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Breaking the Structural Reinforcement: An Agent-based Model on Cultural Consumption and Social Relations

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Theorists since Marx, Bourdieu, and DiMaggio have asked how individual choices on cultural preference interact with collective social network structure. The rise of social media in today's communication landscape motivates us to take a closer look at the involved dynamics. We designed an agent-based model to explore how different behavioral principles for cultural choice and communicative affiliation affect (1) collective consumption patterns, (2) social segregation and (3) resilience of the emergent dynamic during exogenous distributions. We analyze the influence of individual agency on network structure, and vice versa, by simulating agents who pursue elite or popular culture, while communicating with others based on homophily or randomness. Our method allows us to go beyond specific constellations and explore the realm of theoretically possible combinations. We then used an exogenous disturbance on elite culture cost to test the resilience of social network structure. We found that only in societies where economic factors drive cultural consumption, increased access to elite culture can lead to reorganization in the social network and reduce segregation between different social groups. This is because the disturbance on consumption provides agents opportunities to connect with other social groups and opens a window for social mixing. We end by discussing how our model allows us to inform a diverse set of empirical research questions, including the cultural markets of social media, the digital divide, and the split between free misinformation and established news outlets.

The rise of social media and the commercial foundation it is based on rekindles a longstanding debate about the interplay between social relations and cultural consumption. It has long been argued that people's cultural choices — their expressed cultural identities, consumption patterns, and so on — are closely related to their social connections. On the one hand, their social positions and social groups influence the culture they consume (e.g., Marx, 1964; Bearman, 1993); on the other hand, similar cultural consumptions will drive people to reinforce or form social connections (Bourdieu, 1984; DiMaggio, 1987). In this way, the interaction between cultural choice and social network structure is considered a closed-form feedback loop that keeps reinforcing its own structure. Ever since these foundational works in communication, sociology and economics, the question has become if a shift in individuals' choices can break this self-reinforcing pattern and drive changes in the social network structure? And if yes, what kind of individual micro choices would create different social macro structures in this setup?

These questions have gained new relevance in the digital age (Friemel, 2020). Social networks are quickly created and reconfigured and much of their content—and therefore their underlying business models—are based on cultural consumption choices. This extends beyond the cultural consumption of videos or other social media content, and expands into the increasing integration of online- and offline worlds, where every image is clickable and purchasable, and service provision becomes a global freelance phenomenon. Mass-produced media products and services are just one click away from high-brow elite culture, as long as the networks link them. The blurriness of the distinction between elite culture and pop culture in the digital age urges us to reconsider the theorization of cultural choice and social network in a more flexible way. People may pursue one type of culture to signify their social status through their artistic interests, establish common interests with members in their social group, or just as a convenient choice due to accessibility. People may also make social connections for different reasons, including contract-binding economic exchange, common cultural interests, or proximity. Does the distinction in cultural choice and segregation in social positions remain the same under different combinations of these behavioral principles? Can we still use tools in cultural sociology to theorize and predict collective patterns of cultural choice and network structure?

At the same time, technological innovation in the media market and cultural transmission provide opportunities for cultural consumption shift from mass-produced popular culture to rare high-brow elite culture and lead to recurring changes in the culture industry. An elite cultural

product can become accessible to the majority due to technological innovation (e.g., from theatre opera to CDs) or cultural imitation (e.g., fashion). Once it is no longer expensive or rare, technological advancement (high-quality digital music) or cultural innovation (a new trend of high fashion) will replace it with a new elite cultural product. In this way, a technological change provides an exogenous disturbance that can drive a reconfiguration of the social network structure via a change in consumption patterns. On the one hand, technology may lead to social mixing via individuals making social connections through shared cultural experiences. On the other hand, what looks like social mixing may be nothing more than a superficial or temporary exchange that masks persistent separation by class or income. Once the elite cultural goods recover the cost, the majority cannot keep up with the elite cultural expense, and the reorganized social network structure is likely to fall into social segregation again.

Whether this effect caused by consumption shift is superficial or structural in different social contexts remains an open question. The social theories on culture and social network structure have provided us an approach to explore this question, but not the answer. Using the theoretical frameworks provided by social thinkers including Marx, Bourdieu, and DiMaggio, this paper aims at exploring which type of behavioral principles in consumption and affiliation would allow social mixing after the exogenous changes in the cultural product accessibility through an ABM model.

The modeling of individual behaviors and the computer simulation of various social realities allow us to articulate the underlying mechanism of those social science theories and test the effects of exogenous disturbance on system dynamics. After a literature review and an introduction to our chosen method, our analysis specifically focuses on three questions of the cultural choice and social network structure: (1) How do individual's behavioral principle in making cultural choices and social connections influence collective cultural choice patterns and the segregation structure of the social network? (2) How does cultural consumption shift influence the segregation structure in the social network structure in various social environments? (3) Which affiliation and consumption principles allows for changes in network structure when we introduce exogenous disturbance? After discussing what we have learned from our computer simulations of the involved dynamics, we close by discussing potential areas of application. We argue that our model can inform ongoing debates about cultural consumption in social media, about the

opportunities and threats of the digital divide, and about the omnipresent debate of the power of fake news in social media.

Literature Review

Social network structure influences individuals' cultural choices

The relationship between culture and social structure, especially social network structure, has attracted longstanding interest in the disciplines of sociology, anthropology, economics, and communication. It first recognizes that the socio-economic structure has a dominant effect on individuals' cultural choices. The purpose of consuming expensive cultural goods is to signify economic status. Classical statements raised by Marx (1964) and Durkheim (1984) aim at explaining how patterns of social structures influence the composition of cultural systems (Bearman, 1993; Douglas, 1978; Martin, 1997). This approach sees culture as a reflection of the social structure. In other words, individuals with certain cultural tastes consume certain cultural products because they are at a particular position within the social structure. The purpose of pursuing certain cultural goods is thus to signify one's economic capacity or social status.

With the shift from considering culture as disembodied ideas toward thinking of culture as grounded in practice (Bourdieu, 1984; Ortner, 1984O; Peterson, 1979), empirical research explained the connection between culture and social structure by demonstrating how individuals' cultural preferences and practices are influenced by their relations with others in social groups (Anheier et al., 1995; Kay & Hagan, 1998; Mische, 2011) and their position in their social network (DiMaggio & Mohr, 1985; Erickson, 1996; Mark, 2003; McLean, 2016). In other words, this approach suggests that individuals pursue certain cultural goods with the intent to maintain their relations with others or their positions in social networks (McPherson, 2004).

Individuals' cultural choices influence social relations

Individuals' cultural choices and preferences in turn also influence the social structure through social relations and social networks. Bourdieu (1984) proposed the concept of cultural capital, which refers to socially distinctive cultural knowledge, tastes, and skills. Cultural capital can be used to gain social and economic resources in two ways.

First, individuals with specialized cultural knowledge and taste approved by a specific social group can gain or reinforce their membership in the group through their cultural preference and consumption. The access to particular cultural knowledge and the opportunity to cultivate particular cultural tastes is a rare resource that only people in specific social groups have. This resource provides the symbolic recognition afforded by specific cultural skills, knowledge, and tastes of collectively valued cultural goods (DiMaggio & Mohr, 1985). Bourdieu theorized this process as the conversion between cultural capital and social capital. More specifically, the cultural knowledge and skills allow the individual to engage in symbolic interactions and gain membership to prestigious groups, forming social connections with other group members (Carley, 1991; DiMaggio, 1987).

Second, individuals with general knowledge and preference for mass-produced culture can form social connections with those with similar interests as them through conversations on those shared interests and knowledge. One significant change in modern societies is the role of arts and mass-produced culture in maintaining interactions between people across different social groups. This change becomes more significant with increasing geographic mobility and mobile communication, leading to more social connections both within and between different social groups (DiMaggio & Mohr, 1996; Fiske, 2002). The cultural knowledge and practices not only create these more frequent opportunities for conversations to happen but also makes the shared social life meaningful and pleasurable, which is fundamental in constructing social relations and social identities. This socially connective process usually happens in the context of mass-produced popular culture.

The two approaches in this model both produce a homophily phenomenon. That is, people with the same cultural preferences, practices, and consumption patterns are more likely to connect with each other or strengthen the existing social connections.

Communication approach

This relationship between cultural preference and social relations has also been broadly discussed in the field of communication. Specifically, communication research focuses on how cultural choice and social relations influence each other through communication processes. This question has been studied in at least two domains of communication: mass communication and interpersonal communication.

First, interpersonal communication theories posit that people's cultural choices and cultural preferences can be cultivated through repeated interactions within their social groups (Lee et al., 2016). Their cultural choice and preferences, in turn, become a symbolic resource to strengthen their relationships with other members within the group. For example, Hughes and Peterson (1983) and Johnson (2002) established causal links between social network relations and music choice, demonstrating how music choice is a product of interaction within social groups.

Second, mass communication theories point out that the rise of mass media created an assimilated cultural environment for society (McQuail, 1987) as well as opportunities for communication based on common ground (Clark, 1992). Mass media enables the representation of certain aspects of our social experiences, in ways that are collectively meaningful and pleasantly received. The cultural choices and preferences that are shaped by mass media provide a basic form of capital that helps foster new social relations and a sense of identity. On the other hand, the representation of different experiences broadcasted through mass communication reinforces an existing sense of social identity, thus also providing references for cultural choices that are already perceived to be endorsed by the group (Gamson et al., 1992).

The evolving media environment

The difference between the mass communication and interpersonal communication approach is in their explanation of how the relations are formed due to the similar cultural choice. Lizardo (2006) used the distinction between elite cultural taste and popular cultural taste to theorize the two types of processes. Elite cultural taste is characterized by an emphasis on the consumption experience, in which cultural products are seen as a conduit of specific moral and aesthetic values endorsed by certain social groups (Van Eijck, 2001), whereas popular culture consumption is seen as a more generalized engagement with culture. Following this distinction, Lizardo (2006) formulated a specific model encompassing an elite culture conversion process and a popular culture conversion process. Consumption of popular culture provides forms of cultural capital that lend themselves to conversation topics between people from different social groups for fostering weak social connections, whereas consumption of elite culture will enable individuals to form strong social connections with members of the same initial social group.

As with all models and typologies, the distinction between elite culture and popular culture, along with their respective conversion approaches, is not always so straightforward in practice.

First, different from Bourdieu's assumption, the aesthetic dispositions of elite culture and popular culture are not completely correlated with social positions and economic values in contemporary cultural markets. For example, the Internet grants much free access to information and cultural products that may traditionally carry high cultural value, leading to shifts in economic and cultural paradigms. For instance, one can watch a free, culturally esteemed Mozart Concert on YouTube, whereas a Super Bowl ticket costs 7,000 dollars regardless of its origin in poor- and working-class. The symbolic value of those cultural products no longer matches the economic capacity required to pursue them. Additionally, an increasing number of online cultural products, including music and video services, provide both free and paid service with overlapped functions. The small cost difference and the unclear symbolic value difference make it even more difficult to distinguish between "elite" and "popular" through their accessibility and economic value.

Second, the distinction between culture specific to one group and culture generally accepted by a mass audience is blurrier than theorized to be, because the aesthetic values of some cultural goods can be accepted by different social groups for different reasons (Baek, 2015). This pattern becomes more evident in the contemporary world and media market because cultural paradigms and production have witnessed great changes (Manovich, 2009), making it increasingly difficult to infer status directly from cultural preference (Foster, 1985). Many of the distinguishing traits of popular culture and mass reproduction have provided topics and inspirations for elite contemporary. Additionally, many popular cultural forms are produced and consumed in similar forms using similar symbols as modern art, which is considered the elite culture of the contemporary world (Jenkins, 2012; Fiske, 2010).

At the same time, social networks in the online media environment evolve at a way faster rate. Internet and current social networking sites make it easier for individuals to form and drop connections with others, including both weak ties (Kahne & Bowyer, 2018) and strong ties (Vriens & van Ingen, 2018). The online social network is thus always in a dynamical process. The intensity and meaning of social connections in the online media landscape have also changed drastically. The distinction between acquaintance and general friends has been less clear. Strong ties might be eroded or strengthened under different contexts (Vriens & van Ingen, 2018).

The blurriness of the supposed distinctions between elite culture and pop culture and the fast-changing online social network urges us to reconsider the model of interaction between cultural consumption and social connections and theorize this process in a more real-time flexible

way (Mangold & Scharkow, 2020). Can people pursue elite culture and form social connections with out-group members with the same aesthetic values as a pop-culture conversion approach? Can people pursue pop culture based on a particular perspective that popular cultural goods provide, and then also reinforce their membership in a niche cultural group? Most importantly, does the distinction in cultural choice and segregation in social positions between the rich and poor still remain the same as theorized by Bourdieu? These questions emerge from the different possible combinations of principles for pursuing culture and making social connections:

RQ1: Which cultural product, elite or popular, does a collective of individuals prefer when different principles drive:

RQ1a) their cultural consumption choice?

RQ1b) their social connections?

RQ2: Which social network structures, segregated or well-mixed, does a collective of individuals form when different principles drive:

RQ2a) their cultural consumption choice?

RQ2b) their social connections?

The conversion from cultural capital to social capital is a dynamic process. The accessibility of cultural goods changes over time, as well as the symbolic meanings of culture. On one hand, the increased availability of elite cultural goods may change the dynamics of the interaction between culture and structure. On the other hand, individuals with increased spending power may also change the system dynamics through consumption. Veblen's (2005) conspicuous consumption theory mounts to a prediction that individuals with increased spending power will emulate the consumption patterns of those at higher positions in the social hierarchy. Thus, whether the reconfiguration caused by the external disturbance can push the model into a different equilibrium from Lizardo's model is also the key to addressing the neglected role of individuals' agency in the interaction between culture and structure. Salganik, Dodds, and Watts (2006) found that social influence leads to higher levels of unpredictability in individuals' cultural choices, indicating that the effects of external disturbances on the segregation structure may vary across social contexts where influence flows through social relations in different network structures. Thus,

RQ3: How will exogenously induced consumption shifts change network structure?

Method

We designed an agent-based network model (network ABM) to explore the combinatorial space created by cultural choice and social connections and the effects of consumption shift on social network structure. ABMs forces us to specify the parts and relationships of a system that are consistent with concrete assumptions, facilitating falsifiability and therefore accelerating the scientific process (Saunders-Newton, 2002; Smaldino, 2017; Reynolds, 2020). ABMs also enable systematic process tracing, following the generativist motto: "If you didn't grow it, you didn't explain its emergence" (Epstein, 1999; *p.43*). Most empirical models estimate relationships within an input-output model, which is usually not sufficient to explain the causal mechanism; instead, ABMs capture and produce the dynamics of a process(Alvarez-Galvez, 2016). A good fit between ABMs and empirical data provides not only statistical evidence for the result but also the validity of the process (Waldherr, 2014).

Agent-Based Model

We set up a model with a population consisting of n agents aggregated into a rich group and a poor group in a continuous 2D space with periodic boundaries in the modeling software NetLogo (Wilensky, 1999; Detailed code in Appendix A; see Supporting Figure 1 for model interface). The 2D space is created solely for visual purposes and does not have an influence on agents' behaviors. Two types of cultural products are available in the model: elite cultural products at cost C_e and pop culture at cost C_p . The model initiates with no social relations. The agents update the social network in each iteration by creating, maintaining and dropping connections. Agents run through the following interactive steps:



Figure 1. Agent itinerary in the model We model the interaction of social structure and cultural consumption with a population of agents who iteratively invest in cultural consumption and then affiliate with others whose own consumption can influence future investments. Our simulation experiments manipulate steps 2. and 3 with the parameters representing each varied over a 10x10 grid. Cultural choice (step 2) varies along with a strictly economic criterion (buy the best you can afford with available resources) or social influence-based criterion (buy what your peers tend to buy). Affiliation choice (step 3) varies from full homophily (link to agents with similar cultural choices) to complete randomness (link to random agents).

(1) Agents receive endowments based on the social group they are associated with. Every timestep, agents in the rich group receive an endowment of I_r . Agents in the poor group receive an endowment of I_p . The endowment not spent at this step will be saved for following steps, but agents in this model do not purposefully plan to save more through particular cultural choice strategies.

(2) Agents make costly cultural choices. Agents make a probabilistic decision between price-driven choice (naive Marxist approach) and peer-driven choice (Bourdieu/DiMaggio approach) on a scale from 0% to 100% price-driven. A price-driven choice is to consume the most expensive cultural product the agent can afford. When the elite culture is at the same price as the popular culture, a price-driven agent will choose to consume elite cultural products due to the prestige-advantage of a more selective 'elite' (as per definition of the term). A peer-driven choice is a probabilistic choice proportional to the peer's cultural choice. Peers are defined by the network structure. The probability of an agent choosing elite culture is the same as the proportion of agents that choose elite culture in the agent's ego network. Because agents' purchasing power is limited by their economic resources, price-driven choice sometimes comes before peer-driven choice regardless of the parameter settings in conditions when pop culture is the only choice an agent can afford. This also happens when agents don't have any social relations, in which case they cannot make peer-driven choices.

(3) Agents make affiliation choices. Agents will reach out to a fixed percentage of all agents by a reach-out threshold and take decisions about making, dropping or maintaining connections

based on the homophily level. If the other agent is a stranger, the agent can make a probabilistic decision about whether or not to form a connection with the stranger by the level of homophily in this run. Bourdieu proposed the homophily mechanism of social connections driven by consuming the same elite culture, while DiMaggio extended it to social connections driven by the same pop culture consumption. Thus, when agents make highly homophily-driven connections, they will only make connections with the other agent that have the same culture as them. If the other one they reach to is a friend, the agent will make a probabilistic decision about maintaining or dropping the connection with that friend based on the level of homophily. In a high-homophily situation, agents will be more likely to drop ties with friends who don't pursue the same culture as them anymore (See Appendix A and B for detailed specification of this step).

Table 1. Experiment Parameters

Experiments	Parameters	Simulation steps	Repetitions
Simulation Experiment (RQ1 & RQ2)	1 $N = 100$, rich income, $I_r = 5$, poor income, $I_p = 2$, elite culture cost, $C_e = 5$, pop culture cost, $C_p = 2$, rich-poor ratio, $r = 1$, reach out percentage = 0.04, choose as peers = [0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1], homophily = [0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1]	1000	50
Simulation Experiment 2 (RQ3)	C_e before price change = 5, C_e during price change = C_p , C_e after price change = 5	1000	50
Robustness Checks	I_r / I_p ratio = [2, 2.5, 3.33, 5], C_e / C_p ratio = [2, 2.5, 3.33, 5] benchmark network = [random network, preferential attachment]	1000	50

Model assumptions

In this model we built in some assumptions in modeling agent behavior either based on real world experience or to stress the key causal mechanisms. Those designs and assumptions may have an influence on the model results. First of all, in each step, agents are assigned a probabilistic rule to choose elite/pop culture instead of a fixed culture to choose culture. the probability each agent in

each step is assigned to choose as peers or make homophily connections is based on the condition of the level of homophily norms and price-driven norms in that run. For example, in a condition with peer-driven at 0.8, agents at each step have an 80% probability to choose culture as peers as opposed to 20% probability to choose culture based on their economic condition. Therefore, throughout the whole simulation, for 80% of the time, agents will make peer-driven cultural choices and about 20% of the time they will make price-driven cultural choices. This modeling strategy is more realistic when considering how individual follow social norms and make decisions. In a society with a strong norm about group conformism, it is more realistic to have all individuals violating the norm at a smaller chance (e.g., 20% of the time) than 20% of the population violating the norm all the time while the rest of the population never violate the norm.

Additionally, we create social connections from scratch in order to reduce the effects of initial network composition on the overall network dynamics and consumption patterns. Growing from an empty network, we can make sure that the affiliation principles we built in the model is the only mechanism for the network dynamics, although this design makes it difficult and probably not reasonable to analyze the network structure and consumption pattern before the equilibrium state. For its application and mapping to real world examples, this design in the model is unrealistic for some social context. For example, it is hard to imagine upper-class and working-class people in a real-world society have a starting point of no social connections. However, it might still be directly applicable in some social context, such as online communities and online social networking sites where users start from an empty profile and establish their online social connections from scratch.

Simulation Experiment

Three main simulation studies were conducted to investigate RQ1 - RQ3. Table 1 provides parameter values, simulation steps, and simulation repetitions for the simulation studies reported below.

Simulation Experiment 1

These simulations aimed to answer RQ1 and RQ2 by assessing the difference between different cultural choices and affiliation choice conditions with an equal rich-poor population ratio. The manipulation is on the probability of cultural choice principles and the probability of homophily in affiliation.

Simulation Experiment 2

These simulations aimed to answer RQ3 by assessing the effects of consumption shift on social reorganization. We use cost changes to operationalize an exogenous disturbance on cultural consumption. This disturbance occurs in the real world periodically in the forms of technological innovations, policy interventions, and mass productions. We first decrease the elite culture cost to the same as pop culture cost at timestep 500, which allows the model to reach a stable state before introducing the shock. After 50 timesteps, we recover the elite culture price to see if the equilibrium condition changes after the cost recovery (as a structural change) or the equilibrium returns to the state before disturbance (as a superficial change).

Simulation Experiment 3

As a robustness check of the effects of exogenous disturbance on social network structure, we also conduct experiments with various cultural choice and affiliation choice conditions, cost and income ratio, and benchmark networks. Benchmark networks refer to the null network model with no homophily. In this paper, we test whether the observed result is robust to different network-generating models, including Erdős–Rényi model (random network) and Barabási–Albert model (preferential-attachment network).

Simulation Data and Analysis

For each simulation experiment, we collect data on elite and pop culture consumption within rich and poor population, overall network ties, ties between rich and poor agents, and individual degree centrality at each step of each run.

We measure the elite culture ratio by calculating the percentage of agents that pursues elite culture among all agents at each step. We then measure the segregation by the percentage of ties between agents with the same nodal attributes among all ties. Our measure of segregation is different from the commonly used structural measures in community detection (Fortunato, 2010) and component analysis (Osei-Asamoah & Lownes, 2014) because rich and poor in our model are nodal attributes instead of structural features. In other words, if all rich agents are connected to rich agents only and all poor agents are connected to poor agents, the segregation will be the highest at 1. If all rich agents are connected to poor agents only, the segregation will be the lowest at 0. For further analysis, we also calculated the percentage of rich agents that consume pop culture and the percentage of poor agents choosing elite culture at each step.

We first aggregate 50 runs of simulation at each step by average, minimum and maximum. To compare collective patterns between different experimental conditions, we also aggregate elite culture ratio, segregation and degree centrality by the average of all iteration steps in each condition.

Result

RQ1: cultural choice

To analyze the difference in cultural choice influenced by consumption principles and affiliation choice (RQ1), we compare the average number of agents consuming elite culture through 1000 timesteps across all conditions (See Figure 2). We find that in a population with equal proportions of wealthy and poor, different principles of cultural choice and affiliation type lead to variation in elite cultural consumption. Regarding variations in cultural consumption choice (RQ1a), in conditions where agents' consumption follows their peers' cultural choices (right-hand-side of Figure 2), elite culture is less preferred. In those conditions, agents with a popular-dominant ego network will prefer popular culture regardless of their economic resources, and those with an elite-dominant ego network additionally require the economic resources to access elite culture. Regarding variations in affiliation choice (RQ1b), there is not much difference in cultural choice between a high-homophily condition and a low homophily condition when the main behavioral principles for cultural choice is driven by the price of cultural products, because cultural choices are independent of the social connections when the behavioral principle is entirely price-driven. Whereas with more influence from peer's choice on cultural choice, elite culture is more preferred in a high-homophily condition (upper right corner) than a low-homophily condition (lower right corner). In a high-homophily peer-driven cultural world (higher right corner), the result produced Bourdieu's hypothesis of a highly segregated society where the wealthy constantly chooses elite culture and the poor pop culture. The two social groups keep reinforcing their cultural choice patterns to stabilize the segregated social network structure, so the percentage of elite cultural consumption stabilized at the same ratio as the wealthy population ratio. This is the same in a low-homophily peer-driven cultural world (lower right corner) that an agent needs to have both the economic capacity and a friend circle of wealthy agents to choose elite culture. However, the chance of meeting both is smaller when the affiliation mechanism is more random, so we observe

a preference towards pop culture in the lower right corner.

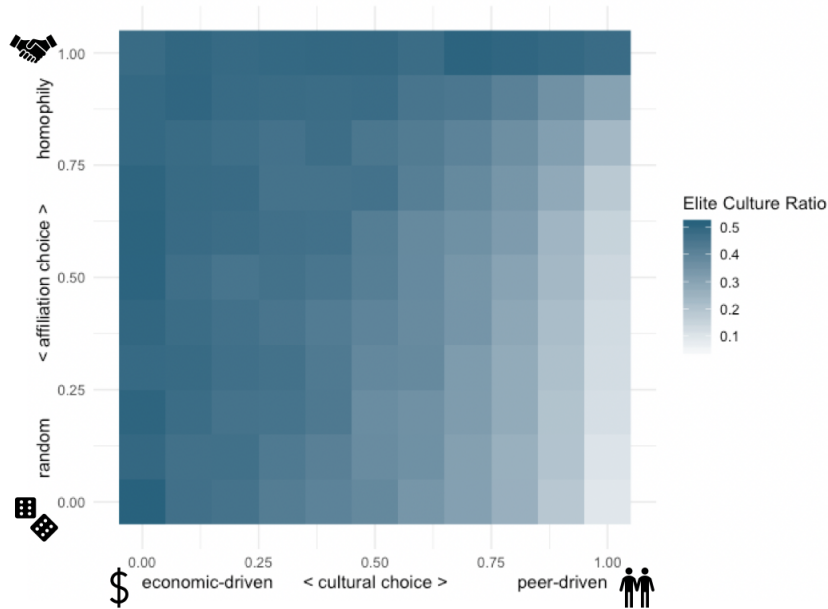


Figure 2. Elite cultural choice ratio among various model conditions. In this figure, preference for elite culture (Elite Culture Ratio) increases with economic-driven choice but shows slightly more nuance with decreases in homophily. Even in a population with equal proportions of wealthy and poor, different principles of cultural choice and affiliation type lead to biased cultural consumption. (All values are averaged across 50 runs.)

RQ2: social segregation

The variation in Figure 3 illustrates the influence of cultural choice and affiliation choice on social network formation (RQ2) in terms of social segregation. We observe a monotone increase of social segregation from peer-driven to price-driven conditions, as well as from random affiliation to homophily affiliation principles. The monotone increase from random affiliation to homophily affiliation can be explained by the homophily process as a social segregation mechanism that people who choose the same culture are more likely to form their closed social group. At the same time, price-driven cultural choices are less likely to be influenced by agents' affiliation choices, making the segregation more stable against other confounds or stochastic factors in the network process.

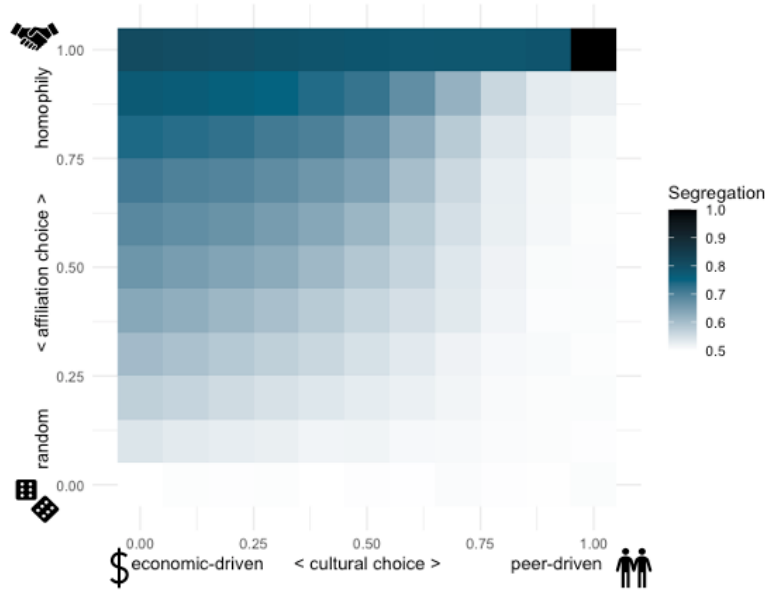


Figure 3. Social segregation among various model conditions average. In this figure, A higher level of heterogeneous tie ratio indicates a lower level of social segregation. We observe a monotone increase in social segregation from peer-driven to economic-driven conditions and from random affiliation to homophily affiliation principles. (All values are averaged across 50 runs.)

RQ3: response to exogenous disturbance

We use one specific exogenous disturbance to reveal the adaptiveness of the model. We choose an exogenous disturbance on elite culture price, which changes the availability of elite culture and causes consumption shifts in price-driven conditions. The disturbance first decreased the cost of elite culture to the same cost as popular culture at timepoint 500. After 50 timesteps, elite culture will recover to its original cost. This duration is long enough for us to observe the influence of cost change on the collective consumption patterns and the resilience of the segregation structure. The recovery of the price then allows us to assess whether the disturbance has lasting effects on the system.

The consumption shifts caused by exogenous disturbance have different patterns under different behavioral principles of individuals' cultural choices. At the same time, different levels of homophily determine whether the changes in network structure caused by consumption shifts would be reinforced or diminished. During the time when the elite cultural cost is decreased to the same as popular culture, although all agents can afford to consume either culture, agents whose cultural choice is driven by price will tend to choose elite culture, whereas, in peer-driven conditions, agents will not switch their cultural choice unless their peers switch.

The result in Figure 4 shows that networks whose affiliation choice is driven purely by homophily have identical behavior in both cultural choice and network structure in terms of degree centrality at equilibrium state regardless of consumption is driven merely by the price and prestige of the cultural product or peers' choice. However, they react very differently to the disturbance. When the cultural choice is determined by peers' choice, the network structure and cultural consumption pattern absorb the disturbance. This does not happen when the cultural choice is determined by price. The degree centrality increases during the disturbance period for price-driven high-homophily boundary condition, because when everyone pursues elite culture, homophily will drive agents to make friends with anyone they reach out to and maintain their connections with all the friends. The disturbance-induced changes happen due to the interaction between homophily principles and cultural choice principle. In random network boundary conditions, the disturbance will not cause changes in the network structure because network processes are independent from agents' cultural choices (See Supporting Figure 2).

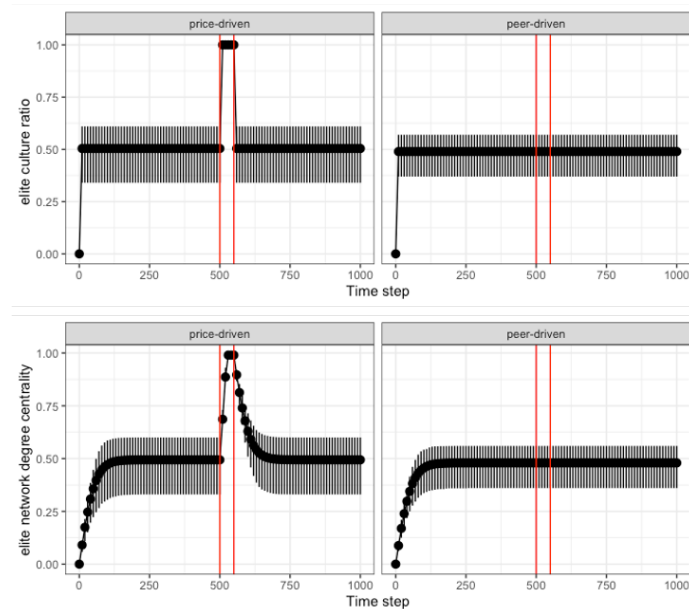


Figure 4. Elite culture ratio and elite network degree centrality response to shock under homophily affiliation principle with different consumption principle After iterating the model, we introduce an exogenous disturbance that lowers the cost of elite culture consumption (evident at time 500 in left two panels, though not in the other two), as in the emergence of mass culture production, which increase the accessibility of elite symbols of status. The shock ends after 50 ticks so that we can observe whether and how the social system recovers to its original equilibrium under choose-as-peers and choose-as-price conditions with homophily as the affiliation principle. We find that homophily leads to similar equilibrium network structure in terms of degree centrality regardless of how cultural choice is made. However, when the cultural choice is determined by economic factors, the social network structure and cultural choices absorb the economic shock. This does not happen when the cultural choice is determined by peer's choice. (All values are averaged across 50 runs.)

We found that increased availability of elite culture causes transient structural changes in social segregation, measured by the proportion of heterogeneous ties, in particular conditions. Figure 5 illustrates how the segregation structure in the network reacts differently towards disturbance across four conditions. The results show that, consistent with Figure 4, social mixing increases after the disturbance in conditions with price-driven cultural consumptions only (Figure 5 (a) and (c)). During the decrease of elite culture cost, segregation drops to 0.5, indicating that agents have an equal chance to connect to another agent from a different class or the same class. In other words, the disturbance provides a chance for complete social mixing. We extend our analysis to various levels of homophily condition and found that for a higher level of homophily, although the segregation reduces in a greater level during the shock, the system bounces back faster ($t_{0.9\text{homophily}} = 250$; $t_{0.8\text{homophily}} = 410$) than conditions with a lower level of homophily ($t_{0.7\text{homophily}} = 650$; See Supporting Figure 3). The duration of the disturbance effect does not depend on the length of shock (See Supporting Figure 4). Here we use a short enough disturbance to explore whether a short-duration shock can still alter the network structure.

The equilibrium in panel (c) moves after the shock because the disturbance happens when the system is not in equilibrium state yet. The disturbance maximizes the social mixing and then proceed to the equilibrium state in advance. To confirm the equilibrium state, we apply a disturbance at timestep 1500 for 50 timestep and found that the disturbance effect reduces to the initial level after 2620 timesteps (see Supporting Figure 5).

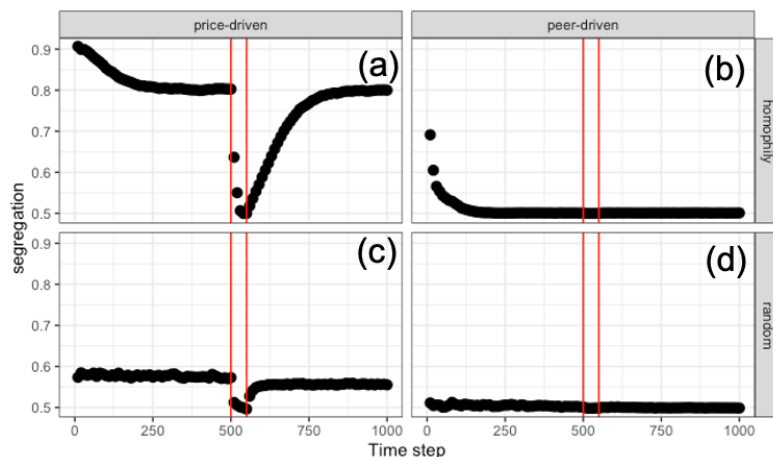


Figure 5. Social segregation dynamics through economic shocks The principles of cultural choice influence the power of disturbance on elite culture availability to reorganize the social structure. Under the price-driven cultural choice condition, a change in the availability of elite goods causes a temporal increase in social mixing that last for more than 8 times of the stimulus time. When the cultural choice is peer-driven, the disturbance does not cause a change to the social structure. (All values are averaged across 50 runs.)

Why does this structural change happen in conditions with price-driven cultural consumption?

To answer this question, we look into the cultural choice dynamics during the price changes separately among rich agents (Figure 6) and poor agents (Supporting Figure 6). We observe that the ratio of rich agents choosing pop culture has a similar pattern as the dynamics of social segregation in the corresponding conditions. This similar pattern, along with the economic limitation on poor agents' choices, allows us to provide a possible explanation for the observed structural change. First, the decreased cost in elite culture cost leads to consumption shift among poor agents in all conditions because elite culture is preferred in the model even when it has the same cost as pop culture. Rich agents instead continue their consumption pattern because they are free from economic limitations. This consumption shift among poor agents increased their probability to affiliate with rich agents in high-homophily conditions. After the price recovers, poor agents no longer can afford elite culture, so they switch back to the pop culture consumption pattern. Will their tie with rich agents be maintained? In a dominantly peer-driven society, poor agents cannot afford to choose what their rich friends choose and their ties with those rich friends will be dropped in a homophily-driven society. The network structure will bounce back to normal. However, in price-driven conditions, rich agents don't originally have much chance to be connected to poor agents and be exposed to pop culture before the price decrease. The price change provides them a chance to be connected to the poor agents. After the price recovers, although most of the rich agent will keep pursuing elite culture and form connections with rich agents only, a small number of them (by the small probability of peer-driven principles) will use the poor connection they never had before to choose pop culture and maintain their connections.

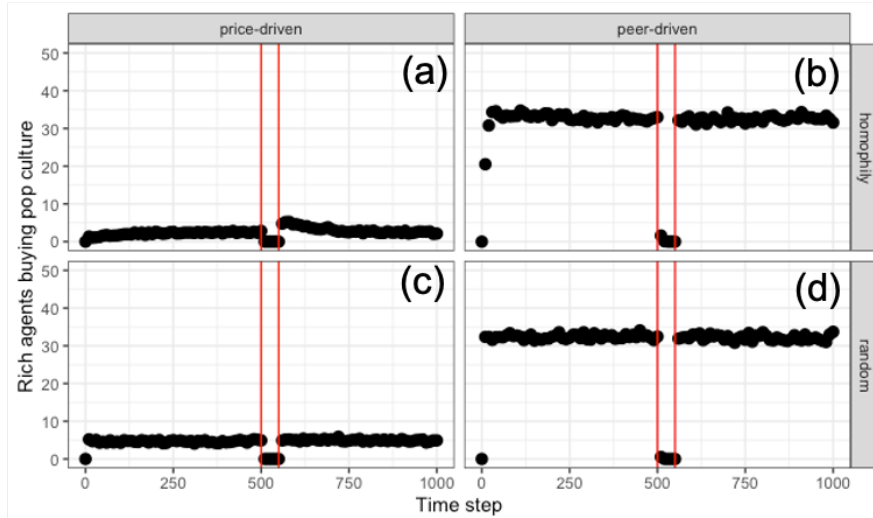


Figure 6. Percentage of rich agents choosing pop culture The lasting effect in panel a of Figure 5 is mostly caused by rich agents starting to switch to pop culture once the social segregation is broken by mass production and price change. After the shock, rich agents are affiliated with poor agents that buy elite culture, which keeps influencing their cultural choice even after the price recovers. (All values are averaged across 50 runs.)

Robustness checks

We compare the direct and lasting effects of the disturbance on social segregation across different setting parameters (See Table 1) and found that the effects of the disturbance are robust against changes in cultural consumption and affiliation principles (See Supporting Figure 7) and income and cost ratio (See Supporting Figure 8). We also test the results against a different benchmark network, preferential attachment null model (See Supporting Figure 9). The results during the decrease are identical to effects in conditions with random network as the benchmark network. However, the effects after the recover does not show the same pattern as the random network, indicating that the null network model may have an influence on the overall segregation structure.

Discussion

Findings

When can shifts in individuals' cultural consumption lead to structural changes in network segregation? Through an agent-based model, we found that the increase in access to elite cultural products can lead to social reorganization in particular social contexts where the price of cultural products drives cultural choices, and homophily characterizes the formation of social ties. Specifically, the disturbance of lowered costs to accessing elite culture reduces the social

segregation between agents with different incomes. This effect on the network structure is stronger but decays faster in conditions with higher homophily, while weaker but lasts longer in conditions with lower homophily. The duration of the disturbance effect on network structure is not influenced by the duration of the disturbance.

The model's reactions to the disturbance in elite cultural choice and elite degree centrality at boundary conditions demonstrate that the disturbance influences the network structure through homophily, while cultural choice principles alter the resilience of the network structure. The consumption patterns of the rich and poor populations around this disturbance further explain the transient effect on network structure in particular conditions. The decrease in elite culture cost provides a chance for poor agents to pursue elite culture in conditions where cultural consumption is price-driven. With elite culture, the poor agents will be able to form ties with rich agents when tie formation is driven by homophily. At the same time, when homophily is too high, poor agents will lose connections with rich agents faster when they cannot afford elite culture anymore. Additionally, we found this structural effect robust to income ratio, cost ratio, but not benchmark network process.

By exploring the different possible combinations of cultural choice and social affiliation principles, we found that preference for elite culture increases with price-driven principles. This difference in collective cultural choice patterns between price-driven and peer-driven conditions is less prominent in low-homophily conditions (RQ1). At the same time, social segregation is higher in conditions with higher homophily and conditions where cultural choice are price-driven (RQ2). The results of RQ1 and RQ2 constitute the explanation for each other, that is social structure and cultural choices are more easily reinforced through the homophily in price-driven conditions, because agents' economic conditions in the model are more stable than their social groups.

Connections to microeconomics theories

The model has a close connection to microeconomics theories, including conspicuous consumption and fads. Conspicuous consumption describes the behavior that consumers will purchase or use goods of a higher quality or in greater quantity than might be considered necessary (Veblen, 2005). Conspicuous consumption is a way of signaling one's economic status. We considered the same motivation and assumptions of conspicuous consumption as theoretical

support in modeling agents' behaviors, but we also constrain the possibility of continuous conspicuous consumption in our model.

First, Veblen's theory has a deep theoretical connection to Bourdieu's theory of habitus and distinctions (Trigg, 2001). To make conspicuous consumption, an individual has to have the knowledge about the prestige conveyed in the cultural product and have an audience to signal this prestige to. At the same time, the individual has to be able to afford the expensive product with prestige. To create this possible theoretical space in our model, two parameter conditions should be satisfied: (1) Homophily cannot be at the boundary condition. In this case, a poor agent has a higher-than-zero probability of having connections with rich friends, which ensures that a poor agent can get information about what the elite fashion is to pursue the elite fashion; (2) A poor agent can afford to consume elite fashion. In our model, poor agents' endowment at each step is not enough to buy in elite culture products. At the same time, although the model allows agents to save, it does not motivate agents to save for continuous conspicuous behavior. An agents' ability to consume elite culture is thus constraint by their fixed endowment. In this way, our model constrains the possibility for continuous conspicuous behavior.

However, we consider conspicuous behavior key theoretical support in modeling agents' behavior after the shock. Conspicuous consumption theory mounts to a prediction that individuals with increased spending power will emulate the consumption patterns of those at higher positions in the social hierarchy; thus, we build in our model the assumption that poor agents would pursue elite culture after the shock.

Fad refers to a product that is popular for a time then unpopular (Aguirre et al., 1988). Our model also demonstrates a possibility that when an elite cultural product is more accessible to everyone, everyone seems to switch to the initially elite culture. And then, when the elite culture cost recovers or a new elite fashion trend is being created, poor agents stop buying the elite culture in most social situations in the model. In this case, the shock does create a fad.

Our model does not explain the mechanism for the shock; in other words, we do not attempt to explain fad but demonstrate one possibility that fad might be a result of the shock on elite culture and conspicuous consumption.

In general, this model is designed in a simplistic manner to incorporate several social science theories driven by similar causes. The simplicity of the model also allows for

extension to explain specific microeconomics phenomena. Admittedly, the model touches upon microeconomic theories, including conspicuous consumption and fad, but it goes one step further in exploring how different types of social connections (at various levels of homophily) might change the consumption behaviors addressed in those theories.

Contribution to communication theory and empirical research

Communication theories have a long tradition of explaining how mass media and interpersonal communication shape cultural preference and cultural identity. At the same time, recent development in social network analysis provides rich implications for how people make social connections (Welles et al., 2014). These two areas are deeply linked, and their interaction offers a cultural approach to explaining the dynamics of social processes. Our model advances this approach by specifying this interaction through agent-based modeling, and demonstrating how network segregation structures emerge from individuals' cultural choices and social affiliation in different contexts. The flexibility of our model demonstrates interesting grey zones among the classical positions taken at the time of Marx (1964) and Bourdieu (1984). Here we illustrate three examples to demonstrate how this model can inform a diverse set of empirical research questions, including the cultural markets of social media, the digital divide, and the split between social media information and established news outlets.

Example application 1: Social Network on Internet

Such a flexible model is especially important today, as the Internet and today's increasing economic inequality transform how people make cultural choices and social connections. First, social media allows people to bridge the elite-popular gap with much more ease than before. Second, the Internet grants free access to multiple cultural products, some of them with much value. For example, music service provider including Spotify offers users not only both music streaming services and opportunities to connect with other users through collaborative playlists, following, and recommendation (Park et al., 2019). The premium version of Spotify provides the same social functions as the paid version but some music may be unavailable in the free version (Spotify, 2021). Thus, free version users may not be able to express their music preference as well as premium users due to lack of certain functions. For example, free users do not have access to some music they like and they cannot select to play the one song they like without shuffling

through other songs. Although they can create a playlist to shuffle play their preferred music, they will still be interrupted by frequent advertisement. These less pleasant experiences reduce their motivations and ability to connect to premium users by common music preference. The model may require specific extensions (e.g., users' ability to express their music tastes) to simulate the connecting mechanisms on Spotify. Nevertheless, this network mechanism creates a similar condition in a price - driven condition in our model, which provides predictions for the collective patterns of cultural choices and social network and predictions on the influence of a free trial of the premium version on the user music choices, generating new theories for empirical research on user preferences.

This model allows us to explore the theory in various social contexts and exogenous disturbances. We use two more examples to illustrate the implications of this model in a broader communication context.

Example application 2: Digital divide

For example, one of the most frequently discussed phenomena in current communication research is the digital divide. The digital divide refers to the issue of technology and information as limited resources unevenly distributed among distinct social groups (Loges & Jung, 2001; Helsper, 2017). People make choices and consumption on information and technology based on their living environment including economic capacity and their peers' choices (Norris, 2001). At the same time, people with digital access also shape the digital environment, possibly making access even harder for those without it. How to reduce the digital divide has been a critical question in contemporary communication research (van Dijk, 2020). The structural effects produced by the disturbance of elite culture availability in our model suggest a potential approach to this question. The result predicts that in environments with homophily as the affiliation principles and cultural price as the consumption principles, even a temporary price decrease or easier access to information and technology (offered by technological innovation or policy intervention) may cause a temporary structural change to the digital divide. In high homophily conditions, the temporary changes can be strong enough to change the social network structure drastically but decays fast. Thus, we may need timely and short-term policy in a high homophily society to create social changes within this short window; whereas in a moderately lower homophily condition, the structural change may not be as strong but lasts longer, which create space for long-term policy to

have a better performance.

Example application3: News consumption

Another area of application has become relevant given the importance of misinformation and 'fake news.' Social media has become an important source of news, which is free and low-brow, but also often of questionable quality, while higher-quality news from newspaper outlets usually requires a subscription (high-brow). Some people can afford an annual subscription of high-quality news outlets at over 100 dollars whereas some people don't have that budget for news and tend to read news from social media and other free outlets. Audience who are exposed more to social media news are likely to agree with each other comparing to those that are exposed to newspaper outlets, due to the similar agenda, perspective and logic. Similarly, those who are exposed more to newspaper outlets may tend to agree with each other comparing to social media users. This segregation may lead to a different type of echo-chamber caused by media channels other than political affiliations.

Furthermore, the cost of elite culture in the model can be interpreted as resources other than money, including attention, time, and literacy. One example that captures the influence of the cost difference in attention, time, and literacy is news sharing. Communication theories and research pointed out that serious news that contains detailed information, credible source, and complete logic frame requires more cognitive resources (Sterrett et al., 2019), time (DeAngelo & Yegiyan, 2019), and literacy (Tully et al., 2020) to process compared to the news with brief content, shocking titles, and social gossip. On the other hand, people are more likely to connect with those that share similar types of news due to selective exposure to reinforce their preference (Messing & Westwood, 2014).

The model contributes to understanding this problem by identifying two main factors in news consumption: The cost of news consumption (cultural cost) and the social function of news consumption to connect with others (affiliation principle). The model predicts that when people are more willing to talk to audiences of similar news outlets (high homophily), the gap between the audience of free social media news and those of high-quality news from credible sources will be reinforced and widen.

The solution provided by the model suggests that when people choose news outlets mostly in consideration of economic or cognitive cost, we can apply a short shock to the high-quality news

by either reducing the economic cost (e.g., publish a few free news articles every month on social media) or reducing the cognitive cost (e.g., publish more news photos or shorter summaries of investigative news) to temporarily reduce the segregation between different audiences and create windows for information exchange between them.

Future work

Other important questions can be addressed in future investigations using this model. For example, we can consider how a different income distribution would influence cultural choice and network structure. Our model provides equal proportions of rich and poor groups to focus attention away from the established subject of wealth inequality and instead toward neglected issues of cultural consumption. Our result suggests that cultural forces should be able to amplify the perception of wealth inequality well beyond their actual level in two ways. First, although we implement equal number of rich and poor population, in most conditions, less than half of the agents choose elite culture. As agents can only tell if other agents consume elite or pop culture rather than their actual wealth, agents may perceive the proportion of the rich lower than the actual level. Second, the segregation between rich agents and poor agents can create a perceived distinction in cultural tastes and social positions, which amplifies the actual difference between the rich and poor and impedes social mobility. Based on this result, it is reasonable to use our model set-up to investigate how income distribution and other social group statuses may influence cultural consumption and network structure.

Another interesting question that can be explored in future studies is how the duration of disturbance may cause further changes in network dynamics. In this model, we focus on how a short-term disturbance may lead to long-term transient effects on the network structure but in real-world settings, long-term cultural shifts do happen from time to time and it may lead to some permanent structural changes to the social network structure. This is because a long-term cultural shift may also influence cultural choice and affiliation choice principles and norms. How the duration of the disturbance interacts with the model parameters and network dynamics is a meaningful question especially when there is cultural resistance to the environmental changes or when the disturbance is emerged from bottom-up individual practices.

Additionally, the model presents an opportunity to investigate the social network structure's permeability, and raises more questions about the role of individual agency. Future extensions can

focus on whether and how individual agency can influence the programmed network structure through learning and aspiration towards particular social positions.

Finally, it is crucial to find empirical examples to test the theoretical claim of this paper. Online venues with both social network services and cultural references (e.g., Spotify, Salo et al., 2013; Goodreads, Worrall, 2019; YouTube, Hussain et al., 2018, etc.) can serve as useful resources to validate the model.

Conclusion

Individuals' cultural choices and social connections are deeply connected, and together influence the formation of the network structure. This interaction between agency and structure has been a constant interest in social science. This paper used agent-based modeling to bridge the two in the context of one theoretical framework. Within this framework, we explored flexible approaches to examining culture and social network structure. We found that temporary shifts in cultural consumption can lead to transient changes in the social network structure at different decay rate by homophily level. Our result suggests a possible approach to social reorganization, even under fixed income and social group composition. Lastly, our model highlights the advancement of ABM in social science, allowing us to explore the space between positions set forth by existing social theories and to address individuals' agency under the restriction of social network structure. In the final discussion, we find a myriad of applications and empirical studies that can be informed by our theoretical setup.

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Supporting Material

Appendix A Netlogo Code

```
extensions [vid nw]
globals
[
  reach-num
  elite-centrality
  pop-centrality
  preferential ;; preferential procedure
  elite-original
]

turtles-own
[
  rich?      ;;social class
  income     ;;income
  resource   ;;current amount resources ture
  elite-culture? ;;elite culture capital
  pop-culture? ;;pop culture capital
  elite-downtime ;;the number of time steps passed since the agent last consumption of elite culture
  pop-downtime ;;the number of time steps passed since the agent last consumption of pop culture
  potential? ;;variable in preferential attachment process to avoid double loop ties
]

links-own
[
  contact    ;;steps that the two agents contact each other
  non-contact ;;steps that the two agents didn't contact each other
]

.....
;;; Setup Procedures ;;;
.....

to setup
  clear-all
  set-default-shape turtles "person"
  make-turtles
  ;; at this stage, all the components will be of size 1,
  ;; since there are no edges yet
  reset-ticks
  ;;create wealth distribution
  set reach-num round reach * num-nodes * 0.01 - 1
  set elite-original elite-culture-cost
  ask turtles
  [
    set color grey
    set potential? false
```

```
ifelse random-float 1 > equality
[
  set income poor-income
  set rich? FALSE
]
[
  set income rich-income
  set rich? TRUE]
set resource 0
set elite-culture? FALSE
set pop-culture? FALSE

]
end

to make-turtles
  create-turtles num-nodes [ set size 1 ]
  layout-circle turtles max-pxcor - 1
end

;;;;;;;;;;;;;;
;;; Main Procedures ;;;
;;;;;;;;;;;;;;

to go
  ask turtles
  [
    set potential? false
    ifelse elite-culture?
      [
        ifelse pop-culture?
          [ set color violet
          ]
          [ set color red ]
      ]
      [set color blue]

    set resource resource + income
    ifelse random-float 1.0 < bourdieu-marx
      [marx-cultural-choice]
      [bourdieu-cultural-choice]
    ifelse random-float 1.0 < random-pref
      [preferential-attachment]
      [random-network]

  ]
; ask turtles [
; set size count links / 500
; ]
```

```
layout
show nw:mean-path-length
tick

if shock = true and ticks = 500 [
  set elite-culture-cost pop-culture-cost
]
if recover = true and ticks = 550 [
  set elite-culture-cost elite-original
]
let total-r 0
ask turtles with [elite-culture? = true] [set total-r total-r + count my-links]
ifelse count turtles with [elite-culture? = true] > 0
[
  set elite-centrality total-r / ((count turtles with [elite-culture? = true]) * num-nodes) ; monitor
elite culture average degree centrality
]
[set elite-centrality 0]

let total-p 0
ask turtles with [pop-culture? = true] [set total-p total-p + count my-links]
ifelse count turtles with [pop-culture? = true] > 0
[
  set pop-centrality total-p / ((count turtles with [pop-culture? = true]) * num-nodes)
]
[
  set pop-centrality 0
]
; monitor elite culture average degree centrality

end

to consume-elite-culture
  set pop-culture? FALSE
  set elite-culture? TRUE
  set resource resource - elite-culture-cost
end

to consume-pop-culture
  set elite-culture? FALSE
  set pop-culture? TRUE
  set resource resource - pop-culture-cost
end

to consume-nothing
  set pop-culture? FALSE
  set elite-culture? FALSE
end
```

```
to marx-cultural-choice
  ifelse elite-culture-cost >= pop-culture-cost ;; in case of economic changes
  [
    ifelse resource >= elite-culture-cost ;;people can afford:
    [consume-elite-culture]
    ;;no elite culture -- get elite culture
    [ifelse resource >= pop-culture-cost
    [consume-pop-culture]
    [consume-nothing]
    ;;people cannot afford elite culture will get pop culture if they are not ambitious, otherwise they save
  up
  ]
  ]
  [
    ifelse resource >= pop-culture-cost ;; buy the best they can afford
    [consume-pop-culture]
    [consume-nothing]
  ]
  ]
; ]
end

to bourdieu-cultural-choice
  let elite-culture-friend count turtles with [link-neighbor? myself and elite-culture?]
  let all-friends count turtles with [link-neighbor? myself]
  ifelse all-friends > 0
  [ifelse random-float 1 < elite-culture-friend / all-friends
  [ifelse resource >= elite-culture-cost
  [consume-elite-culture]
  [consume-nothing]]
  [ifelse resource >= pop-culture-cost
  [consume-pop-culture]
  [consume-nothing]
  ]] ;;what you consume depends on what your friends consume and your income
  [marx-cultural-choice]
end

to preferential-attachment

  ;;there's a limit to how many people a turtle can reach out to each round, but turtles will reach to
  their friends first
  ifelse random-float 1.0 > homophily
  [;; not homophily situation
  let strangers count other turtles with [link-neighbor? myself = false]
  if count other turtles with [link-neighbor? myself] > reach-num
  [
    ask min-n-of reach-num other turtles with [link-neighbor? myself][count links]
    [
      ask link who [who] of myself [die]
    ]
  ]
  ]
  ]
end
```

```

]
]
ifelse strangers > reach-num or strangers < 3
[
  let numerator 1
  ask max-n-of strangers other turtles with [link-neighbor? myself = false] [count links]
  [
    if random-float 1.0 < exp(0 - numerator)
      [ set potential? true ]
    set numerator numerator + 1
  ]
]
]
;; possibility of making tie is exp(-rank)
[
  let numerator 1
  ask max-n-of reach-num other turtles with [link-neighbor? myself = false] [count links]
  [
    if random-float 1.0 < exp(0 - numerator)
      [ set potential? true ]
    set numerator numerator + 1
  ]
]
]
[;; homophily situation
ifelse pop-culture?
[;;popculture situation
  let strangers count other turtles with [link-neighbor? myself = false and pop-culture?]
  if count other turtles with [link-neighbor? myself] > reach-num
  [
    ask min-n-of reach-num other turtles with [link-neighbor? myself][count links]
    [
      ask link who [who] of myself [die]
    ]
  ]
]
ifelse strangers > reach-num or strangers < 3
[
  let numerator 1
  ask max-n-of strangers other turtles with [link-neighbor? myself = false and pop-culture?]
[count links]
  [
    if random-float 1.0 < exp(0 - numerator)
      [ set potential? true ]
    set numerator numerator + 1
  ]
]
]
;; possibility of making tie is exp(-rank)
[
  let numerator 1

```

```

    ask max-n-of reach-num other turtles with [link-neighbor? myself = false and pop-culture?]
[count links]
    [
        if random-float 1.0 < exp(0 - numerator)
            [ set potential? true ]
            set numerator numerator + 1
        ]
    ]
    [;;elite culture situation
let strangers count other turtles with [link-neighbor? myself = false and elite-culture?]
    if count other turtles with [link-neighbor? myself] > reach-num
    [
        ask min-n-of reach-num other turtles with [link-neighbor? myself][count links]
        [
            ask link who [who] of myself [die]
        ]
    ]
    ifelse strangers > reach-num or strangers < 3
    [
        let numerator 1
        ask max-n-of strangers other turtles with [link-neighbor? myself = false and elite-culture?]
[count links]
        [
            if random-float 1.0 < exp(0 - numerator)
                [ set potential? true ]
                set numerator numerator + 1
            ]
        ]
    ]
;; possibility of making tie is exp(-rank)
    [
        let numerator 1
        ask max-n-of reach-num other turtles with [link-neighbor? myself = false and elite-
culture?] [count links]
        [
            if random-float 1.0 < exp(0 - numerator)
                [ set potential? true ]
                set numerator numerator + 1
            ]
        ]
    ]]
]
ask other turtles with [potential? = true]
[create-link-with myself]
;; come back to normal
ask other turtles
[set potential? false]
end

to random-network
ifelse random-float 1.0 > homophily

```

```
[;;random network with no homophily
let strangers count other turtles with [link-neighbor? myself = false]
;; random rewire, first give up reach-num number of friends
if count other turtles with [link-neighbor? myself] > reach-num
[ask n-of reach-num other turtles with [link-neighbor? myself]
 [ask link who [who] of myself [die]]
]
;;randomly make friends with reach-num strangers
ifelse strangers > reach-num
 [ ask n-of reach-num other turtles with [link-neighbor? myself = false]
   [
     create-link-with myself
     [set color blue]
   ]
 ]

 [ask other turtles with [link-neighbor? myself = false]
  [create-link-with myself
   [set color blue]
 ]
]]
]

[;;random network + homophily
let strangers count other turtles with [link-neighbor? myself = false]
if pop-culture?[
if count other turtles with [link-neighbor? myself] > reach-num
[ask n-of reach-num other turtles with [link-neighbor? myself]
 [if pop-culture? = false
  [ask link who [who] of myself [die]]]
]
;;reach to strangers, if they are not popular, a [randomfriend] chance to form a tie
ifelse strangers > reach-num
 [ ask n-of reach-num other turtles with [link-neighbor? myself = false]
   ;; input homophily
   [ifelse pop-culture? = false
    [if random 100 < randomfriend
     [create-link-with myself
      [set color blue]
    ]
  ]
 ]
]

;;if they are popular, form the tie
[create-link-with myself
 [set color blue]] ]
[ask other turtles with [link-neighbor? myself = false]
 [ifelse pop-culture? = false
  [if random 100 < randomfriend
   [create-link-with myself
    [set color blue]]]
 ]
];;if they are popular, form the tie
[create-link-with myself
```

```

        [set color blue]
    ]]]]
if elite-culture?[
  if count other turtles with [link-neighbor? myself] > reach-num
    [ask n-of reach-num other turtles with [link-neighbor? myself]
      [if elite-culture? = false
        [ask link who [who] of myself [die]]]
    ]
    ;;reach to strangers, if they are not popular, a [randomfriend] chance to form a tie
  ifelse strangers > reach-num
    [ ask n-of reach-num other turtles with [link-neighbor? myself = false]
      [ifelse elite-culture? = false
        [if random 100 < randomfriend
          [create-link-with myself
            [set color blue]]]
        ;;if they are popular, form the tie
        [create-link-with myself
          [set color blue]] ] ]
      [ask other turtles with [link-neighbor? myself = false]
        [ifelse elite-culture? = false
          [if random 100 < randomfriend
            [create-link-with myself
              [set color blue]]]
          ;;if they are popular, form the tie
          [create-link-with myself
            [set color blue]]]]]
    ]
end

to layout
  repeat 12 [
    layout-spring turtles links 0.5 10 2
    display
  ]
end

to-report elite-density
  nw:set-context turtles with [elite-culture?] links
  let complete count turtles * ( count turtles - 1 )
  report count my-links / complete
end

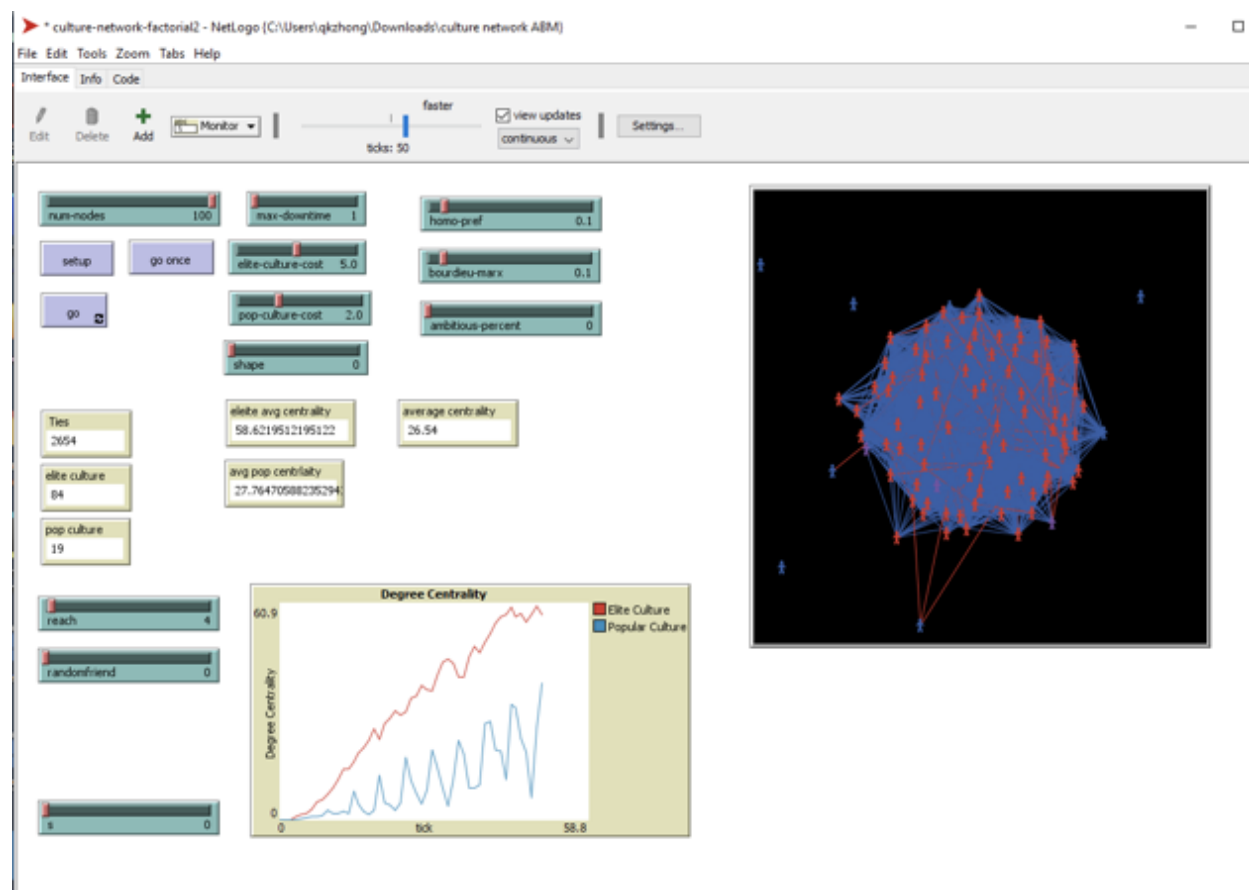
to-report pop-density
  nw:set-context turtles with [pop-culture?] links
  let complete count turtles * ( count turtles - 1 )
  report count my-links / complete
end

to-report heterogeneous-ties
```



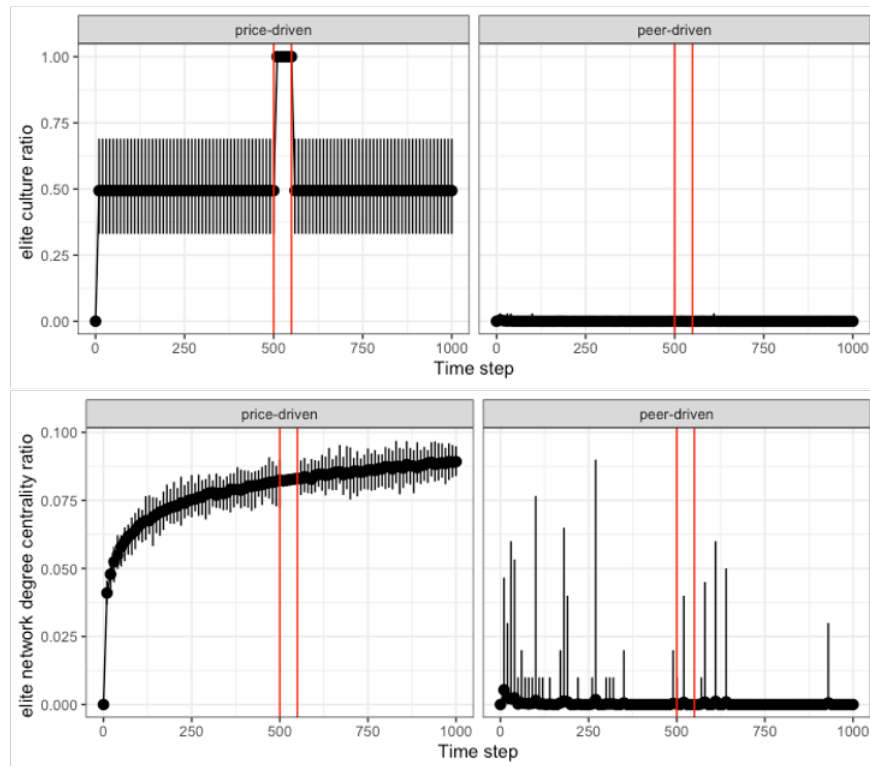
```
let total-ties 0
ask turtles with [rich?]
  [set total-ties total-ties + count other turtles with [link-neighbor? myself and rich? = false]]
report total-ties
end
```

Supporting Figure 1



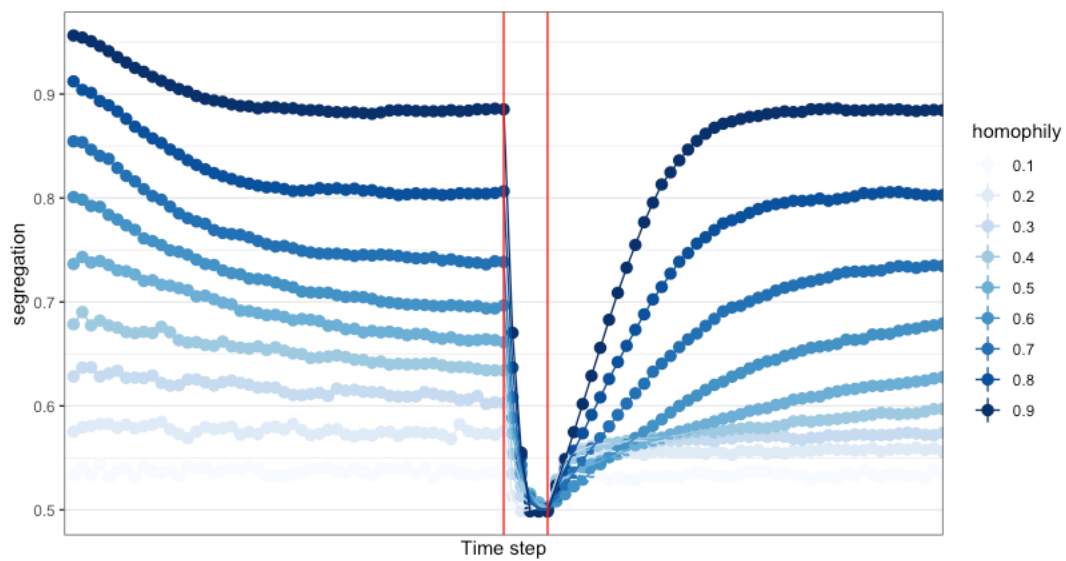
Supporting Figure 1. Model interface from Netlogo The Netlogo interface includes all variables in the model, a visual network monitor and a real-time degree centrality monitor. In this figure, the network monitor displays the agent network in one run around step 58.

Supporting Figure 2



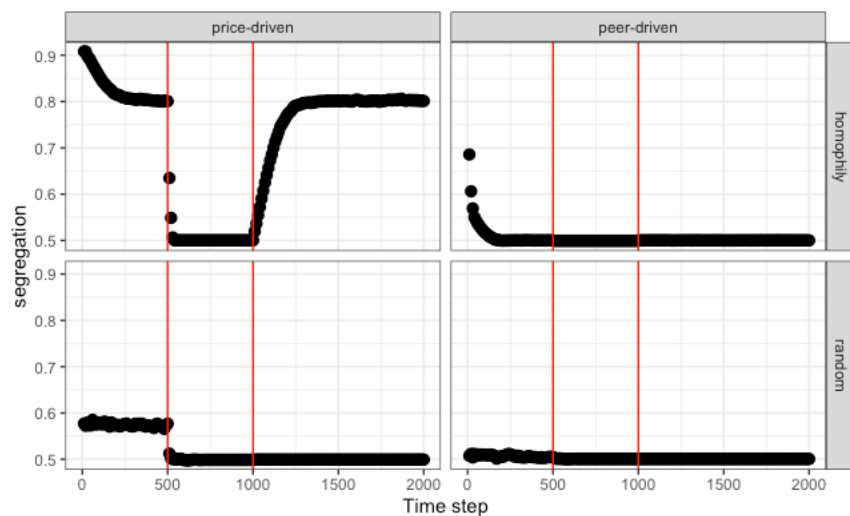
Supporting Figure 2. Elite culture ratio and elite network degree centrality response to shock under fully random affiliation principle with different consumption principle After the elite culture price decreased, all poor agents switch to elite culture. Similarly, after the price recovers poor agents return to their previous consumption patterns. Poor agents pattern alone cannot explain the changes in network we observed in Figure 5.

Supporting Figure 3



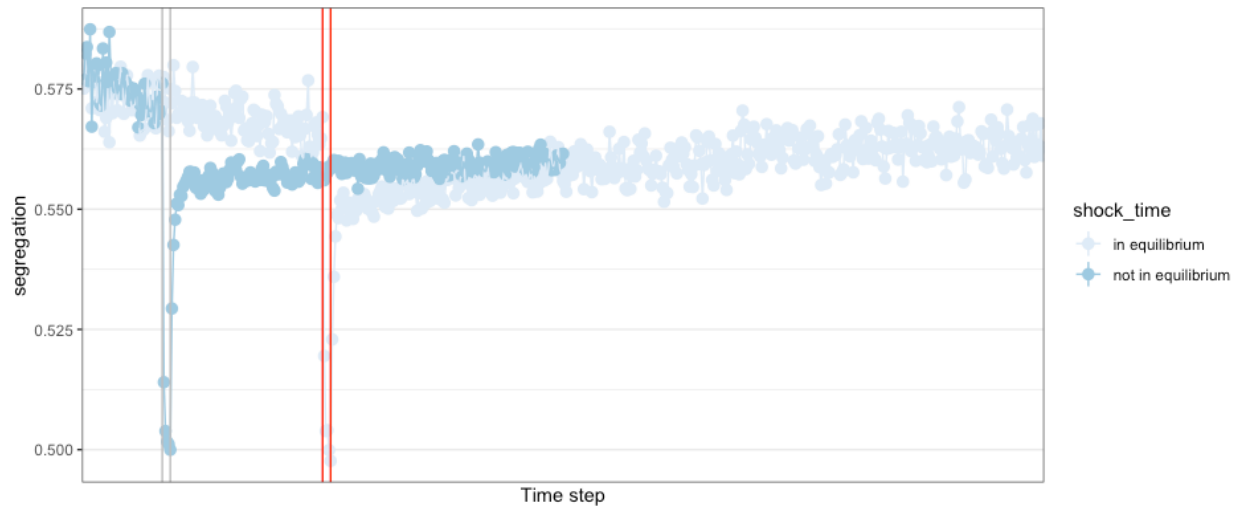
Supporting Figure 3. The reaction of network segregation structure to the disturbance in price-driven conditions are consistent at different homophily level

Supporting Figure 4



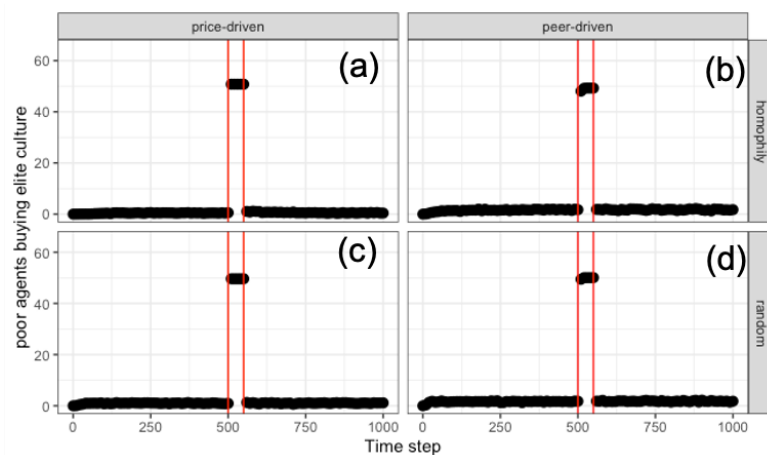
Supporting Figure 4. Segregation dynamics with a long-time disturbance The segregation dynamics with a long-time disturbance ($t = 500$) on elite-culture cost resembles the pattern of the network segregation under a short-time disturbance. The seemingly changed equilibrium in the bottom left panel is explained by the same reason in a short-disturbance condition—the disturbance happens long before the equilibrium and thus advances the equilibrium.

Supporting Figure 5



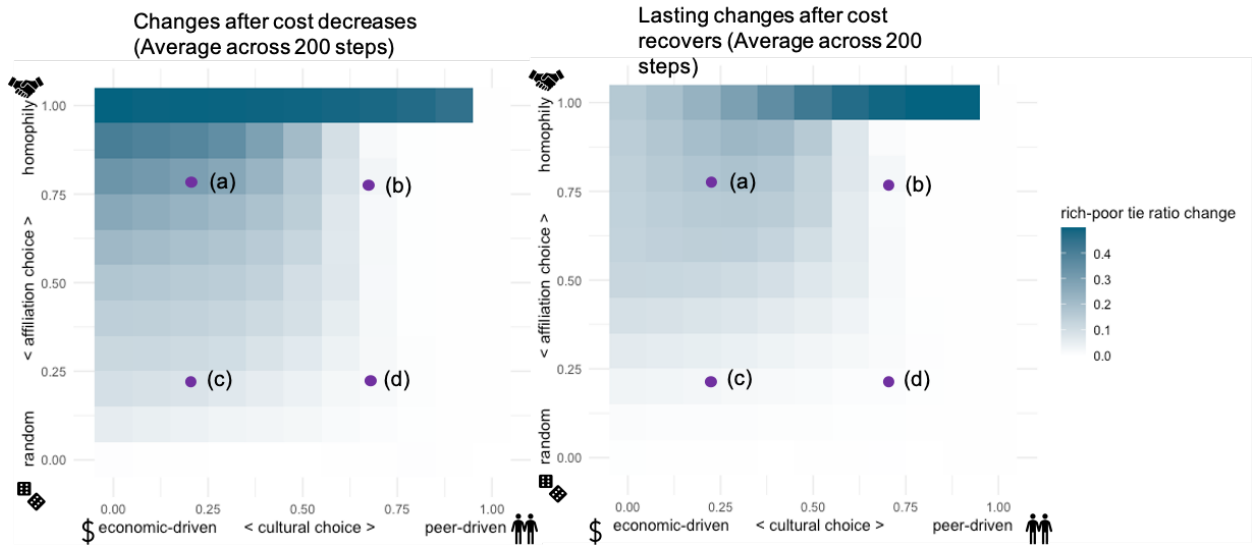
Supporting Figure 5. Comparison between response to shock in equilibrium and not in equilibrium The seemingly moved equilibrium in panel (c) is due to the shock happens when the system is not in equilibrium yet. The disturbance maximizes the social mixing and advances the equilibrium state. We then apply a shock at timestep 1500 for 50 timesteps and found that the network segregation comes back to the initial level after 2620 timestep.

Supporting Figure 6



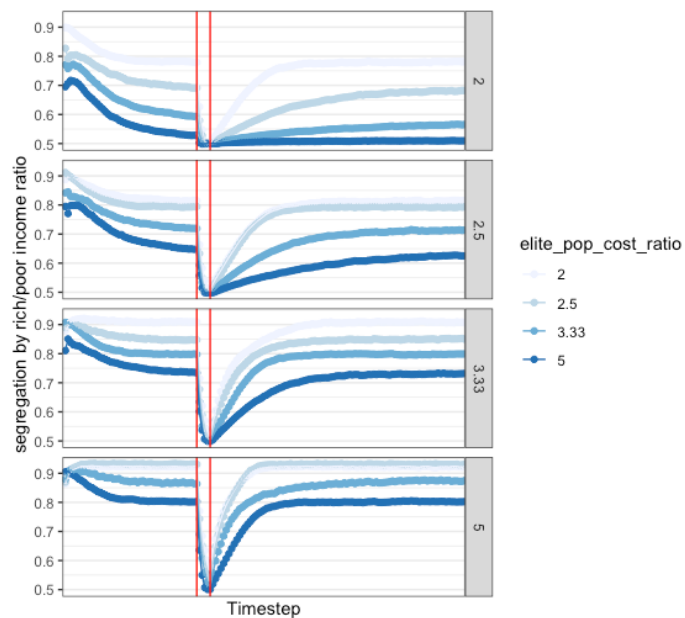
Supporting Figure 6. Poor agents' cultural choice pattern before and after the price change do not vary across conditions After the elite culture price decreased, all poor agents switch to elite culture. Similarly, after the price recovers poor agents return to their previous consumption patterns. Poor agents pattern alone cannot explain the structural change we observed in Figure 5.

Supporting Figure 7



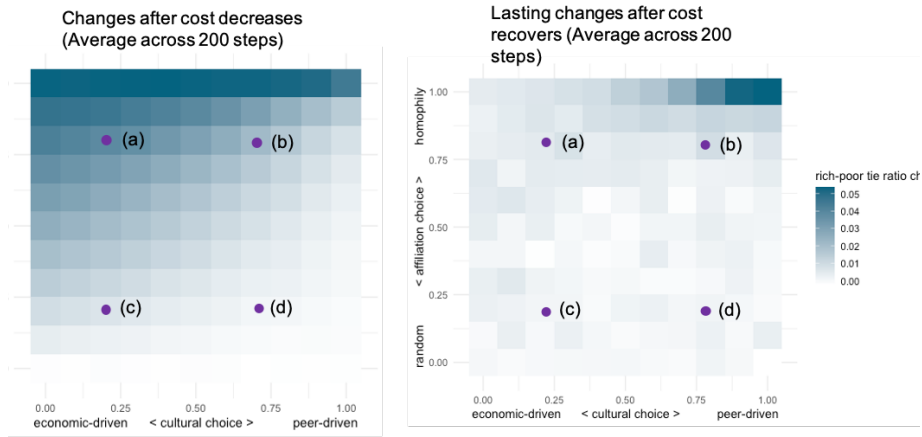
Supporting Figure 7. The effect is robust to changes in cultural consumption principles and affiliation choices We mark here the four conditions (a)(b)(c)(d) presented in Figure 5 to provide a more complete comparison across the 10 X 10 conditions. Consistent with Figure 5, the structural effects caused by the economic shock is the most evident in the condition area around (a) where economic motivation drives cultural choices and homophily drives affiliation choices. The effects around this condition area also last after the cost recovers.

Supporting Figure 8



Supporting Figure 8. The structural effects are robust to different income and cost ratios The results presented in the figure show that the structural effects we observed in Figure 5 panel (a) is robust to most income ratio and cost ratio, except for the conditions where the elite culture cost is much higher than pop culture cost while the rich and poor income does not differ as much or when the rich income is much higher than the poor income while the cost ratio is low.

Supporting Figure 9



Supporting Figure 9. Effects of the disturbance in preferential attachment network. This figure presents the effects of the shock on social segregation during the time when the elite culture price decreases and 200 timestep after the price recovers the null-model is a scale-free network. The results during the decrease are identical to effects in conditions with random network as the benchmark network. However, the effects after the recover does not show the same pattern as the random network, indicating that the null network model may have an influence on the overall segregation structure.