players' incentives for seeking out similar others, we study an extended game where players first choose a project (e.g., hobbies, professions, or neighborhoods) and subsequently play the coordination game with an opponent that has chosen the same project. We analyze this extended game using the same method as before. Players introspect on their impulses, use them to form initial beliefs and modify them through higher-order reasoning. We show that there is a unique introspective equilibrium. When skill complementarities are limited, similar players overwhelmingly choose the same project, regardless of their intrinsic sentiments over projects. Thus, the introspective process leads players to coordinate effectively. The level of homophily depends on economic incentives (i.e., the coordination payoffs) and the strength of cultural identity (i.e., similarity in impulses). So, when focal points depend on cultural background and on the context, introspection leads to homophily. When there are significant complementarities in skills, by contrast, players mix with members of the other group. Again, the level of homophily depends on both cultural and economic factors.

These results allow us to explain why we observe homophily in some settings, but not in others, even if the underlying game is the same. For example, in rapidly changing environments, organizational culture may not strongly guide initial impulses, and this leads to more integrated networks (Staber, 2001). Consistent with these observations, our model predicts that the level of homophily is lower when cultural identity is weaker. Also, the level of homophily is lower when there are significant complementarities in skills across groups (Aldrich and Kim, 2007), consistent with our results. Our model shows how these factors interact: if cultural codes give little guidance, then complementarities of skills become more important in shaping interactions. Finally, the mechanism that leads people to seek out similar others may also lead them to become similar on other dimensions as well. For example, in order to associate with others that have similar values, people choose the same hobbies, professions, or clubs as them (Kossinets and Watts, 2009).[4]

[3] Alternatively, players could reduce the risk of miscoordinating by learning the cultural code of the other group (Lazear, 1999). However, this may be costly.

[4] This is different from the well-known phenomenon that individuals who interact frequently influence each other, and thus become more similar in terms of behavior (e.g., Benhabib et al., 2010). Here, becoming more

An important question is whether the choices of self-interested players lead to levels of homophily that are socially optimal. It turns out that in the absence of skill complementarities, there is too little homophily in equilibrium; and if there are complementarities of skills, the equilibrium level of homophily is only slightly higher than the social optimum. This would suggest that there is no economic rationale for diversity policy in our setting. Indeed, in the absence of skill complementarities, social welfare is highest when groups have a strong cultural identity. This may explain common policies aimed at strengthening cultural identity, for example, in organizations (Cameron and Quinn, 2011) and at the national level (e.g., Smith et al., 1998). Our theory suggests that such policies can increase segregation.

However, strengthening cultural identity may not be optimal in environments where economic incentives are subject to change. As we show, highly homophilous groups with a strong cultural identity can display excessive conformism, while more inclusive societies are more agile. In that case, social welfare may be higher when cultural identities are weakened and groups are fully integrated. This finding provides an economic rationale for measures that enhance intergroup exposure, such as introduction programs and cross-visits following a merger (Larsson and Lubatkin, 2001), having highly structured school environments that stimulate interactions based on shared interests rather than group identity (Moody, 2001; McFarland et al., 2014), or randomly assigning roommates in college (Boisjoly et al., 2006; Burns et al., 2013). Temporarily restricting individuals' social interactions in this way appears to be highly successful in increasing intergroup interactions in later years, at least in some settings (also see Rao, 2013). This provides an important economic rationale for diversity policies in our setting. However, our theory suggests that such policies are effective only to the extent that they lead to culture change. Moreover, they improve welfare only for societies that need to adapt quickly to a changing economic environments.

So far, we have assumed that all players are matched with exactly one other player. Section 5 develops an extension of the model that can capture network formation, by allowing players to interact with multiple players at a cost. The level of homophily can now be even higher, as greater success in coordinating with similar others translates into greater incentives to form connections. In addition, the model accommodates important properties of social and economic networks. Since these features arise endogenously, the model provides novel testable hypotheses about how these properties change when the fundamentals vary. For example, when cultural identity is strong, networks tend to be densely connected, with high levels of homophily and significant inequality in the number of connections. This means that the network consists of a tightly connected core of gregarious players from one group, with a periphery of hermits from the other group that are loosely connected with the core. These

similar is a pre-condition for interaction, not the result thereof.

phenomena are widely observed in social and economic networks (Jackson, 2008).

The heart of our contribution lies in the modeling of players' reasoning process. Explicitly modeling the reasoning process allows us to make three important contributions. First, it gives a unique prediction in the games that we consider – coordination, sorting, and network formation –, and this prediction has intuitive properties. This makes it possible to do comparative statics and to derive unambiguous welfare implications. This is not possible using a standard equilibrium analysis, as the games we study have multiple equilibria with sometimes very different properties (Appendix B). Second, it makes it possible to understand some subtle but important aspects of intergroup interactions, such as how identities can shift over time and how individuals handle nested identities, as we discuss in Section 3. Third, opening the black box of cultural identity enables us to ask what type of culture is optimal for a given economic environment. For example, our results suggest that segregated societies with a strong cultural identity do well in stable economic environments, but inclusive societies with a weak identity do better when incentives change over time.

1.1. Related literature

Homophily is a widespread phenomenon that has important economic implications, affecting hiring and promotion decisions, the spread of information, and educational outcomes (Jackson, 2014). The literature on homophily in economics mostly assumes homophilous preferences and investigates the implications for network structure and economic outcomes (e.g., Schelling, 1971; Alesina and La Ferrara, 2000; Currarini et al., 2009; Golub and Jackson, 2012; Alger and Weibull, 2013), with Baccara and Yariv (2013) and Peski (2008) being notable exceptions.[5] By contrast, we derive players' incentives to interact with similar others from a desire to reduce strategic uncertainty. This makes it possible to obtain intuitive comparative statics and to evaluate the tradeoffs inherent in diversity policies.

An important difference between our model and other models of stratification, discrimination, and segregation (e.g., Bénabou, 1996; Becker and Murphy, 1994) is that groups do not differ in their (expected) ability or productivity. Moreover, modeling cultural identity explicitly, we are able to study the effects of policies that lead to culture change.

The process we consider bears some resemblance with level-k models (see Crawford et al.,

[5]In a public good provision model, Baccara and Yariv (2013) show that groups are stable if and only if their members have similar preferences. Peski (2008) shows that segregation is possible if players have preferences over the interactions that their opponents have with other players (also see Peski and Szentes, 2013). No such assumption is needed for our results. In addition, there is a literature that shows that it may be optimal for individuals to interact with members of the own group if there are market imperfections (e.g., Greif, 1993). We show that homophily may be optimal even in the absence of market imperfections.

2013, for a survey). A key difference is that we are interested in equilibrium selection, while the level-k literature focuses on nonequilibrium behavior. Indeed, one contribution of our paper is that it demonstrates that modeling players' reasoning process can give rise to new insights even if one focuses on the equilibrium limit. Another difference is that the level-k literature does not consider payoff-irrelevant signals such as impulses, which are critical in our setting. Our model is also very different from global games (e.g., Morris and Shin, 2003), as there is no payoff uncertainty in our model. Importantly, global games do not select an equilibrium in all pure coordination games, while our process does.[6]

Our work sheds light on experimental findings that social norms and group identity can lead to an efficient equilibrium and can improve coordination, as in the minimum-effort game (Weber, 2006; Chen and Chen, 2011), the provision point mechanism (Croson et al., 2008) and the Battle of the Sexes (Charness et al., 2007; Jackson and Xing, 2014). Chen and Chen (2011) explain the high coordination rates on the efficient equilibrium in risky coordination games in terms of social preferences. Our model provides an alternative explanation, based on beliefs: players are better at predicting the actions of players with a similar background. Our mechanism operates when no equilibrium is superior to another, as in some pure coordination games, as well as in risky coordination games.

2. Coordination, culture and introspection

There are two groups, A and B, each consisting of a unit mass of players. Members of these groups may be called A-players and B-players, respectively. Group membership is not observable. Players are matched with an opponent of the same group with probability $\tilde{p} \in (0, 1]$. In this section, the probability $\tilde{p}$ is exogenous. In Section 3, we endogenize $\tilde{p}$. Players that are matched interact in a (2×2) coordination game. Payoffs in the game depend on whether players are matched with a member of their own group or from the other group. Players earn a payoff of v if they successfully coordinate with a member of the own group, and they receive a payoff of V if they coordinate with a member of the other group, where $V > v > 0$; see Figure 1. The game is commonly known.

Nature draws a state $\theta_G = 1, 2$ for each group $G = A, B$, independently across groups. The state is the focal point of the group. So, if $\theta_A = 1$ then the culture of A-players takes s^1 to be the appropriate action in the current context. Ex ante, states 1 and 2 are equally likely for both groups.

[6] The introspective process also bears some formal resemblance to the deliberative process introduced by Skyrms (1990). Skyrms focuses on the philosophical underpinnings of learning processes and the relation with classical game theory.

	s^1	s^2
s^1	v,v	0,0
s^2	0,0	v,v

Own group

	s^1	s^2
s^1	V,V	0,0
s^2	0,0	V,V

Other group

Figure 1: The coordination game, with the left panel giving the payoffs for interacting with the own group, and the right panel giving the payoffs for interacting with the other group ($V > v > 0$).

Each player has an initial impulse to take an action. Their impulse is influenced by their culture. That is, a player's initial impulse is more likely to match the focal point of his group than the alternative action. So, if $\theta_A = 1$ then A-players initial impulse is to take action s^1 with probability $q > \frac{1}{2}$, independently across players. The same statement holds for B-players. When q is close to 1, a player's culture strongly guides initial impulses. When q is close to $\frac{1}{2}$, a player's culture has a negligible influence on initial impulses. Thus, players have an imperfect understanding of their cultural code.

A player's first instinct is to follow his initial impulse, without any strategic considerations. We refer to this initial stage as level 0. At higher levels, players realize that if their opponent is in the same group, then they are likely to have a similar impulse. So, by introspecting (i.e., by observing their own impulses), players obtain an informative signal about what their opponents will do. At level 1, a player formulates a best response to the belief that his opponent will follow her impulse. This process needs not stop at level 1. At level $k > 1$, players formulate a best response to the belief that the opponent is at level $k - 1$. Together, this constitutes a reasoning process of increasing levels. These levels do not represent actual behavior; they are constructs in a player's mind. We are interested in the limit of this process, as the level k goes to infinity. If such a limit exists for each player, then the profile of such limiting strategies is referred to as an *introspective equilibrium*.

This approach is motivated by the dual process account of the Theory of Mind in psychology (Apperly, 2012; Baron-Cohen et al., 2013; Epley and Waytz, 2010; Fiske and Taylor, 2013). The key idea behind the dual process account of Theory of Mind is that reasoning about other people's beliefs and desires involves reasoning about unobservable mental states, which starts from a base of readily accessible knowledge and proceeds by adjusting instinctive responses in light of less accessible information, for example, how the other person's mental state may differ from one's own. So, while people have instinctive reactions (modeled here with impulses), they may modify their initial views using theoretical inferences about others (captured here by the different levels).[7,8] A critical assumption is that players' impulses are correlated (perhaps mildly) within groups (i.e., $q > \frac{1}{2}$), that is, a player's own impulses are informative of the impulses of similar players. Thus, players find it easier to put themselves in the shoes of those from their own group. This is consistent with experimental evidence from neuroscience and psychology that shows that it is easier to predict the behavior or feelings of similar people (de Vignemont and Singer, 2006; Mitchell et al., 2006; Mitchell, 2009). This is also supported by experimental studies in economics (Currarini and Mengel, 2013; Jackson and Xing, 2014).

Our first result shows that the seemingly naive strategy of following one's initial impulse is the optimal strategy that follows from the infinite process of high order reasoning.

Proposition 2.1. *There is a unique introspective equilibrium. In this equilibrium, each player follows his initial impulse.*

So, the reasoning process delivers a simple answer: it is optimal to act on instinct. Intuitively, the initial appeal of following one's impulse is reinforced at higher levels, through introspection: if a player realizes that his opponent follows his impulse, it is optimal for her to do so as well; this, in turn, makes it optimal for the opponent to follow his impulse. While simple and intuitive, this result goes against the common intuition that individuals behave differently in a coordination game depending on the identity of their opponent. For example, while in the well-known "meeting in New York" experiment of Schelling (1960, p. 56), subjects (who all knew New York City well) successfully coordinate on meeting at Grand Central Station, it has been argued that the outcome would be indeterminate if subjects were asked to coordinate with a tourist (for whom some other location, say the Empire State building, may be more focal).

As is well-known, coordination games have multiple (correlated) equilibria. For example, all players choosing action s^1, regardless of their signal, is a correlated equilibrium. Moreover, standard equilibrium refinements have no bite in pure coordination games such as the one considered here. By contrast, the introspective process selects only one equilibrium. This uniqueness will prove critical for predictions and comparative static results in the next sec-

[7] These ideas have a long history in philosophy. According to Locke (1690/1975) people have a faculty of "Perception of the Operation of our own Mind" which, "though it be not Sense, as having nothing to do with external Objects; yet it is very like it, and might properly enough be call'd internal Sense," and Mill (1872/1974) writes that understanding others' mental states first requires understanding "my own case." Kant (1781/1997) suggests that people can use this "inner sense" to learn about mental aspects of themselves, and Russell (1948) observes that "[t]he behavior of other people is in many ways analogous to our own, and we suppose that it must have analogous causes."

[8] Kimbrough et al. (2013) interpret Theory of Mind as the ability to learn other players' payoffs, and shows that this confers an evolutionary benefit in volatile environments.

tions.[9]

While it is natural to assume that nonstrategic players follow their impulse, our results do not depend on this. For example, as long as each player is more likely than not to follow his impulse, our results continue to hold. What is needed for our results is that players do not have a strong predisposition to choose a fixed action, independent of context. Also, the result does not hinge on the states of the groups being independent, or on impulses coming in the form of action recommendations (as opposed to, say, beliefs about the other's belief or action).

Let $Q := q^2 + (1-q)^2 > \frac{1}{2}$ be the odds that two players from the same group have the same initial impulse. If Q is close to 1, impulses are strongly correlated within a group. If Q is close to $\frac{1}{2}$, impulses within a group are close to independent, as they are across groups. We refer to Q as the strength of players' *cultural identity*. If players share common cultural identity, they are more likely to coordinate their actions on the focal point determined by their culture (which may be context-dependent). This is consistent with work in social psychology showing that people want to interact with members of their own group as a means of reducing uncertainty (see Hogg, 2007, for a survey). Our identity concept thus differs from the identity concept in the work of Akerlof and Kranton (2000), where a person's identity directly enters his utility function. An advantage of our approach is that it provides a rich framework for investigating what happens when cultures evolve. We exploit this in our assessment of diversity policies in Section 4.

In the unique introspective equilibrium, a player's expected payoff is:

$$\tilde{p}Qv + (1-\tilde{p})\tfrac{1}{2}V.$$

It follows that the *marginal benefit of interacting with the own group* is

$$\beta := Qv - \tfrac{1}{2}V.$$

Thus, the expected utility of a player strictly increases with the probability $\tilde{p}$ of being matched with a player from the own group if and only if $\beta > 0$. If $\beta > 0$, then the greater predictability of interacting with the own group has a greater impact (on the margin) than skill complementarities, and we say that *strategic uncertainty dominates*. This is the case when cultural identity is strong and skill complementarities are limited. If $\beta < 0$, then the extra rewards from coordinating with the other group are more important than the reduction in strategic

[9] Bacharach and Stahl (2000) similarly show that if nonstrategic players favor a certain option in a coordination game, then this advantage gets magnified at higher levels. However, they focus on nonequilibrium outcomes, and their procedure does not guarantee uniqueness.

uncertainty when interacting with the own group, and we say that *skill complementarities dominate* in that case.

When strategic uncertainty dominates, players have an incentive to seek out similar players.[10] This is above and beyond any direct preferences players may have over interacting with similar others. It follows from the benefits from coordination. On the other hand, when skill complementarities are important, players benefit from interacting with the own group. We explore players' incentives to segregate in the next section.

3. Homophily

In ordinary life, there is often no exogenous matching mechanism. People meet after they have independently chosen a common place or a common activity. Accordingly, we model an extended game in which there are two *projects* (e.g., occupation, club, neighborhood), labeled a and b. Players first choose a project and are then matched uniformly at random with someone that has chosen the same project. Once matched, players play the coordination game described in Section 2.

Each player has an intrinsic value for each project. Players in group A have a slight tendency to prefer project a. Specifically, for A-players, the value of project a is drawn uniformly at random from $[0, 1]$, while the value of project b is drawn uniformly at random from $[0, 1 - 2\varepsilon]$, for small $\varepsilon > 0$. For B-players, an analogous statement holds with the roles of projects a and b reversed. So, B-players have a slight tendency to prefer project b. Values are drawn independently (across players, projects, and groups). Under these assumptions, a fraction $\frac{1}{2} + \varepsilon$ of A-players intrinsically prefer project a, and a fraction $\frac{1}{2} + \varepsilon$ of B-players intrinsically prefers project b (Appendix A). Thus, project a is the *group-preferred project* for group A, and project b is the group-preferred project for group B. Such a slight asymmetry in preferences between could result if some project fits better with culture-specific norms than others (Akerlof and Kranton, 2000). Players' payoffs are the sum of the intrinsic value of the chosen project and the (expected) payoff from the coordination game.

Players follow the same process as before. At level 0, players follow their impulse and select the project they intrinsically prefer. At level $k > 0$, players formulate a best response to actions selected at level $k - 1$: a player chooses project a if and only if the expected payoff from a is at least as high as from b, given the choices at level $k - 1$. Let p_k^a be the fraction of A-players among those with project a at level k, and let p_k^b be the fraction of B-players among

[10] Similar results have been shown in other settings. See, for example, Cornell and Welch (1996) on hiring practices, Sethi and Yildiz (2014) on prediction and information aggregation, and Crawford (2007) and Ellingsen and Östling (2010) on coordination and communication.

those with project b at level k. The limiting behavior, as k increases, is well-defined.

Lemma 3.1. *The limit p^π of the fractions $p^\pi_0, p^\pi_1, \ldots$ exists for each project $\pi = a, b$. Moreover, the limits are the same for both projects: $p^a = p^b$.*

Let $p := p^a = p^b$ be the *limiting probability* in the introspective equilibrium. So, p is the probability that a player with the group-preferred project is matched with a player from the same group. Let the *level of homophily* $h := p - \frac{1}{2}$ be the difference between the probability that a player with the group-preferred project meets a player from the same group in the introspective equilibrium and the probability that he is matched with a player from the same group uniformly at random, independent of project choice. When the level of homophily is close to 0, there is almost full integration. When the level of homophily is close to $\frac{1}{2}$, there is nearly complete segregation.

There is a fundamental difference between exogenous and endogenous matching. When matching is exogenous, as in Section 2, players end up following their impulses after they have gone through the entire reasoning process. Thus, their ability to successfully coordinate is determined by their cultural identity, that is, by the degree to which their culture shapes their initial impulses over actions. In contrast, in the case of endogenous matching, players may not act on impulse. Intuitively, at level 1, player realize that there is a slightly higher chance of meeting a similar player if they choose the group-preferred project. So, if skill complementarities are limited, they may select the group-preferred project even if their intrinsic value for the alternative project is slightly higher. At level 2 an even higher fraction of agents may select the group-preferred project because the odds of finding a similar player this way are now higher than at level 1. So, the attractiveness of the group-preferred project is reinforced throughout the entire process in this case. It is possible that all players, even those who have a strong intrinsic preference for the alternative project, choose their group-preferred project. Complete segregation may arise even in cases where there would be almost complete integration if players were to act on their initial impulses (i.e., ε small). In this sense, introspection and reasoning are root causes of segregation. On the other hand, if there are significant complementarities of skill, then we end up with almost complete integration, as more and more players decide to mix with the other group. This intuition is formalized in the next result.

Proposition 3.2. *There is a unique introspective equilibrium. In the unique equilibrium:*

- *If strategic uncertainty dominates, then the fraction of players choosing the group-preferred project exceeds the initial level (i.e., $h > \varepsilon$). Moreover, there is complete segregation ($h = \frac{1}{2}$) if and only if*

$$vQ - \tfrac{1}{2}V \geq 1 - 2\varepsilon.$$

If segregation is not complete ($h < \frac{1}{2}$), then the level of homophily is given by:

$$h = \frac{(1-2\varepsilon)}{4(Qv - \frac{1}{2}V)^2} \cdot \Big[2(Qv - \tfrac{1}{2}V) - 1 + \sqrt{\frac{4(Qv - \frac{1}{2}V)^2}{1-2\varepsilon} - 4(Qv - \tfrac{1}{2}V) + 1}\Big].$$

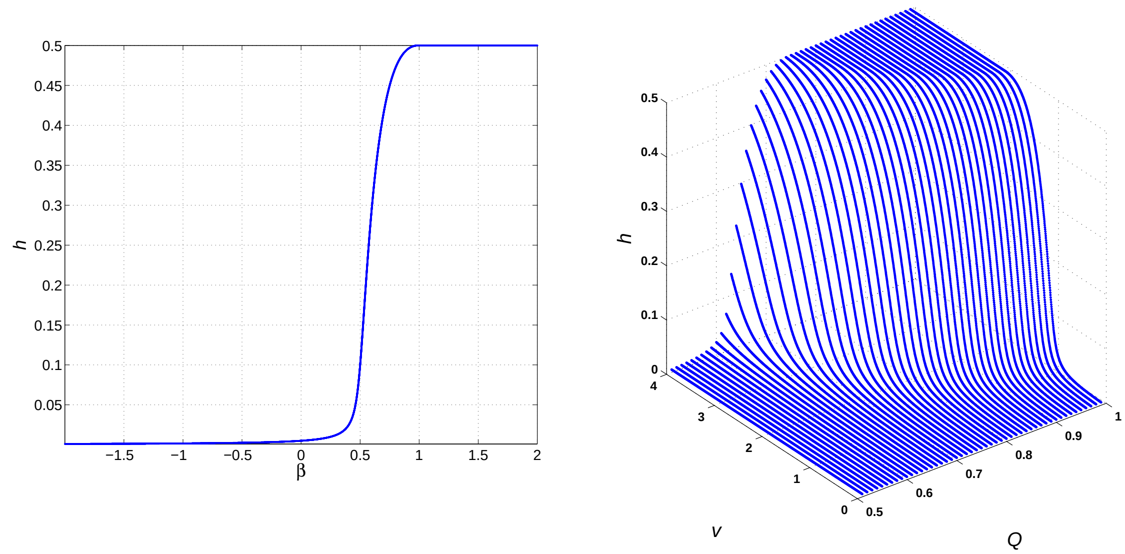
- *If skill complementarities dominate, then the fraction of players choosing the group-preferred project strictly below the initial level (i.e., $h < \varepsilon$), and is given by*

$$h = \frac{\varepsilon}{1 - 2(Qv - \frac{1}{2}V)} > 0.$$

Proposition 3.2 characterizes the introspective equilibrium. When complementarities of skills are significant (i.e., $\beta < 0$), there is almost full integration (i.e., $h \in (0, \varepsilon)$). On the other hand, when complementarities of skills are limited (i.e., $\beta > 0$), a large share of players choose the group-preferred project. In fact, strategic considerations *always* produce more segregation than would follow from differences in intrinsic preferences over projects alone (i.e., $h > \varepsilon$). The result demonstrates that strong cultural identities may give rise to segregation. If cultural identity is sufficiently strong and skill complementarities are limited, then all players choose the group-preferred project, regardless of their intrinsic preferences. So, introspection and reasoning may lead to complete segregation even if players do not have any direct preferences for interacting with similar others and, ex ante, players have arbitrarily similar preferences over projects (i.e., ε small). The comparative statics for the level of homophily follow directly from Proposition 3.2:

Corollary 3.3. *The level of homophily h increases with the marginal benefit of interacting with the own group, and thus with the strength of the cultural identity Q and with the coordination payoff v. Cultural identity and economic incentives are complements: the level of homophily is high whenever either cultural identity or the coordination payoff is high.*

Figure 2(a) plots the level of homophily as a function of the marginal benefit of interacting with the own group β. Figure 2(b) shows the level of homophily as a function of the coordination payoff v and the strength of players' cultural identity Q when there are no skill complementarities (i.e., $V = v$, and thus $\beta > 0$). Regardless of the strength of the cultural identity, the level of homophily increases with economic incentives to coordinate. These comparative statics results deliver clear and testable predictions for the model. That is, even if it is not possible to observe the strength of players' cultural identity, the model still predicts a positive correlation between coordination payoffs and homophily (keeping skill complementarities fixed). Also, when cultural rules provide clear guidance (i.e., Q close to 1), the level of homophily increases. While intuitive, these predictions require a form of equilibrium selection,



(a) (b)

Figure 2: (a) The equilibrium level of homophily h as a function of the marginal benefit of interacting with the own group β; (b) The equilibrium level of homophily h as a function of the coordination payoff v and the strength of players' cultural identity Q when there are no skill complementarities (i.e., $V = v$).

which we obtain here through the dual process account of Theory of Mind. Standard analysis delivers a multiplicity of equilibria. Some of these equilibria are highly inefficient. For example, there may be equilibria in which all players choose the non-group preferred project (e.g., all A-players choose project b); see Appendix B. In such equilibria, the majority of players choose a project that they do not intrinsically prefer. Choosing a project constitutes a coordination problem, and inefficient lock-in can occur in equilibrium. In contrast, when players are introspective, the majority always chooses the group-preferred project, society avoids inefficient lock-in, and successful coordination on the payoff-maximizing outcome ensues. In turn, this gives rise to unambiguous and intuitive comparative statics for the introspective equilibrium.

Our model can capture some subtle features of social interactions and cultural identity. First, the incentives for segregation are not affected by the type of the other group in our model, provided that the degree of strategic uncertainty is kept constant. If a group, say B, is replaced by another group B', and B'-players are as unpredictable for members of group A as B-players (and vice versa), then the level of homophily remains unchanged. This is consistent with empirical evidence which shows that homophily often stems from beneficial interaction with similar players, rather than a dislike of a particular group of outsiders (e.g., Marsden, 1988; Jacquemet and Yannelis, 2012). Second, consistent with our model, homophily is often situational. For example, homophily on the basis of race is reduced substantially when individuals are similar on some other dimension, such as socioeconomic status (Park et al., 2013). This suggest that individuals do not have some immutable preference or dislike of other groups. Third, consistent with our model, individuals may have a tendency to identify with groups that strongly distinguish themselves in their values and practices, even if these distinctions are valued negatively (Ashford and Mael, 1989). Finally, if homophily is driven by a desire to reduce strategic uncertainty, this may help understand interaction patterns when identities are nested. As strategic uncertainty is reduced more when groups have a stronger identity, individuals may have a preference for interacting with people that match their narrowly defined identity rather than a more broadly defined one (e.g., Korean-Americans vs. Asian-Americans); but when given the choice between individuals that fit their broader identity and people with a distinct cultural background, they prefer to interact with someone with whom they share some some commonality (e.g., Asian-Americans vs. Americans at large), consistent with empirical evidence (Nagel, 1994; Ashford and Johnson, 2014). While these features can potentially be captured by models that directly posit homophilous preferences, this would require tailoring preferences to observed phenomena. More fundamentally, it would not allow one to predict interaction patterns ex ante.

Our results do not depend on our specific assumptions, such as the exact distribution of values or the signal structure. Moreover, similar results obtain in variations of the model. For example, suppose players can "opt out" of the coordination game. That is, in addition to projects a and b, there is an outside option that gives each player a fixed utility $\bar{u}$, independent of which other players choose this option or what further actions players take. Again, high levels of homophily can result. Intuitively, the outside option is more attractive to players who would receive low coordination payoffs if they choose the project that they intrinsically prefer. So, more B-players prefer the outside option over project a than A-players, and analogously for project b; cf. Alesina and La Ferrara (2000). In Appendix C, we show that our results also go through if players cannot sort by choosing projects, but instead can signal identity using observable attributes such as tattoos or specific attire. This variant helps explain why groups are often marked by seemingly arbitrary traits (Barth, 1969), and shows that this phenomenon can be more pronounced when cultural identity is strong.

4. Welfare and policy implications

We now turn to normative issues. Policy makers often care about both social welfare and diversity, and this can be a rationale for implementing a diversity policy. Our model can help elucidate the tradeoffs inherent in these policies. Social welfare is given by the sum of players' (expected) payoffs. It has two components: coordination payoffs and project values. Social welfare thus depends on the level of homophily in two ways. First, as the level of homophily increases, more players can coordinate effectively. So, higher levels of homophily correspond to higher coordination payoffs. On the other hand, when the level of homophily is high, a large majority of players chooses a project that they do not intrinsically prefer. High levels of homophily are thus associated with lower project values. Define the *socially optimal level of homophily* to be the level of homophily h^* that maximizes the sum of the total coordination payoffs and project values. The next result characterizes the socially optimal level of homophily.

Proposition 4.1.

- *If strategic uncertainty dominates, then full segregation is socially optimal (i.e., $h^* = \frac{1}{2}$) if and only if*

$$Qv - \tfrac{1}{2}V \geq \tfrac{1}{2} - \varepsilon.$$

  If full segregation is not socially optimal (i.e., $h^* < \frac{1}{2}$), then the socially optimal level of homophily is given by:

$$h^* = \frac{(1-2\varepsilon)}{4(Qv - \frac{1}{2}V)^2} \cdot \left[Qv - \tfrac{1}{2}V - \frac{1}{4} + \sqrt{\frac{4(Qv - \frac{1}{2}V)^2}{1-2\varepsilon} - \tfrac{1}{2}(Qv - \tfrac{1}{2}V) + \tfrac{1}{16}} \right].$$

  In all cases, the fraction of players choosing the group-preferred project exceeds the initial level (i.e., $h^* > \varepsilon$).

- *If skill complementarities dominate, then full segregation is never optimal. The socially optimal level of homophily is given by:*

$$h^* = 4(Qv - \tfrac{1}{2}V)(1-2\varepsilon) + 5\varepsilon - 2 + \sqrt{4(Qv - \tfrac{1}{2}V)^2 - 5(Qv - \tfrac{1}{2}V) + 1 + \frac{(Qv - \frac{1}{2}V)}{1-2\varepsilon}}.$$

  In all cases, the fraction of players choosing the group-preferred project is below the initial level (i.e., $h^* < \varepsilon$).

Comparing Proposition 4.1 to Proposition 3.2 gives the following corollary:

Corollary 4.2.

- *If strategic uncertainty dominates, the level of homophily in the unique introspective equilibrium never exceeds the socially optimal level of homophily; and if $vQ - \frac{1}{2}V \leq 1 - 2\varepsilon$, the equilibrium level of homophily is strictly below the socially optimal level of homophily.*

- *If skill complementarities dominate, the level of homophily in the unique introspective equilibrium is strictly greater than the socially optimal level.*

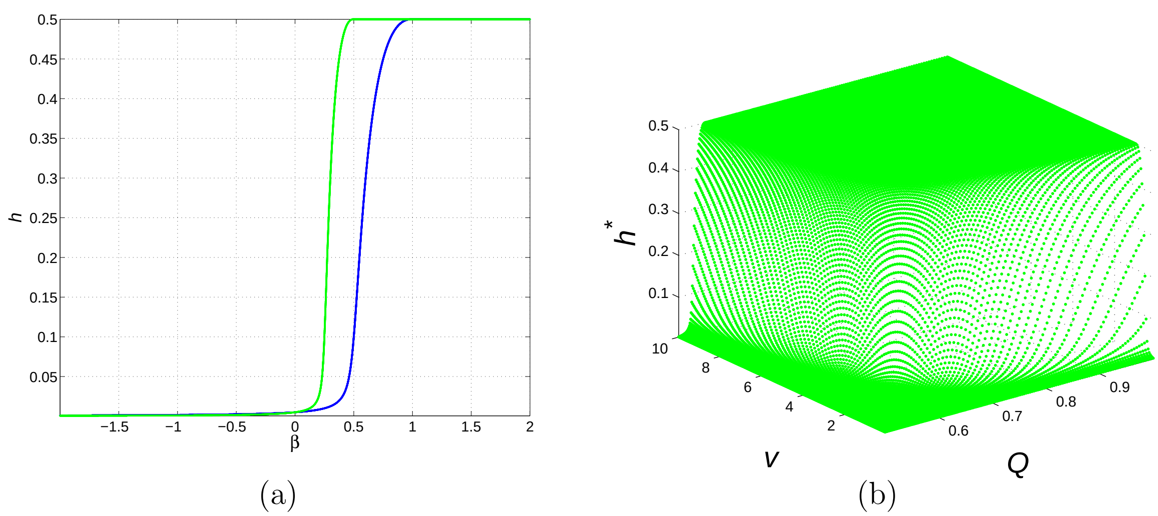


Figure 3: (a) The socially optimal (green) and equilibrium (blue) level of homophily as a function of the marginal benefit of interacting with the own group β; (b) The socially optimal level of homophily as a function of the coordination payoff v and the strength of players' cultural identity Q when there are no skill complementarities (i.e., $V = v$).

Figure 3 illustrates the results. Like the equilibrium level of homophily, the socially optimal level of homophily increases with the marginal benefit of interacting with the own group. However, the equilibrium level of homophily is not socially optimal. If skill complementarities dominate, there can be too much homophily in equilibrium. This is consistent with other arguments that show that reducing segregation can improve welfare when there are significant complementarities of skills (e.g., Alesina and La Ferrara, 2005; Ottaviano and Peri, 2006). However, the difference between the socially optimal and equilibrium level of homophily is only slight, as both are below ε. It can be checked that also the equilibrium level of welfare is close to the social optimum in this case.

On the other hand, if strategic uncertainty dominates, then there is too little homophily in equilibrium, and the effect can be substantial. If the marginal benefit of interacting with the own group is positive but not too large ($\beta \in (0, 1-2\varepsilon)$), then full segregation is socially optimal, but there is only partial segregation in equilibrium. Intuitively, while there are both positive and negative externalities associated with players choosing the group-preferred project, the positive externality dominates. Consider a player who considers switching to the group-preferred project. His switching increases the expected coordination payoff for the players with the group-preferred project, as it increases the probability that they interact with players of their own group. On the other hand, the switch lowers the expected coordination payoff to the players with the other project, as there are now fewer players of their group with that project. Since there are more players with the group-preferred project, the positive externality dominates the negative one, and we tend to have too little homophily in equilibrium. The finding that there tends to be too little homophily in equilibrium contrasts with results from Becker and Murphy (1994) and others that there can be excessive segregation.

Since the difference between the socially optimal level and the equilibrium level of homophily is only slight when skill complementarities dominate, we concentrate on the case where there are no skill complementarities (i.e., $V = v$) for the remainder of the section. In this case, increasing the level of homophily improves welfare. There are different ways a policy maker could implement the socially optimal level of homophily. One way is to implement a policy that affects the determinants of homophily, that is, the economic incentives for coordination and the strength of individuals' cultural identity. While the economic incentives for coordination are typically determined by the production technology (and thus outside the reach of the policy maker), we often observe policies to strengthen cultural identity. For example, post-Soviet states engage in identity politics to build or reconstruct national identities (Smith et al., 1998). In 19th-century Europe, newly formed nation states built national museums to strengthen national identity (Macdonald, 2012), and current challenges to cultural identities have led to a renewed interest in the role of museums in redefining and shaping identity (Eilertsen and Amundsen, 2012). And social movements in 19th-century U.S. stimulated public school enrollment to build a new, common identity (Meyer et al., 1979).

The next result states that strengthening cultural identity enhances welfare both in the short run (when the level of homophily is fixed) and in the intermediate run (when the level of homophily adjusts to the new equilibrium).

Corollary 4.3. *Suppose there are no skill complementarities. Social welfare increases when cultural identity is strengthened both in the short run and in the intermediate run.*

The increase in welfare in the short run results from a reduction in strategic uncertainty when players interact with members of their own group. In the intermediate run, there are two effects that determine welfare consequences. First, as in the short run, a stronger cultural identity means that there is less strategic uncertainty, which improves coordination. Second, when cultural identity becomes stronger, the level of homophily increases (Corollary 3.3). While some players now choose a project that they do not intrinsically prefer, this is more than compensated by the higher coordination rates for all players.

So, skill complementarities provide only a weak rationale for diversity in our setting, and society is often better off when cultural identity is strengthened and levels of homophily are higher. However, this argument ignores that diversity may foster a more inclusive culture. Our model allows us to directly model the evolution of cultural identities, and is thus able to provide a clear economic rationale for diversity policies aimed at fostering an inclusive culture.

Consider the question of whether students should be assigned to dormitories at random, or whether they should be free to select their roommates. If students that can choose their own roommates mostly selected roommates with a cultural background similar to their own, then this may give them higher expected payoffs in the short run, but prevents them from gaining a greater understanding from individuals outside their group, which may hurt them in the longer run, and this is a rationale for schools to limit social choices and to prescribe formats of interaction more generally (McFarland et al., 2014). Likewise, following a merger, integration of the two cultures is best achieved if the buying firm relies on "social controls," such as introduction programs, joint retreats and socialization rituals (Larsson and Lubatkin, 2001).

In such cases, a policy maker faces a tradeoff between the greater coordination benefits that come with a strong cultural identity and the resulting segregation and conformism. If groups have a very strong cultural identity ($Q = 1$, say), then clearly players earn high payoffs in the coordination game, and full segregation ($h = \frac{1}{2}$) is both an equilibrium outcome and socially optimal. In this case, expected payoffs in the coordination game are maximized and are equal to v. This would suggest that employing social controls, like merging firms often do, to create a "melting pot" with a potentially weakened joint culture is not optimal in any way. At best, the joint cultural identity is as strong as the identities of the merging firms; but if that is the case, then individuals are no better off than under the baseline of strong cultural identity and full segregation. At worst a weak joint identity leads to high rates of miscoordination.

This need not be true when we take into account that economic incentives may change. As an extreme, suppose that social controls create culturally homogeneous groups, so that for each player, players of the other group are as predictable as players of the own group: $Q_{\text{other}} = Q_{\text{own}}$. If the new identity is weak, that is, $Q_{\text{other}} = Q_{\text{own}} = \frac{1}{2}$, then obviously instances of miscoordination abound, and the expected payoff in the coordination game is $v/2$ (independent of the level of homophily). Suppose that over time, one of the actions becomes payoff dominant, so that successful coordination on that action yields a payoff of $w > v$. In a segregated society with a strong cultural identity, players will continue to follow their impulses, as doing otherwise leads to miscoordination. More formally, if a player's impulse tells him to take the Pareto-inferior action, and he expects other players to follow their impulses, then his best response is to choose the Pareto-inferior action, as that yields a payoff of v as opposed to the payoff of 0 he would obtain by choosing the payoff-dominant action. So, if both impulses are equally likely ex ante, such conformism leads players to coordinate on the Pareto-inferior equilibrium about half the time. By contrast, players in a culturally homogenous society with a weak culture will ignore their impulses, and successfully coordinate on the Pareto-superior equilibrium: the expected payoff of choosing the payoff-dominant action is at least

$w/2$, while the expected payoff of choosing the other action is at most $v/2$.[11] Intuitively, players' impulses do not give any guidance as to what other players will do, so economic incentives have free rein. So, while a segregated society with strong cultural identities may do better in stable economic environments than a cultural homogenous society, this need not be true in more dynamic economic environments: segregation and strong cultural identities can lead to excessive conformism.[12]

5. Network formation

In many situations, people can choose how many people they interact with. So, we extend the basic model to allow players to choose how much effort they want to invest in meeting others. We show that the basic mechanisms that drive the tendencies to segregate may be reinforced, and that the model gives rise to network properties that are commonly observed in social and economic networks.

To analyze this setting, it is convenient to work with a finite (but large) set of players.[13] Each group $G = A, B$ has N players, so that the total number of players is $2N$. Players simultaneously choose effort levels and projects in the first stage. They then interact in the coordination game. For simplicity, we assume that there are no complementarities of skill (i.e., $V = v$). Effort is costly: a player that invests effort e pays a cost $ce^2/2$. By investing effort, however, a player meets more partners to play the coordination game with (in expectation). Specifically, if two players j, ℓ have chosen the same project $\pi = a, b$, and invest effort e_j and e_ℓ, respectively, then the probability that they are matched (and play the coordination game) is

$$\frac{e_j \cdot e_\ell}{E^\pi},$$

where E^π is the total effort of the players with project π.[14] Thus, efforts are complements:

[11] At level 0, all players follow their impulse. At level 1, a player with an impulse to choose the Pareto-inferior action receives an expected payoff of $v \cdot [p \cdot \frac{1}{2} + (1-p) \cdot \frac{1}{2}] = v/2$ in the coordination game by following his impulse, while choosing the other action gives an expected payoff equal to $w \cdot [p \cdot \frac{1}{2} + (1-p) \cdot \frac{1}{2}] = w/2$. At level 1, therefore, players choose the payoff-dominant action. At level $k > 1$, choosing the Pareto-inferior action gives an expected payoff of 0 in the coordination game, while choosing the payoff-dominant action gives an expected payoff of w.

[12] These arguments extend to less extreme choices of parameters.

[13] Defining networks with a continuum of players gives rise to technical problems. Our results in Sections 2 and 3 continue to hold under the present formulation of the model (with a finite player set), though the notation becomes more tedious.

[14] To be precise, to get a well-defined probability, if $E^\pi = 0$, we take the probability to be 0; and if $e_j \cdot e_\ell > E^\pi$, we take the probability to be 1.

players tend to meet each other when they both invest time and resources. This is related to the assumption of bilateral consent in deterministic models of network formation (Jackson and Wolinsky, 1996). By normalizing by the total effort E^π, we ensure that the network does not become arbitrarily dense as the number of players grows large.[15] So, the probability of being matched with a member of the own group is endogenous here, as in Section 3. Matching probabilities are now affected not only by players' project choice, as in Section 3, but also by their effort levels.

As before, at level 0 players choose the project that they intrinsically prefer. So, the probability that a player chooses the group-preferred project is $\frac{1}{2}+\varepsilon$. In addition, each player chooses some default effort $e_0 > 0$, independent of his project or group. At higher levels k, each player formulates a best response to their partners choices at level $k-1$. As before, each player receives a (single) signal that tells him which action is appropriate in the coordination game. He then plays the coordination game with each of the players he is matched to.[16]

A preliminary result is that the limiting behavior is well-defined, and that it is independent of the choice of effort at level 0.

Lemma 5.1. *The limiting probability p and the limiting effort choices exist and do not depend on the effort choice at level 0.*

As before, we have a unique introspective equilibrium, with potentially high levels of homophily:

Proposition 5.2. *There is a unique introspective equilibrium. In the unique equilibrium, all players choose positive effort. Players that have chosen the group-preferred project exert strictly more effort than players with the other project. In all cases, the fraction of players choosing the group-preferred project exceeds the initial level (i.e., $h > \varepsilon$).*

As before, players segregate for strategic reasons and the level of homophily is greater than what would be expected on the basis of intrinsic preferences alone (i.e., $h > \varepsilon$). Importantly, players with the group-preferred project invest more effort in equilibrium than players with the other project. This is intuitive: a player with the group-preferred project has a high chance of meeting people from her own group, and thus a high chance of coordinating successfully. In turn, this reinforces the incentives to segregate.

Figure 4 illustrates the comparative statics of the unique equilibrium. As before, the level of homophily increases with the strength of players' cultural identity and with economic

[15] See, e.g., Cabrales et al. (2011) and Galeotti and Merlino (2014) for applications of this model in economics.

[16] We allow players to take different actions in each of the (two-player) coordination games he is involved in. Nevertheless, in any introspective equilibrium, a player chooses the same action in all his interactions, as it is optimal for him to follow his impulse (Proposition 2.1).

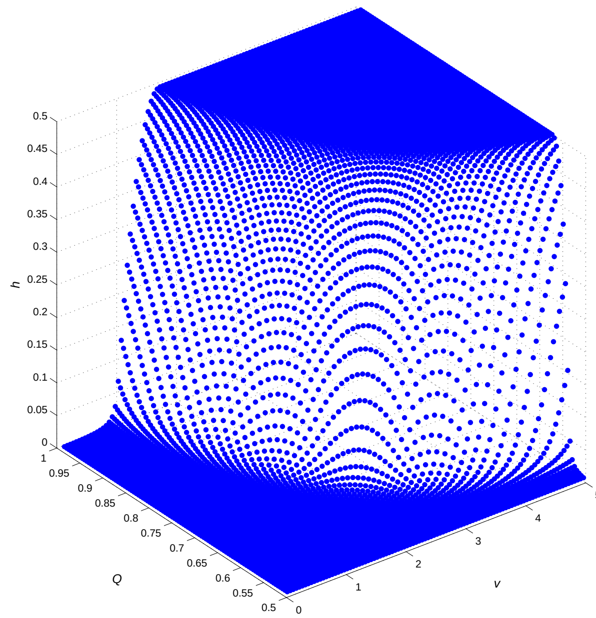


Figure 4: The level of homophily h as a function of the coordination payoff v and the strength of players' cultural identity Q ($c = 1$).

incentives, and the two are complements. While the proof of Proposition 5.2 provides a full characterization of the equilibrium, the comparative statics cannot be analyzed analytically, as the effort levels and the level of homophily depend on each other in intricate ways. We therefore focus on deriving analytical results for the case where the network becomes arbitrarily large (i.e., $|N| \to \infty$). As a first step, we give an explicit characterization of the unique introspective equilibrium:

Proposition 5.3. *Consider the limit where the number of players in each group goes to infinity. The effort chosen by the players with the group-preferred project in the unique introspective equilibrium converges to*

$$e^* = \frac{v}{4c} \cdot \left(1 + 2Q - \frac{1}{2h} + \sqrt{4Q^2 - 1 + \frac{1}{4h^2}}\right),$$

while the effort chosen by the players with the other project converges to

$$e^- = \frac{v}{c} \cdot (Q + \tfrac{1}{2}) - e^*,$$

which is strictly smaller than the effort e^* (while positive).

Proposition 5.3 shows that in the unique introspective equilibrium, the effort levels depend on the level of homophily. The level of homophily, in turn, is a function of the equilibrium effort levels. For example, by increasing her effort, an A-player with the group-preferred project a increases the probability that players from both groups interact with her and thus with members from group A. This makes project a more attractive for members from group A, strengthening the incentives for players from group A to choose project a, and this leads to higher levels of homophily. Conversely, if more players choose the group-preferred project, this strengthens the incentives of players with the group-preferred project to invest effort, as it increases their chances of meeting a player from their own group. This, in turn, further increases the chances for players with the group-preferred project of meeting someone from the own group, reinforcing the incentives to segregate. On the other hand, if effort is low, then the incentives to segregate are attenuated, as the probability of meeting similar others is small. This, in turn, reduces the incentives to invest effort.

As a result of this feedback loop, there are two different regimes. If effort costs are small relative to the benefits of coordinating, then players are willing to exert high effort, which in turn leads more players to choose the group-preferred project, further enhancing the incentives to invest effort. In that case, groups are segregated, and players are densely connected. Importantly, players with the group-preferred project face much stronger incentives to invest effort than players with the other project, as players with the group-preferred project have a high chance of interacting with players from their own group. On the other hand, if effort costs are sufficiently high, then the net benefit of interacting with others is small, even if society is fully segregated. In that case, choices are guided primarily by intrinsic preferences over projects, and the level of homophily is low. As a result, players face roughly the same incentives to invest effort, regardless of their project choice, and all players have approximately the same number of connections. Hence, high levels of homophily go hand in hand with inequality in the number of connections that players have. The following result makes this precise:[17]

Proposition 5.4. *Consider the limit where the number of players in each group goes to infinity. In the unique introspective equilibrium, the distribution of connections of players with the group-preferred project first-order stochastically dominates the distribution of the number of connections of players with the other project. The difference in the expected number of connections of the players with the group-preferred project and the other project strictly increases with the level of homophily.*

These results are consistent with empirical evidence. More homogeneous societies have a

[17]This result follows directly from Proposition 5.2 and Theorem 3.13 of Bollobás et al. (2007). In fact, more can be said: the number of connections of a player with the group-preferred project converges to a Poisson random variable with parameter e^*, and the number of connections of players with the other project converges to a Poisson random variable with parameter $e^- < e^*$.

higher level of social interactions (Alesina and La Ferrara, 2000); and the distribution of the number of connections in social and economic networks has considerable variance (Jackson, 2008). Furthermore, consistent with the theoretical results, friendships are often biased towards own-group friendships, and larger groups form more friendships per capita (Currarini et al., 2009).

Our results put restrictions on the type of networks that can be observed. When relative benefits v/c are high and there is a strong cultural identity Q, networks are dense and are characterized by high levels of homophily and a skewed distribution of the number of connections that players have. Moreover, the network consists of a tightly connected core of players from one group, with a smaller periphery of players from the other group. When v/c increases further, segregation is complete ($h = \frac{1}{2}$), and a densely connected homogenous network results. On the other hand, when economic benefits are limited and cultural identity is weak, networks are disconnected, and feature low levels of homophily and limited variation in the number of connections. Most data on network on social and economic networks is consistent with the case where there is a strong cultural identity and sizeable economic benefits to coordination, with many networks featuring high levels of homophily, a core-periphery structure, high levels of connectedness, and a skewed degree distribution (Jackson, 2008). More research is needed, of course, to establish to what extent these observations can indeed be attributed to the economic and cultural factors that drive players' preferences for reducing strategic uncertainty.

6. Conclusions

We introduced a novel approach to model players' introspective process, grounded in evidence on Theory of Mind in psychology, that allows for unique predictions in settings where individuals form connections and want to reduce strategic uncertainty. We show that high levels of segregation are possible even in the absence of any preferences for interactions with similar others. Consistent with empirical and experimental evidence, homophily is high when cultural identities are strong, benefits from coordination are large, and networks are formed endogenously. The theory elucidates trade-offs, inherent in diversity and inclusion policies, in regards to coordination and skill complementarities. In addition, it makes it possible to show that policies that stimulate an inclusive culture can have important economic benefits, in addition to their non-economic merits: while societies with a strong cultural identity have an advantage in stable economic environments, more inclusive societies do better in more volatile environments. In future work, we plan to develop a methodology based on Theory of Mind for general games, and to investigate experimentally to what extent a preference for reducing strategic uncertainty drives homophily.

Appendix A Intrinsic preferences

We denote the values of an A-player j for projects a and b are denoted by $w_j^{A,a}$ and $w_j^{A,b}$, respectively; likewise, the values of a B-player for projects b and a are $w_j^{B,b}$ and $w_j^{B,a}$, respectively. As noted in the main text, the values $w_j^{A,a}$ and $w_j^{A,b}$ are drawn from the uniform distribution on $[0,1]$ and $[0,1-2\varepsilon]$, respectively. Likewise, $w_j^{B,b}$ and $w_j^{B,a}$ are uniformly distributed on $[0,1]$ and $[0,1-2\varepsilon]$. All values are drawn independently (across players, projects, and groups). So, players in group A (on average) intrinsically prefer project a (in the sense of first-order stochastic dominance) over project b; see Figure 5. Likewise, on average, players in group B have an intrinsic preference for b.

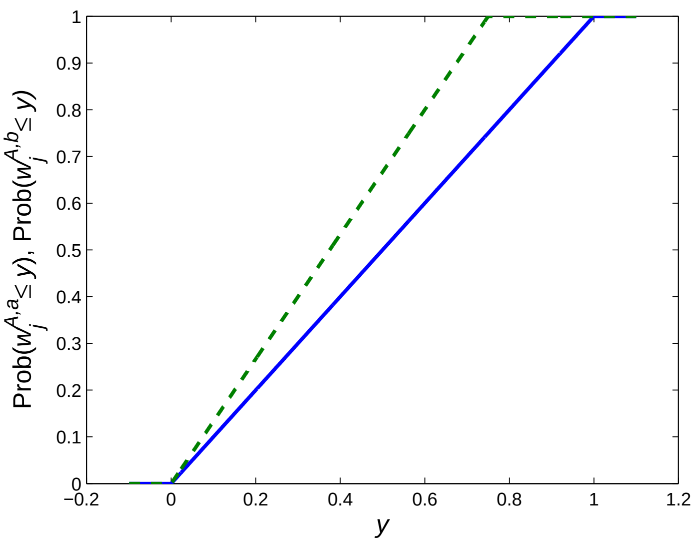


Figure 5: The cumulative distribution functions of $w_i^{A,a}$ (solid line) and $w_i^{A,b}$ (dashed line) for $x = 0.75$.

Given that the values are uniformly and independently distributed, the distribution of the difference $w_j^{A,a} - w_j^{B,a}$ in values for an A-player is given by the so-called trapezoidal distribution. That is, if we define $x := 1-2\varepsilon$, we can define the tail distribution $H_\varepsilon(y) := \mathbb{P}(w_j^{A,a} - w_j^{A,b} \geq y)$ by

$$H_\varepsilon(y) = \begin{cases} 1 & \text{if } y < -(1-2\varepsilon); \\ 1 - \frac{1}{2-4\varepsilon} \cdot (1-2\varepsilon+y)^2 & \text{if } y \in [-(1-2\varepsilon), 0); \\ 1 - \frac{1}{2} \cdot (1-2\varepsilon) - y & \text{if } y \in [0, 2\varepsilon); \\ \frac{1}{4(\frac{1}{2}-\varepsilon)} \cdot (1-y)^2 & \text{if } y \in [2\varepsilon, 1]; \\ 0 & \text{otherwise.} \end{cases}$$

By symmetry, the probability $\mathbb{P}(w_j^{B,b} - w_j^{B,a} \geq y)$ that the difference in values for the B-player is at least y is also given by $H_\varepsilon(y)$. So, we can identify $w_j^{A,a} - w_j^{A,b}$ and $w_j^{B,b} - w_j^{B,a}$ with the same random variable, denoted Δ_j, with tail distribution $H_\varepsilon(\cdot)$; see Figure 6.

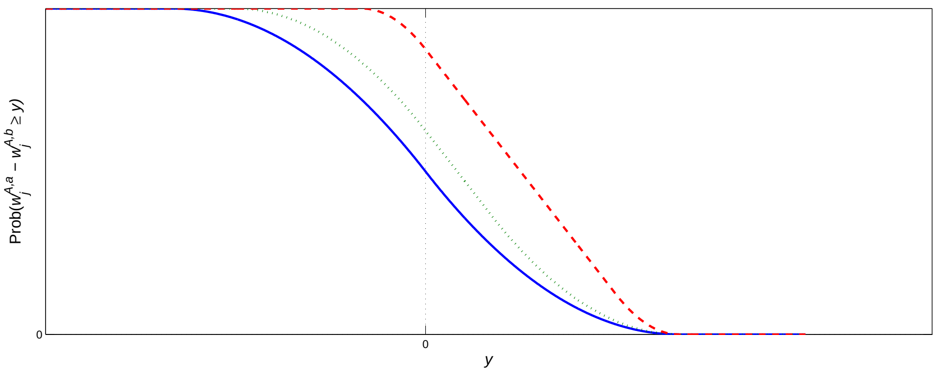


Figure 6: The probability that $w_j^{A,a} - w_j^{A,b}$ is at least y, as a function of y, for $\varepsilon = 0$ (solid line); $\varepsilon = 0.125$ (dotted line); and $\varepsilon = 0.375$ (dashed line).

The probability that A-players prefer the a-project, or, equivalently, the share of A-players that intrinsically prefer a (i.e., $w_j^{A,a} - w_j^{A,b} > 0$), is $1 - \frac{1}{2}x = \frac{1}{2} + \varepsilon$, and similarly for the B-players and project b.

Appendix B Equilibrium analysis

We compare the outcomes predicted using the introspective process to equilibrium predictions. As we show, the introspective process selects a correlated equilibrium of the game that has the highest level of homophily among the set of equilibria in which players' action depends on their signal, and thus maximizes the payoffs within this set.

We study the correlated equilibria of the extended game: in the first stage, players choose a project and are matched with players with the same project; and in the second stage, players play the coordination game with their partner. It is not hard to see that every introspective equilibrium is a correlated equilibrium. The game has more equilibria, though, even if we fix the signal structure. For example, in the coordination stage, the strategy profile under which all players choose the same fixed action regardless of their signal is a correlated equilibrium, as is the strategy profile under which half of the players in each group choose s^1 and the other half of the players choose s^2, or where players go against the action prescribed by their signal (i.e., choose s^2 if and only the signal is s^1). Given this, there is a plethora of equilibria for the extended game.

We restrict attention to equilibria in anonymous strategies, so that each player's equilibrium strategy depends only on his group, the project of the opponent he is matched with, and the signal he receives in the coordination game. In the coordination stage, we focus on equilibria in which players follow their signal. If all players follow their signal, following one's signal is a best response: for any probability p of interacting with a player of the own group, and any value w_j of a player's project, choosing action s^i having received signal i is a best response if and only if

$$\left[pQ + (1-p)\cdot\tfrac{1}{2}\right]\cdot v + w_j \geq \left[p\cdot(1-Q) + (1-p)\cdot\tfrac{1}{2}\right]\cdot v + w_j.$$

This inequality is always satisfied, as $Q > \frac{1}{2}$.

So, it remains to consider the matching stage. Suppose that $m^{A,a}$ and $m^{B,b}$ are the shares of A-players and B-players that choose projects a and b, respectively. Then, the probability that a player with project a belongs to group A is

$$p^{A,a} = \frac{m^{A,a}}{m^{A,a} + 1 - m^{B,b}};$$

similarly, the probability that a player with project b belongs to group B equals

$$p^{B,b} = \frac{m^{B,b}}{m^{B,b} + 1 - m^{A,a}}.$$

An A-player with intrinsic values $w_j^{A,a}$ and $w_j^{A,b}$ for the projects chooses project a if and only if

$$\left[p^{A,a}Q + (1-p^{A,a})\cdot\tfrac{1}{2}\right]\cdot v + w_j^{A,a} \geq \left[(1-p^{B,b})\cdot Q + p^{B,b}\tfrac{1}{2}\right]\cdot v + w_j^{A,b};$$

or, equivalently,

$$w_j^{A,a} - w_j^{A,b} \geq -(p^{A,a} + p^{B,b} - 1)\cdot\beta,$$

where we have defined $\beta := v\cdot(Q - \frac{1}{2})$. Similarly, a B-player with intrinsic values $w_j^{B,b}$ and $w_j^{B,a}$ chooses b if and only if

$$w_j^{B,b} - w_j^{B,a} \geq -(p^{A,a} + p^{B,b} - 1)\cdot\beta$$

In equilibrium, we must have that

$$\begin{aligned}\mathbb{P}\big(w_j^{A,a} - w_j^{A,b} \geq -(p^{A,a} + p^{B,b} - 1)\cdot\beta\big) &= m^{A,a}; \text{ and}\\ \mathbb{P}\big(w_j^{B,b} - w_j^{B,a} \geq -(p^{A,a} + p^{B,b} - 1)\cdot\beta\big) &= m^{B,b}.\end{aligned}$$

Because the random variables $w_j^{A,a} - w_j^{A,b}$ and $w_j^{B,b} - w_j^{B,a}$ have the same distribution (cf. Appendix A), it follows that $m^{A,a} = m^{B,b}$ and $p^{A,a} = p^{B,b}$ in equilibrium. Defining $p := p^{A,a}$ (and recalling the notation $\Delta_j := w_j^{A,a} - w_j^{A,b}$ from Appendix A), the equilibrium condition reduces to

$$\mathbb{P}(\Delta_j \geq -(2p-1)\cdot\beta) = p. \tag{B.1}$$

Thus, equilibrium strategies are characterized by a fixed point p of Equation (B.1).

It is easy to see that the introspective equilibrium characterized in Proposition 3.2 is an equilibrium. However, the game has more equilibria. The point $p = 0$ is a fixed point of (B.1) if and only if $\beta \geq 1$. In an equilibrium with $p = 0$, all A-players adopt project b, even if they have a strong intrinsic preference for project a, and analogously for B-players. In this case, the incentives for interacting with the own group, measured by β, are so large that they dominate any intrinsic preference.

But even if β falls below 1, we can have equilibria in which a minority of the players chooses the group-preferred project, provided that intrinsic preferences are not too strong. Specifically, it can be verified that there are equilibria with $p < \frac{1}{2}$ if and only if $\varepsilon \leq \frac{1}{2} - 2\beta(1-\beta)$. This condition is satisfied whenever ε is sufficiently small.

So, in general, there are multiple equilibria, and some equilibria in which players condition their action on their signal are inefficient as only a minority gets to choose the project they (intrinsically) prefer. Choosing a project is a coordination game, and society can get stuck in an inefficient equilibrium. The introspective process described in Section 3 selects the payoff-maximizing equilibrium, with the largest possible share of players coordinating on the group-preferred project.

Appendix C Signaling identity

Thus far, we have assumed that players can choose projects to sort. An alternative way in which people can bias the meeting process is to signal their identity to others. Here, we assume that players can use markers, that is, observable attributes such as tattoos, to signal their identity. This alternative model helps explain why groups are often marked by seemingly arbitrary traits.

There are two markers, a and b. Players first choose a marker, and are then matched to play the coordination game as described below. As before, each A-player has values $w_j^{A,a}$ and $w_j^{A,b}$ for markers a and b, drawn uniformly at random from $[0,1]$ and $[0, 1-2\varepsilon]$, respectively; and mutatis mutandis for a B-player. Thus, a is the *group-preferred marker* for group A, and b is the group-preferred marker for group B.

Players can now choose whether they want to interact with a player with an a- or a b-marker. Each player is chosen to be a *proposer* or a *responder* with equal probability, independently across players. Proposers can propose to play the coordination game to a responder. He chooses whether to propose to a player with an a- or a b-marker. If he chooses to propose with a player with an a-marker, he is matched uniformly at random with a responder with marker, and likewise if he chooses to propose to a player with a b-marker. A responder decides whether to accept or reject a proposal from a proposer, conditional on his own marker and the marker of the proposer.[18] Each player is matched exactly once.[19] Players' decision to propose or to accept/reject a proposal may depend on project choices, but do not depend on players' identities or group membership, which is unobservable. If player j proposed to player j', and j' accepted j's proposal, then they play the coordination game; if j's proposal was rejected by j', both get a payoff of zero. For simplicity, assume that there are no skill complementarities (i.e., $V = v$).

Players' choices are determined by the introspective process introduced earlier. At level 0, players choose the marker that they intrinsically prefer. Moreover, players propose to/accept proposals from anyone. At level 1, an A-player therefore has no incentive to choose a marker other than his intrinsically preferred marker, and thus chooses that marker. However, since at level 0, a slight majority of players with marker a belongs to group A, proposers from group A have an incentive to propose only to players with marker a, unless they have a strong intrinsic preference for marker b. Because players are matched only once, and because payoffs in the coordination game are nonnegative, a responder always accepts any proposal. The same holds, mutatis mutandis, for B-players.

We can prove an analogue of Proposition 3.2 for this setting:

Proposition C.1. *There is a unique introspective equilibrium. In the unique equilibrium, there is complete segregation ($h = \frac{1}{2}$) if and only if*

$$v \cdot (Q - \tfrac{1}{2}) \geq \tfrac{1}{2} - \varepsilon;$$

If segregation is not complete ($h < \frac{1}{2}$), then the level of homophily is given by:

$$\tfrac{1}{2} - \frac{1}{2 - 4\varepsilon}\big(1 - 2\varepsilon - \tfrac{v}{2} \cdot (Q - \tfrac{1}{2})\big)^2.$$

In all cases, the fraction of players choosing the group-preferred project exceeds the initial level (i.e., $h > \varepsilon$).

Also the comparative statics are similar:

[18] So, a proposer only proposes to play, and a responder can only accept or reject a proposal. In particular, he cannot propose transfers. The random matching procedure assumed in Section 2 can be viewed as the reduced form of this process.

[19] Such a matching is particularly straightforward to construct when there are finitely many players, as in Section 5. Otherwise, we can use the matching process of Alós-Ferrer (1999) (where the types need to be defined with some care). The results continue to hold when players are matched a fixed finite number of times, or when there is discounting and players are sufficiently impatient. Without such restrictions, players have no incentives to accept a proposal from a player with the non-group preferred marker, leaving a significant fraction of the players unmatched.

Corollary C.2. *The level of homophily h increases with the strength of the cultural identity Q and with the coordination payoff v. Cultural identity and economic incentives are complements: the level of homophily is high whenever the coordination payoff is high and cultural identity is strong.*

So, even if players cannot influence the probability of meeting similar others by locating in a particular neighborhood or joining an exclusive club, they can nevertheless associate preferentially with other members of their own group, provided that they can signal their identity.[20]

Appendix D Proofs

D.1 Proof of Proposition 2.1

By assumption, a player chooses action s^i at level 0 if and only if his initial impulse is $i = 1, 2$. For $k > 0$, assume, inductively, that at level $k-1$, a player chooses s^i if and only if his initial impulse is i. Consider level k, and suppose a player's impulse is i. Choosing s^i is the unique best response for him if the expected payoff from choosing s^i is strictly greater than the expected payoff from choosing the other action $s^j \neq s^i$. That is, if we write $j \neq i$ for the alternate impulse, s^i is the unique best response for the player if

$$p \cdot v \cdot \mathbb{P}(i \mid i) + (1-p) \cdot V \cdot \mathbb{P}(i) > p \cdot v \cdot \mathbb{P}(j \mid i) + (1-p) \cdot V \cdot \mathbb{P}(j) \cdot v,$$

where $\mathbb{P}(m \mid i)$ is the conditional probability that the impulse of a player from the same group is $m = 1, 2$ given that the player's own impulse is i, and $\mathbb{P}(m)$ is the probability that a player from the other group has received signal m. Using that $\mathbb{P}(m) = \frac{1}{2}$, $\mathbb{P}(i \mid i) = q^2 + (1-q)^2$ and $\mathbb{P}(j \mid i) = 1 - q^2 - (1-q)^2$, and rearranging, we find that this holds if and only if

$$pv(q^2 + (1-q)^2) > p(1 - q^2 - (1-q)^2),$$

and this holds for every $p > 0$, since $q^2 + (1-q)^2 > \frac{1}{2}$. This shows that at each level, it is optimal for a player to follow his impulse. So, in the unique introspective equilibrium, every player follows his impulse. $\square$

[20] Unlike classical models of costly signaling, adopting a certain marker is *not* inherently more costly for one group than for another. The difference in signaling value of the markers across groups is endogenous in our model.

D.2 Proof of Lemma 3.1

At level 0, players choose the project that they intrinsically prefer. So, the share of players that choose project a that belong to group A is

$$p_0^a = \frac{\frac{1}{2}+\varepsilon}{\frac{1}{2}+\varepsilon+(1-(\frac{1}{2}+\varepsilon))} = \frac{1}{2}+\varepsilon.$$

Likewise, the share of players that choose project b that belong to group B is $p_0^b = \frac{1}{2}+\varepsilon$. Also, recall that $x := 1-2\varepsilon$ (Appendix A).

We start with the case where the marginal benefit of interacting with the own group, given by $\beta = vQ - \frac{1}{2}V$, is positive. We show that the sequence $\{p_k^\pi\}_k$ is (weakly) increasing and bounded for every project π.

At higher levels, players choose projects based on their intrinsic values for the project as well as the coordination payoff they expect to receive at each project. Suppose that a share p_{k-1}^a of players with project a belong to group A, and likewise for project b and group B. Then, the probability that an A-player with project a is matched with a player of the own group is p_{k-1}^a, and the probability that a B-player with project a is matched with a player of the own group is $1-p_{k-1}$. Applying Proposition 2.1 (with $\tilde{p} = p_{k-1}$ and $\tilde{p} = 1-p_{k-1}$) shows that both A-players and B-players with project a follow their signal in the coordination game, and similarly for the A- and B-players with project b.

So, for every $k>0$, given p_{k-1}^a, a player from group A chooses project a if and only if

$$\left[p_{k-1}^a \cdot Q + (1-p_{k-1}^a)\cdot \tfrac{1}{2}\right]\cdot v + w_j^{A,a} \geq \left[(1-p_{k-1}^a)\cdot Q + p_{k-1}^a \cdot \tfrac{1}{2}\right]\cdot v + w_j^{A,b}.$$

This inequality can be rewritten as

$$w_j^{A,a} - w_j^{A,b} \geq -(2p_{k-1}^a - 1)\cdot\beta, \tag{D.1}$$

and the share of A-players for whom this holds is

$$p_k^a := H_\varepsilon\big(-(2p_{k-1}-1)\cdot\beta\big),$$

where we have used the expression for the tail distribution H_ε from Appendix A. The same law of motion holds, of course, if a is replaced with b and A is replaced with B.

Fix a project π. Notice that $-(2p_0^\pi - 1)\cdot\beta < 0$. We claim that $p_1^\pi \geq p_0^\pi$ and that $p_1^\pi \in (\frac{1}{2}, 1]$. By the argument above,

$$\begin{aligned}
p_1^\pi &= \mathbb{P}(w_j^{A,a} - w_j^{A,b} \geq -(2p_0^\pi - 1)\cdot\beta)\\
&= H_\varepsilon(-(2p_0^\pi - 1)\cdot\beta)\\
&= \begin{cases} 1 - \frac{1}{2-4\varepsilon}\cdot(1-2\varepsilon-(2p_0^\pi-1)\cdot\beta)^2 & \text{if } (2p_0^\pi-1)\cdot\beta \leq 1-2\varepsilon;\\ 1 & \text{if } (2p_0^\pi-1)\cdot\beta > 1-2\varepsilon;\end{cases}
\end{aligned}$$

where we have used the expression for the tail distribution $H_\varepsilon(y)$ from Appendix A. If $(2p_0^\pi - 1) \cdot \beta > 1 - 2\varepsilon$, the result is immediate, so suppose that $(2p_0^\pi - 1) \cdot \beta \leq 1 - 2\varepsilon$. We need to show that

$$1 - \tfrac{1}{2-4\varepsilon} \cdot (1 - 2\varepsilon - (2p_0^\pi - 1) \cdot \beta)^2 \geq p_0^\pi.$$

Rearranging and using that $p_0^\pi \in (\frac{1}{2}, 1]$, we see that this holds if and only if

$$(2p_0^\pi - 1) \cdot \beta \leq 2 \cdot (1 - 2\varepsilon).$$

But this holds because $(2p_0^\pi - 1) \cdot \beta \leq 1 - 2\varepsilon$ and $1 - 2\varepsilon \geq 0$. Note that the inequality is strict whenever $\beta < 1 - 2\varepsilon$, so that $p_1^\pi > p_0^\pi$ in that case.

For $k > 1$, suppose, inductively, that $p_{k-1}^\pi \geq p_{k-2}^\pi$ and that $p_{k-1}^\pi \in (\frac{1}{2}, 1]$. By a similar argument as above,

$$p_k^\pi = \begin{cases} 1 - \frac{1}{2-4\varepsilon} \cdot (1 - 2\varepsilon - (2p_{k-1}^\pi - 1) \cdot \beta)^2 & \text{if } (2p_{k-1}^\pi - 1) \cdot \beta \leq 1 - 2\varepsilon; \\ 1 & \text{if } (2p_{k-1}^\pi - 1) \cdot \beta > 1 - 2\varepsilon. \end{cases}$$

Again, if $(2p_{k-1}^\pi - 1) \cdot \beta > 1 - 2\varepsilon$, the result is immediate, so suppose $(2p_{k-1}^\pi - 1) \cdot \beta \leq 1 - 2\varepsilon$. We need to show that

$$1 - \tfrac{1}{2-4\varepsilon} \cdot (1 - 2\varepsilon - (2p_{k-1}^\pi - 1) \cdot \beta)^2 \geq p_{k-1}^\pi,$$

or, equivalently,

$$2 \cdot (1 - 2\varepsilon) \cdot (1 - p_{k-1}^\pi) \geq (1 - 2\varepsilon - (2p_{k-1}^\pi - 1) \cdot \beta)^2.$$

By the induction hypothesis, $p_{k-1}^\pi \geq p_0^\pi$, so that $1 - 2\varepsilon \geq 2 - 2p_{k-1}^\pi$. Using this, we have that $2 \cdot (1 - 2\varepsilon) \cdot (1 - p_{k-1}^\pi) \geq 4 \cdot (1 - p_{k-1}^\pi)^2$. Moreover,

$$(1 - 2\varepsilon - (2p_{k-1}^\pi - 1) \cdot \beta)^2 \leq 4 \cdot (1 - p_{k-1}^\pi)^2 - 2\beta(1 - 2\varepsilon)(2p_{k-1}^\pi - 1) + (2p_{k-1}^\pi - 1)^2\beta^2.$$

So, it suffices to show that

$$4 \cdot (1 - p_{k-1}^\pi)^2 \geq 4 \cdot (1 - p_{k-1}^\pi)^2 - 2\beta(1 - 2\varepsilon)(2p_{k-1}^\pi - 1) + (2p_{k-1}^\pi - 1)^2\beta^2.$$

The above inequality holds if and only if

$$(2p_{k-1}^\pi - 1)\beta \leq 2 \cdot (1 - 2\varepsilon),$$

and this is true since $(2p_{k-1}^\pi - 1) \cdot \beta \leq 1 - 2\varepsilon$.

So, the sequence $\{p_k^\pi\}_k$ is weakly increasing and bounded when $\beta > 0$. It now follows from the monotone sequence convergence theorem that the limit p^π exists. The argument clearly does not depend on the project π, so we have $p^a = p^b$.

A similar argument can be used to show that if $\beta \in (-\frac{1}{2}, 0)$, then the sequence $\{p_k^\pi\}_k$ is weakly decreasing and bounded for every project π, and $p_k^\pi < \frac{1}{2} + \varepsilon$ for all k. Again, by the monotone convergence theorem, the sequences $\{p_k^a\}_k$ and $\{p_k^b\}_k$ converge to a common limit p. It can be checked that if $\beta < -\frac{1}{2}$, then the sequence $p_0^\pi, p_1^\pi, \ldots$ does not settle down. Intuitively, players have an incentive to "flee" from players of their own group to reap the high payoffs from interacting with the other group. For example, if A-players make up the majority of players with project a at level k, then even an A-player for whom it is optimal to choose project a at level k may find it beneficial to choose project b at level $k+1$, and A-players form the minority of players with project a at that level. Finally, if $\beta = 0$, then at each level, players choose the project that they intrinsically prefer, so that $p_k^\pi = p_0^\pi = \frac{1}{2} + \varepsilon$ for each project. □

D.3 Proof of Proposition 3.2

We first consider the case $\beta > 0$. The first step is to characterize the limiting fraction p, and show that $p > \frac{1}{2} + \varepsilon$. By the proof of Lemma 3.1, we have $p_k \geq p_{k-1}$ for all k. By the monotone sequence convergence theorem, $p = \sup_k p_k$, and by the inductive argument, $p \in (\frac{1}{2} + \varepsilon, 1]$. It is easy to see that $p = 1$ if and only if $H_\varepsilon(-(2 \cdot 1 - 1) \cdot \beta) = 1$, which holds if and only if $\beta \geq 1 - 2\varepsilon$.

So suppose that $\beta < 1 - 2\varepsilon$, so that $p < 1$. Again, $p = H_\varepsilon(-(2p-1) \cdot \beta)$, or, using the expression from Appendix A,

$$p = 1 - \tfrac{1}{2-4\varepsilon} \cdot (1 - 2\varepsilon - (2p-1) \cdot \beta)^2.$$

It will be convenient to substitute $x = 1 - 2\varepsilon$ for ε, so that we are looking for the solution of

$$p = 1 - \tfrac{1}{2x} \cdot (x - (2p-1) \cdot \beta)^2. \tag{D.2}$$

Equation (D.2) has two roots,

$$r_1 = \tfrac{1}{2} + \tfrac{1}{4\beta^2}\Big((2\beta - 1) \cdot x + \sqrt{4\beta^2 x - (4\beta - 1) \cdot x^2}\Big)$$

and

$$r_2 = \tfrac{1}{2} + \tfrac{1}{4\beta^2}\Big((2\beta - 1) \cdot x - \sqrt{4\beta^2 x - (4\beta - 1) \cdot x^2}\Big).$$

We first show that r_1 and r_2 are real numbers, that is, that $4\beta^2 x - (4\beta - 1) \cdot x^2 \geq 0$. Since $x > 0$, this is the case if and only if $4\beta \geq (4\beta - 1) \cdot x$. This holds if $\beta \leq \frac{1}{4}$, so suppose that $\beta > \frac{1}{4}$. We need to show that

$$x \leq \frac{4\beta^2}{4\beta - 1}.$$

Since the right-hand side achieves its minimum at $\beta = \frac{1}{2}$, it suffices to show that $x \le (4 \cdot (\frac{1}{2})^2)/(4 \cdot \frac{1}{2} - 1) = 1$. But this holds by definition. It follows that r_1 and r_2 are real numbers.

We next show that $r_1 > \frac{1}{2}$, and $r_2 < \frac{1}{2}$. This implies that $p = r_1$, as $p = \sup_k p_k > p_0 > \frac{1}{2}$.

It suffices to show that $4\beta^2 x - (4\beta - 1) \cdot x^2 > (1 - 2\beta)^2 x^2$. This holds if and only if $\beta > (2 - \beta) \cdot x$. Recalling that $\beta \le 1 - 2\varepsilon < 1$ by assumption, we see that this inequality is satisfied. We conclude that $p = r_1$ when $\beta > 0$.

Next consider the case $\beta < 0$. By Lemma 3.1, $p_k \le p_{k-1}$ for all k. By the monotone sequence convergence theorem, $p = \inf_k p_k$. As before, we can find p by solving the fixed point equation

$$p = H_\varepsilon(-(2p - 1) \cdot \beta).$$

Writing $y := -(2p - 1) \cdot \beta$, we now need to consider two regimes: $y \in (0, \varepsilon)$ and $y \in [2\varepsilon, 1]$ (cf. Appendix A). In the second regime, $H_\varepsilon(y) = \frac{1}{2x}(1 - y)^2$, and the fixed point equation $p(y) = H_\varepsilon(y)$ has two roots y_1, y_2 that lie outside the domain $(0, 2\varepsilon)$. So consider the first regime, where $H_\varepsilon(y) = 1 - \frac{1}{2}x - y$. The fixed point equation has a unique solution y^*, with corresponding limiting probability

$$p = \tfrac{1}{2} - \frac{\varepsilon}{2\beta - 1}.$$

It can be checked that p is increasing in β, and lies in $(\frac{1}{2}, \frac{1}{2} + \varepsilon)$ for $\beta < 0$. Finally, when $\beta = 0$, players choose the project that they intrinsically prefer at each level, and $p = \frac{1}{2} + \varepsilon$. $\square$

As for the comparative statics in Corollary 3.3, it is straightforward to verify that the derivative of p with respect to β is positive whenever $p < 1$ (and 0 otherwise). It then follows from the chain rule that the derivatives of p with respect to v and Q are both positive for any $p < 1$ (and 0 otherwise). It is immediate that p decreases with V.

D.4 Proof of Proposition 4.1

It is easy to verify that if the share of players with the group-preferred project is p, then the total coordination payoff per project is given by

$$Qv \cdot \left(p^2 + (1 - p)^2\right) + 2 \cdot p \cdot (1 - p) \cdot \tfrac{1}{2}V \tag{D.3}$$

for each project, where the first term is the expected payoff for players of interacting with their own group, and the second term is the expected payoff of players interacting with the own group. For example, there is a measure p of players from group A with project a, each of which has probability p of being matched with a member of their own group, while there is a measure $1 - p$ of B-players with project a, each of which is matched with an B-player with probability $1-p$. Similarly, a measure $1-p$ of B-players have chosen project a and have probability p of being matched with a A-player, and a measure p of A-players with project a that have probability $1-p$ of interacting with a B-player.

To calculate social welfare, first note that it is optimal if players with the strongest preference for the group-preferred project choose that project, that is, if players choose the group-preferred project if and only if the preference for the group-preferred project exceeds some threshold (and, likewise, for the other project). For example, if in the social optimum, an A-player j with preference $w_j^{A,a} - w_j^{A,b}$ chooses project a, then so does an A-player with $\tilde{w}_j^{A,a} - \tilde{w}_j^{A,b} > w_j^{A,a} - w_j^{A,b}$.

Next note that it is never optimal to have less than half the players choose the group-preferred project (i.e., $p < \frac{1}{2}$). To see this, suppose by contradiction that a share $p < \frac{1}{2}$ of players (of a given group, say A) chooses the group-preferred project (say a). Then social welfare increases if the share $1-p$ of players with the strongest preference for the group-preferred project chooses that project (and the other players choose the other project). This does not impact total coordination payoffs (as (D.3) remains unchanged if we replace p by $1-p$ and vice versa), but it increases the share of players that choose the project that they intrinsically prefer.

The next result characterizes social welfare as a function of the probability $p = h + \frac{1}{2}$ of interacting with the own group. It will be convenient to use the notation $x := 1-2\varepsilon$ (Appendix A).

Lemma D.1. *Social welfare as a function of the probability p of interacting with the own group is given by*

$$W(p) = 2\Big[\big(p^2 + (1-p)^2\big) \cdot Qv + 2p(1-p) \cdot \tfrac{1}{2}V + \ell(p)\Big], \tag{D.4}$$

where $2\ell(p)$ is the total project value, with the value per project $\ell(p)$ given by:

$$\ell(p) = \begin{cases} \frac{1}{2x} \cdot \Big[x + \frac{x^3}{3} - 2x\big(1-p-\frac{x}{2}\big)^2 + \frac{1}{3}\big(1-p-\frac{x}{2}\big)^3\Big] & \text{if } p \in [\frac{1}{2}, \frac{1}{2}+\varepsilon); \\ \frac{1}{2x} \cdot \Big[x + \frac{x^3}{3} - x\big(x - \sqrt{2x(1-p)}\big)^2 + \frac{2}{3}\big(x - \sqrt{2x(1-p)}\big)^3\Big] & \text{if } p \in [\frac{1}{2}, 1); \end{cases}$$

assuming that a share p with the strongest preference for the group-preferred project chooses that project.

Proof. Let $p \in [\frac{1}{2}, 1]$ be the share of players that have chosen the group-preferred project. Fix a project, say a, and consider an A-player with that project, that is, a player that has chosen the group-preferred project. The expected coordination payoff to such a player is

$$pQv + (1-p)\tfrac{1}{2}V;$$

and since the share of A-players with project a is p, the total expected payoff to A-players with project a is

$$p \cdot \left[pQv + (1-p)\tfrac{1}{2}V\right].$$

Similarly, the expected coordination payoff to a B-player with project a is

$$(1-p)Qv + \tfrac{pV}{2};$$

and the total expected payoff to B-players with project a is

$$(1-p) \cdot \left[(1-p)Qv + \tfrac{pV}{2}\right].$$

Performing the same analysis for B- and A-players with project b and adding all terms together gives the first two terms of (D.4).

To calculate the project value, fix a group, say A. As noted above, in the social optimum, all A-players for whom the difference $w_j^{A,a} - w_j^{A,b}$ exceeds a certain threshold y choose project a, and the other A-players choose project b. The share of players for whom $w_j^{A,a} - w_j^{A,b}$ is at least y is given by $p = H_\varepsilon(y)$, where $H_\varepsilon(y)$ is the tail distribution introduced in Appendix A. Since this tail distribution has different regimes, depending on y, we need to consider different cases. Rather than considering different ranges for the threshold y, it will be easier to work with different ranges for $p = H_\varepsilon(y)$.

Case 1: $p \in [\frac{1}{2}, \frac{1}{2}+\varepsilon)$. First suppose that the share p of players choosing the group-preferred project lies in the interval $[\frac{1}{2}, \frac{1}{2}+\varepsilon)$. As noted above, the threshold $y = y(p)$ solves the equation $p = H_\varepsilon(y)$. It is easy to check that for every $p \in [\frac{1}{2}, \frac{1}{2}+\varepsilon)$, the equation $p = H_\varepsilon(y)$ has a solution $y \in [0, 2\varepsilon)$, so that (by the definitions in Appendix A) the equation reduces to $p = 1 - \frac{x}{2} - y$, or, equivalently,

$$y = 1 - \tfrac{x}{2} - p.$$

For a given $y = y(p)$, if every A-player chooses project a if and only if $w_j^{A,a} - w_j^{A,b} \geq y$, then the share of A-players choosing project a is p. If the A-players with $w_j^{A,a} - w_j^{A,b} \geq y$ choose project a, then their total project value is

$$\tfrac{1}{x} \int_0^x \int_{w_j^{A,a}+y}^1 w_j^{A,a} dw_j^{A,a} dw_j^{A,b},$$

where the factor $1/x$ comes from the uniform distribution of $w_j^{A,b}$ on $[0, x]$. The total project value for A-players that choose project b is given by

$$\tfrac{1}{x} \int_y^x \int_{w_j^{A,a}-y}^x w_j^{A,b} dw_j^{A,b} dw_j^{A,a} + \tfrac{1}{x} \int_0^y \int_0^x w_j^{A,b} dw_j^{A,b} dw_j^{A,a}.$$

The second term is for A-players for whom $w_j^{A,a}$ is so small (relative to the threshold y) that they choose b for any value $w_j^{A,b} \in [0, x]$ (that is, $w_j^{A,a} - y < 0$). The first term describes the total value for A-player for whom $w_j^{A,a} - y \geq 0$. Working out the integrals and summing the terms gives the expression for $\ell(p)$ in the lemma for $p \in [\frac{1}{2}, \frac{1}{2} + \varepsilon)$.

Case 2: $p \in [\frac{1}{2} + \varepsilon, 1]$**.** Next suppose $p \in [\frac{1}{2} + \varepsilon, 1]$. Again, fix a group, say A, and note that the A-players for whom $w_j^{A,a} - w_j^{A,b}$ exceeds a threshold $z = z(p)$ choose project a (and the other A-players choose project b). The threshold is again given by the equation $p = H_\varepsilon(z)$, and for $p \in [\frac{1}{2} + \varepsilon, 1]$, this equation reduces to

$$p = 1 - \tfrac{1}{2x}(x + z).$$

It will be convenient to work with a nonnegative threshold, so define $y := -z \geq 0$. Then, rewriting gives[21]

$$y = x - \sqrt{(}2x(1 - p)).$$

The total project value for A-players that choose project a (given p) is

$$\tfrac{1}{x} \int_0^y \int_0^1 w_j^{A,a} dw_j^{A,a} dw_j^{A,b} + \tfrac{1}{x} \int_y^x \int_{w_j^{A,b} - y}^1 w_j^{A,a} dw_j^{A,a} dw_j^{A,b},$$

where the first term is for A-players for whom $w_j^{A,b}$ is sufficiently low that they choose project a for any $w_j^{A,a} \in [0, 1]$ (given y), and the second term describes the total project value for the other A-players for whom $w_j^{A,a} - w_j^{A,b} \geq -y$, analogously to before. Again, working out the integrals and summing the term gives the expression for $\ell(p)$ for $p \in [\frac{1}{2} + \varepsilon, 1]$. $\square$

We are now ready to prove Proposition 4.1. As in the proof of Lemma D.1, we need to consider two cases.

Case 1: $p \in [\frac{1}{2}, \frac{1}{2} + \varepsilon)$**.** In this case, we have

$$\frac{dW}{dp} = 2 \cdot (2p - 1)\beta + \tfrac{1}{2x}\Big[4x(1 - p - \tfrac{x}{2}) - (1 - p - \tfrac{x}{2})^2\Big].$$

Setting $dW/dp = 0$ and solving for p gives two roots:

$$r_1 = 4\beta x - \tfrac{5x}{2} + 1 + \sqrt{4\beta^2 - 5\beta + 1 + \tfrac{\beta}{x}},$$

[21]Note that $y' = x + \sqrt{(}2x(1 - p))$ also solves the equation. However, a threshold $z' = -y$ less than $-x$ is not feasible: it corresponds to a share of players that choose the group-preferred project that is greater than 1.

and

$$r_2 = 4\beta x - \tfrac{5x}{2} + 1 - \sqrt{4\beta^2 - 5\beta + 1 + \tfrac{\beta}{x}}.$$

It is straightforward to verify that $r_2 \le \frac{1}{2}$ whenever $x \ge \frac{1}{9}$. Also, if $x \ge \frac{1}{9}$, the root r_1 lies in $[\frac{1}{2}, \frac{1}{2}+\varepsilon)$ if and only if $\beta < 0$. It can be checked that the second-order conditions are satisfied, so $h^* = r_1 - \frac{1}{2}$ is the optimal level of homophily if $\beta < 0$.

Case 2: $p \in [\frac{1}{2}+\varepsilon, 1]$**.** In this case, the derivative is

$$\frac{dW}{dp} = 2 \cdot (2p-1)\beta + \sqrt{2x(1-p)} - x.$$

Again, the first-order condition gives two solutions:

$$r_1' = \tfrac{1}{2} + \frac{x}{4\beta^2}\Big[\beta - \tfrac{1}{4} + \sqrt{\tfrac{\beta^2}{x} - \tfrac{\beta}{2} + \tfrac{1}{16}}\Big],$$

and

$$r_2' = \tfrac{1}{2} + \frac{x}{4\beta^2}\Big[\beta - \tfrac{1}{4} - \sqrt{\tfrac{\beta^2}{x} - \tfrac{\beta}{2} + \tfrac{1}{16}}\Big].$$

For any combination of parameters, $r_2' \le \frac{1}{2}$. Clearly, $r_1' > r_2'$; moreover, r_1' is a saddle point (and thus a point of inflection) if and only if $2\beta \ge x$. If $2\beta \ge x$, then dW/dp is positive in the neighborhood of r_1'. In that case, the function $W(p)$ attains its maximum at the boundary $p = 1$, and the optimal level of homophily is $h^* = 1 - \frac{1}{2} = \frac{1}{2}$. If $2\beta \in (0, x)$, then $r_1' \in (\frac{1}{2}+\varepsilon, 1]$, and conversely, if $r_1' \in [\frac{1}{2}+\varepsilon, 1]$, then $B \in (0, \frac{x}{1-x}]$. Hence, if $2\beta \in (0, x)$, the optimal level of homophily is $h^* = r_1' - \frac{1}{2} > \varepsilon$. □

As for the comparative statics when there are no skill complementarities (i.e., $V = v$), the short-run effect of a policy to strengthen cultural identity (Corollary **??**) is given by the partial derivative of W with respect to Q:

$$\frac{\partial W}{\partial Q} = (p^2 + (1-p)^2) \cdot v > 0.$$

The effect of such a policy in the intermediate run is given by the total derivative of W with respect to Q:

$$\frac{dW}{dQ} = \frac{\partial W}{\partial Q} + \frac{\partial W}{\partial p} \cdot \frac{dp}{dQ}.$$

Straightforward but tedious calculations show that dW/dQ is positive.

D.5 Proof of Lemma 5.1

Recall that at level 0, players invest effort $e_0 > 0$ in socializing. Moreover, they choose project a if and only if they intrinsically prefer project a over project b. It follows from the distribution of the intrinsic values (Appendix A) that the number $N_0^{A,a}$ of A-players with project a at level 0 follows the same distribution as the number $N_0^{B,b}$ of B-players with project b at level 0; similarly, the number $N_0^{A,a}$ of A-players with project b at level 0 has the same distribution as the number $N_0^{B,a}$ of B-players with project a at level 0. Let N_0^D and N_0^M be random variables with the same distribution as $N_0^{A,a}$ and $N_0^{B,a}$, respectively (where D stands for "dominant group" and M stands for "minority group"; the motivation for this terminology is that a slight majority of the players with an intrinsic preference for project a belongs to group A).

Conditional on N_0^D and N_0^M, the expected utility of project a to an A-player at level 1 is[22]

$$v \cdot \left[\frac{e_j \cdot N_0^D \cdot e_0 \cdot Q + e_j \cdot N_0^M \cdot e_0 \cdot \frac{1}{2}}{N_0^D \cdot e_0 + N_0^M \cdot e_0}\right] + w_j^{A,a} - \frac{ce_j}{2}$$

if he invests effort e_j and his intrinsic value for project a is $w_j^{A,a}$. Likewise, conditional on N_0^D and N_0^M, the expected utility of project b to an A-player at level 1 is

$$v \cdot \left[\frac{e_j \cdot N_0^M \cdot e_0 \cdot Q + e_j \cdot N_0^D \cdot e_0 \cdot \frac{1}{2}}{N_0^D \cdot e_0 + N_0^M \cdot e_0}\right] + w_j^{A,b} - \frac{ce_j}{2}$$

if he invests effort e_j and his intrinsic value for project b is $w_j^{A,b}$. Taking expectations over N_0^D and N_0^M, it follows from the first-order conditions that the optimal effort levels for an A-player at level 1 with projects a and b are given by

$$\begin{aligned} e_1^{A,a} &= \left(\frac{v}{c}\right) \cdot \mathbb{E}\left[\frac{N_0^D \cdot e_0 \cdot Q + N_0^M \cdot e_0 \cdot \frac{1}{2}}{N_0^D \cdot e_0 + N_0^M \cdot e_0}\right]; \text{ and} \\ e_1^{A,b} &= \left(\frac{v}{c}\right) \cdot \mathbb{E}\left[\frac{N_0^M \cdot e_0 \cdot Q + N_0^D \cdot e_0 \cdot \frac{1}{2}}{N_0^D \cdot e_0 + N_0^M \cdot e_0}\right]; \end{aligned}$$

respectively, independent of the intrinsic values. It can be checked that the optimal effort levels $e_1^{B,a}$ and $e_1^{B,b}$ for a B-player at level 1 with projects a and b are equal to $e_1^{A,b}$ and $e_1^{A,a}$, respectively. It will be convenient to define $e_1^D := e_1^{A,a} = e_1^{B,b}$ and $e_1^M := e_1^{A,b} = e_1^{B,a}$. We claim that $e_1^D > e_1^M$. To see this, note that N_0^D is binomially distributed with parameters $|N|$ and $p_0 := \frac{1}{2}+\varepsilon > \frac{1}{2}$ (the probability that a player has an intrinsic preference for the group-preferred project) and that N_0^M is binomially distributed with parameters $|N|$ and $1 - p_0 < \frac{1}{2}$. If we define

$$\begin{aligned} g_1^D(N_0^D, N_0^M, e_0) &:= \left(\frac{v}{c}\right) \cdot \left(\frac{N_0^D \cdot e_0 \cdot Q + N_0^M \cdot e_0 \cdot \frac{1}{2}}{N_0^D \cdot e_0 + N_0^M \cdot e_0}\right); \text{ and} \\ g_1^M(N_0^D, N_0^M, e_0) &:= \left(\frac{v}{c}\right) \cdot \left(\frac{N_0^M \cdot e_0 \cdot Q + N_0^D \cdot e_0 \cdot \frac{1}{2}}{N_0^D \cdot e_0 + N_0^M \cdot e_0}\right); \end{aligned}$$

[22] If $N_0^D = N_0^M = 0$, then the expected benefit from networking is 0. In that case, the player's expected utility is thus $w_j^{A,a} - \frac{ce_j}{2}$. A similar statement applies at higher levels.

so that e_1^D and e_1^M are just the expectations of g_1^D and g_1^D, respectively, then the result follows immediately from the fact that N_0^D first-order stochastically dominates N_0^M, as g_1^D is (strictly) increasing in N_0^D and (strictly) decreasing in N_0^M, and g_1^M is decreasing in N_0^D and increasing in N_0^M (again, strictly).

Substituting the optimal effort levels e_1^D and e_1^M into the expression for the expected utility for each project shows that the maximal expected utility of an A-player at level 1 of projects a and b is given by

$$\begin{aligned}&\frac{c}{2}(e_1^D)^2 + w_j^{A,a}; \text{ and}\\ &\frac{c}{2}(e_1^M)^2 + w_j^{A,b};\end{aligned}$$

respectively. At level 1, an A-player therefore chooses project a if and only if

$$w_j^{A,a} - w_j^{A,b} \geq -\frac{c}{2}\big((e_1^D)^2 - (e_1^M)^2\big).$$

The analogous argument shows that a B-player chooses project b at level 1 if and only if

$$w_j^{B,b} - w_j^{B,a} \geq -\frac{c}{2}\big((e_1^D)^2 - (e_1^M)^2\big).$$

Since $w_j^{A,a} - w_j^{A,b}$ and $w_j^{B,b} - w_j^{B,a}$ both have tail distribution $H_\varepsilon(\cdot)$ (Appendix A), the probability that an A-player chooses project a (or, that a B-player chooses project b) is

$$p_1 := H_\varepsilon\left(-\frac{c}{2}\big((e_1^D)^2 - (e_1^M)^2\big)\right).$$

Since $e_1^D > e_1^M$, we have $p_1 > p_0$. Note that both the number $N_1^{A,a}$ of A-players at level 1 with project a and the number $N_1^{B,b}$ of B-players at level 1 with project b are binomially distributed with parameters $|N|$ and $p_1 > \frac{1}{2}$; the number $N_1^{A,a}$ of A-players at level 1 with project b and the number $N_1^{B,a}$ of B-players at level 1 with project a are both binomially distributed with parameters $|N|$ and $1 - p_1$. Let N_1^D and N_1^M be random variables that are binomially distributed with parameters $(|N|, p_1)$ and $(|N|, 1 - p_1)$, respectively, so that the distribution of N_1^D first-order stochastically dominates the distribution of N_1^M.

Note that while $N_1^{A,a}$ and $N_1^{A,a}$ are clearly not independent (as $N_1^{A,a} + N_1^{A,a} = N$), $N_1^{A,a}$ and $N_1^{B,a}$ are independent (and similarly if we replace $N_1^{A,a}$, $N_1^{A,a}$, and $N_1^{B,a}$ with $N_1^{B,b}$, $N_1^{B,a}$, and $N_1^{A,a}$, respectively). When we take expectations over the number of players from different groups with a given project (e.g., $N_1^{A,a}$ and $N_1^{B,a}$) to calculate optimal effort levels, we therefore do not have to worry about correlations between the random variables. A similar comment applies to levels $k > 1$.

Finally, it will be useful to note that

$$e_1^D + e_1^M = \frac{v}{c}(Q + \tfrac{1}{2}).$$

Both e_1^D and e_1^M are positive, as they are proportional to the expectation of a nonnegative random variable (with a positive probability on positive realizations), and we have

$$e_1^D - e_1^M > e_0^D - e_0^M = 0,$$

where $e_0^D = e_0^M = e_0$ are the effort choices at level 0.

For $k > 1$, assume, inductively, that the following hold:

- we have $p_{k-1} \geq p_{k-2}$;
- the number $N_{k-1}^{A,a}$ of A-players with project a at level $k-1$ and the number $N_{k-1}^{B,b}$ of B-players with project b at level $k-1$ are binomially distributed with parameters $|N|$ and p_{k-1};
- the number $N_{k-1}^{A,a}$ of A-players with project b at level $k-1$ and the number $N_{k-1}^{B,a}$ of B-players with project a at level $k-1$ are binomially distributed with parameters $|N|$ and $1-p_{k-1}$;
- for every level $m \leq k-1$, the optimal effort level at level m for all A-players with project a and for all B-players with project b is equal to e_m^D;
- for every level $m \leq k-1$, the optimal effort level at level m for all A-players with project b and for all B-players with project a is equal to e_m^M;
- we have $e_{k-1}^D > e_{k-1}^M > 0$ for $k \geq 2$;
- we have $e_{k-1}^D - e_{k-1}^M \geq e_{k-2}^D - e_{k-2}^M$.

We write N_{k-1}^D and N_{k-1}^M for random variables that are binomially distributed with parameters $(|N|, p_{k-1})$ and $(|N|, 1-p_{k-1})$, respectively.

By a similar argument as before, it follows that the optimal effort level for an A-player that chooses project a or for a B-player that chooses b is

$$e_k^D := \left(\frac{v}{c}\right) \cdot \mathbb{E}\left[\frac{N_{k-1}^D \cdot e_{k-1}^D \cdot Q + N_{k-1}^M \cdot e_{k-1}^M \cdot \frac{1}{2}}{N_{k-1}^D \cdot e_{k-1}^D + N_{k-1}^M \cdot e_{k-1}^M}\right],$$

and that the optimal effort level for an A player that chooses project b or for a B-player that chooses a is

$$e_k^M := \left(\frac{v}{c}\right) \cdot \mathbb{E}\left[\frac{N_{k-1}^M \cdot e_{k-1}^M \cdot Q + N_{k-1}^D \cdot e_{k-1}^D \cdot \frac{1}{2}}{N_{k-1}^D \cdot e_{k-1}^D + N_{k-1}^M \cdot e_{k-1}^M}\right].$$

Again, it is easy to verify that

$$e_k^D + e_k^M = \frac{v}{c}(Q + \tfrac{1}{2}). \tag{D.5}$$

We claim that $e_k^D \geq e_{k-1}^D$ (so that $e_k^M \leq e_{k-1}^M$). It then follows from the induction hypothesis that $e_k^D > e_k^M$ and that $e_k^D - e_k^M \geq e_{k-1}^D - e_{k-1}^M$.

To show this, recall that for $m = 1, \ldots, k-1$, we have that $e_m^D > e_m^M$ and $e_m^D + e_m^M = \frac{v}{c}(Q + \frac{1}{2})$. Define

$$\begin{aligned} g_{k-1}^D(N_{k-2}^D, N_{k-2}^M, e_{k-2}^D) &:= \left(\frac{v}{c}\right) \cdot \left(\frac{N_{k-2}^D \cdot e_{k-2}^D \cdot Q + N_{k-2}^M \cdot e_{k-2}^M \cdot \frac{1}{2}}{N_{k-2}^D \cdot e_{k-2}^D + N_{k-2}^M \cdot e_{k-2}^M}\right) \\ g_k^D(N_{k-1}^D, N_{k-1}^M, e_{k-1}^D) &:= \left(\frac{v}{c}\right) \cdot \left(\frac{N_{k-1}^D \cdot e_{k-1}^D \cdot Q + N_{k-1}^M \cdot e_{k-1}^M \cdot \frac{1}{2}}{N_{k-1}^D \cdot e_{k-1}^D + N_{k-1}^M \cdot e_{k-1}^M}\right) \end{aligned}$$

so that e_{k-1}^D and e_k^D are just proportional to the expectation of g_{k-1}^D and g_k^D (over N_{k-1}^D and N_{k-1}^M), respectively, analogous to before. It is easy to verify that $g_k^D(N_{k-1}^D, N_{k-1}^M, e_{k-1}^D) \geq g_k^D(N_{k-1}^D, N_{k-1}^M, e_{k-1}^M)$. Consequently,

$$\begin{aligned} e_k^D &\geq \left(\frac{v}{c}\right) \cdot \mathbb{E}\left[\frac{N_{k-1}^D \cdot e_{k-1}^M \cdot Q + N_{k-1}^M \cdot e_{k-1}^M \cdot \frac{1}{2}}{N_{k-1}^D \cdot e_{k-1}^M + N_{k-1}^M \cdot e_{k-1}^M}\right] \\ &= \left(\frac{v}{c}\right) \cdot \mathbb{E}\left[\frac{N_{k-1}^D \cdot Q + N_{k-1}^M \cdot \frac{1}{2}}{N_{k-1}^D + N_{k-1}^M}\right]. \end{aligned}$$

Using that g_k^D is decreasing in its second argument, and that the distribution of N_{k-2}^M first-order stochastically dominates the distribution of N_{k-1}^M, we have

$$e_k^D \geq \left(\frac{v}{c}\right) \cdot \mathbb{E}\left[\frac{N_{k-1}^D \cdot Q + N_{k-2}^M \cdot \frac{1}{2}}{N_{k-1}^D + N_{k-2}^M}\right]. \tag{D.6}$$

From the other direction, use that $g_{k-1}^D(N_{k-2}^D, N_{k-2}^M, e_{k-2}^M) \leq g_{k-1}^D(N_{k-2}^D, N_{k-2}^M, e_{k-1}^D)$ to obtain

$$e_{k-1}^D \leq \left(\frac{v}{c}\right) \cdot \mathbb{E}\left[\frac{N_{k-2}^D \cdot e_{k-2}^D \cdot Q + N_{k-2}^M \cdot e_{k-2}^D \cdot \frac{1}{2}}{N_{k-2}^D \cdot e_{k-2}^D + N_{k-2}^M \cdot e_{k-2}^D}\right].$$

Using that g_{k-1}^D is increasing in its first argument, and that the distribution of N_{k-1}^D first-order stochastically dominates the distribution of N_{k-2}^D, we obtain

$$e_{k-1}^D \leq \left(\frac{v}{c}\right) \cdot \mathbb{E}\left[\frac{N_{k-1}^D \cdot Q + N_{k-1}^M \cdot \frac{1}{2}}{N_{k-1}^D + N_{k-1}^M}\right]. \tag{D.7}$$

The result now follows by comparing Equations (D.6) and (D.7). Also, using that g_k^D is increasing and decreasing in its first and second argument, respectively, we have that

$$\begin{aligned} e_k^D &\geq \left(\frac{v}{c}\right) \cdot \mathbb{E}\left[\frac{N \cdot e_{k-1}^M \cdot \frac{1}{2}}{N \cdot e_{k-1}^M}\right] = \frac{v}{2c} \\ e_k^D &\leq \left(\frac{v}{c}\right) \cdot \mathbb{E}\left[\frac{N \cdot e_{k-1}^D \cdot Q}{N \cdot e_{k-1}^D}\right] = \frac{v \cdot Q}{c}, \end{aligned}$$

and it follows from (D.5) that $e_k^D, e_k^M \in [\frac{v}{2c}, \frac{v \cdot Q}{c}]$.

By a similar argument as before, the probability at level k that an A-player chooses project a (or, that a B-player chooses project b) is

$$p_k := H_\varepsilon\left(-\frac{c}{2}\big((e_k^D)^2 - (e_k^M)^2\big)\right).$$

Hence, the number $N_k^{A,a}$ of A-players with project a (or, the number $N^{B,b}$ of B-players with project b) at level k is a binomially distributed random variable N_k^D with parameters $|N|$ and p_k. Similarly, the number $N_k^{A,a}$ of A-players with project b (or, the number $N^{B,a}$ of B-players with project a) at level k is a binomially distributed random variable with parameters $|N|$ and $1 - p_k$.

Using that $e_k^D - e_k^M \geq e_{k-1}^D - e_{k-1}^M > 0$, and Equation (D.5) again, it follows that $(e_k^D)^2 - (e_k^M)^2 \geq (e_{k-1}^D)^2 - (e_{k-1}^M)^2 > 0$, it follows that $p_k \geq p_{k-1}$, and the induction is complete.

We thus have that the sequences p_0, p_1, p_2 and $e_1^D, e_2^D, \ldots$ are monotone and bounded, so that by the monotone convergence theorem, their respective limits $p := \lim_{k\to\infty} p_k$ and $e^D := \lim_{k\to\infty} e_k^D$ exist (as does $e^M := \lim_{k\to\infty} e_k^M = \frac{v}{c}(Q + \frac{1}{2}) - e^D$). $\square$

D.6 Proof of Proposition 5.2

Recall the definitions from the proof of Lemma 5.1. It is straightforward to check that the random variables N_k^D and N_k^M converge in distribution to a binomially distributed random variable N^D with parameters $|N|$ and p and a binomially distributed random variable N^M with parameters $|N|$ and $1 - p$. It then follows from continuity and the Helly-Bray theorem that e^D satisfies

$$e^D = \left(\frac{v}{c}\right) \cdot \mathbb{E}\left[\frac{N^D \cdot e^D \cdot Q + N^M \cdot e^M \cdot \frac{1}{2}}{N^D \cdot e^D + N_{k-2}^M \cdot e^M}\right].$$

where the expectation is taken over N^D and N^M, so that e^D is a function of p. Also, by continuity, the limit p satisfies

$$p = H_\varepsilon\left(-\frac{c}{2}\big((e^D)^2 - (e^M)^2\big)\right).$$

By the proof of Lemma 5.1, we have $0 < e^M < e^D < \frac{v}{c}(Q + \frac{1}{2})$. Moreover, $e^D + e^M = \frac{v}{c}(Q + \frac{1}{2})$.

It remains to show that the equilibrium is unique (after all, the equations above could have multiple solutions). Define

$$h^D(e^D) := \left(\frac{v}{c}\right) \cdot \mathbb{E}\left[\frac{N^D \cdot e^D \cdot Q + N^M \cdot e^M \cdot \frac{1}{2}}{N^D \cdot e^D + N^M \cdot e^M}\right],$$

so that $e^D = h^D(e^D)$ in the introspective equilibrium.[23] Since $e^D + e^M = \frac{v}{c}(Q + \frac{1}{2})$ and $e^M > 0$, we have $e^D \in (0, \frac{v}{c}(Q + \frac{1}{2}))$. It is easy to check that $\lim_{e^D \downarrow 0} h^D(e^D) = \frac{v}{2c} > 0$ and

[23] As before, the expectation is taken over N^D, N^M such that $N^D > 0$ or $N^M > 0$.

that $\lim_{e^D \uparrow \frac{v}{c}(Q+\frac{1}{2})} h^D(e^D) = \frac{vQ}{c} < \frac{v}{c}(Q + \frac{1}{2})$. So, to show that there is a unique introspective equilibrium, it suffices to show that $h^D(e^D)$ is increasing and concave.

To show that $h^D(e^D)$ is increasing, define

$$g^D(N^D, N^M, e^D) := \frac{N^D \cdot e^D \cdot Q + N^M \cdot e^M \cdot \frac{1}{2}}{N^D \cdot e^D + N^M_{k-2} \cdot e^M},$$

so that $h^D(e^D)$ is proportional to the expectation of g^D over N^D and N^M, as before. It is easy to verify that $g^D(N^D, N^M, e^D)$ is increasing in e^D for all N^D and N^M, and it follows that $h^D(e^D)$ is increasing in e^D.

To show that $h^D(e^D)$ is concave, consider the second derivative of $h^D(e^D)$:[24]

$$\frac{d^2 h^D(e^D)}{de^D} = \frac{2v^2}{c^2} \cdot (Q^2 - \frac{1}{4}) \sum_{n^D=1}^{N} \binom{N}{n^D} p^{n_D} (1-p)^{N-n^D} \sum_{n^M=1}^{N} \binom{N}{n^M} p^{N-n_M} (1-p)^{n^M} \cdot \frac{n^D n^M (n^M - n^D)}{(n^D \cdot e^D + n^M \cdot e^M)^3}.$$

We can split up the sum and consider the cases $n^M > n^D$ and $n^D \geq n^M$ separately. To prove that $h^D(e^D)$ is concave, it thus suffices to show that

$$\sum_{n^D=1}^{N} \binom{N}{n^D} p^{n_D} (1-p)^{N-n^D} \sum_{n^M=n^D+1}^{N} \binom{N}{n^M} p^{N-n_M} (1-p)^{n^M} \cdot \frac{n^D n^M (n^M - n^D)}{(n^D \cdot e^D + n^M \cdot e^M)^3} - \sum_{n^M=1}^{N} \binom{N}{n^M} p^{N-n_M} (1-p)^{n^M} \sum_{n^D=n^M}^{N} \binom{N}{n^D} p^{n_D} (1-p)^{N-n^D} \cdot \frac{n^D n^M (n^D - n^M)}{(n^D \cdot e^D + n^M \cdot e^M)^3} \leq 0.$$

We can rewrite this condition as

$$\sum_{n^D=1}^{N} \sum_{n^M=n^D+1}^{N} \binom{N}{n^D} \binom{N}{n^M} \cdot \frac{n^D n^M (n^M - n^D)}{(n^D \cdot e^D + n^M \cdot e^M)^3} \cdot \Big[p^{n_D} (1-p)^{N-n^D} p^{N-n_M} (1-p)^{n^M} - (1-p)^{n_D} p^{N-n^D} (1-p)^{N-n_M} p^{n^M} \Big] \leq 0.$$

But this is equivalent to the inequality

$$\sum_{n^D=1}^{N} \sum_{n^M=n^D+1}^{N} \binom{N}{n^D} \binom{N}{n^M} \frac{n^D n^M (n^M - n^D)}{(n^D \cdot e^D + n^M \cdot e^M)^3} \cdot \left[1 - \left(\frac{p}{1-p} \right)^{2n^M - 2n^D} \right] \leq 0,$$

and this clearly holds, since $p > p_0 > \frac{1}{2}$ and $n^M > n^D$ for all terms in the sum.

[24] As before, we can ignore the case $n^D = n^M = 0$; and if $n^D = 0$ and $n^M > 0$, then the contribution to the sum is 0, and likewise for $n^D > 0, n^M = 0$.

It remains to make the connection between the effort level e^D of the dominant group and the effort level e^* of the players with the group-preferred project. By definition, the two are equal (see the proof of Lemma 5.1). For example, A-players with project a are the dominant group at project a, but they are also the players with the group-preferred project among the players from group A. Similarly, the effort level e^M of the minority group and the effort level e^- of the players with the non-group preferred project are equal. For example, A-players with project b form the minority group at project b, and are the A-players that have chosen the non-group preferred project among A-players. $\square$

D.7 Proof of Proposition 5.3

Recall the notation introduced in the proof of Lemma 5.1. By the results of Bollobás et al. (2007, p. 8, p. 10), the total number $N^D + N^M$ of players with a given project converges in probability to $|N|$, and the (random) fraction $\frac{N^D}{|N|}$ converges in probability to p. It is then straightforward to show that the fraction $\frac{N^D}{N^D+N^M}$ converges in probability to p. Hence, the function $h^D(e^D)$ (defined in the proof of Proposition 5.2) converges (pointwise) to

$$h^D(e^D) = \left(\frac{v}{c}\right) \cdot \left[\frac{p \cdot e^D \cdot Q + (1-p) \cdot e^M \cdot \frac{1}{2}}{p \cdot e^D + (1-p) \cdot e^M}\right].$$

The effort in an introspective equilibrium thus satisfies the fixed-point condition $e^D = h^D(e^D)$. This gives a quadratic expression (in e^D), which has two (real) solutions. One root is negative, so that this cannot be an introspective equilibrium by the proof of Proposition 5.2. The other root is as given in the proposition (where we have substituted e^D for e^*, e^M for e^- (see the proof of Proposition 5.2), and where we have used that $h = p - \frac{1}{2}$). $\square$

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