9. Social networks: effects and formation[*]

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1. INTRODUCTION

Wholesale diamond markets, in the decades following WWII, are a vignette of how networks affect economic life (Wechsberg 1966, pp. 81–86, is a vivid sketch; these markets are topics in influential contributions on social capital and economic sociology: Coleman 1988; Granovetter 1985). Merchants form small communities with extensive ethnic, religious, and kinship ties and high frequency of interactions. Coleman (1988, p. S99) describes this as follows: 'The wholesale diamond market in New York City, for example, is Jewish, with a high degree of intermarriage, living in the same community in Brooklyn, and going to the same synagogues. It is essentially a closed community.' Extensive ties in terms of kin and communication exist not only within but also between merchant communities (Wechsberg 1966). Economic exchange between merchants has features that are at first sight surprising: when negotiating a sale, valuable stones are routinely handed over for private examination without formal insurance against theft and fraud, such as substituting inferior stones for much more valuable ones. Organizing transactions in this way enhances efficient functioning of the market by avoiding complex and costly bonding and insuring devices. On the other hand, considerable trust problems are introduced due to incentives and opportunities for malfeasance. The argument then is that reputational concerns mitigate malfeasance: a cheating merchant risks not only losing the victim as a partner for future business, but also future business opportunities with other merchants and family, religious, and community ties. Research on social networks studies a wide variety of such effects as well as the formation and dynamics of certain network structures.

Much research on social networks reflects core features of rigorous sociology. This includes explanation of individual (micro-) behavior in social contexts. It also, and particularly, includes the explanation of social (macro-) phenomena. On the one hand, micro-level questions in the diamond merchants vignette include: Why and under what conditions does a merchant hand over stones for examination without formal insurance? Why and under what conditions does the other merchant abstain from malfeasance? How do merchants' behaviors depend on network characteristics? On the other hand, the association between characteristics of the network of diamond merchants and the more or less efficient functioning of the market is a macro-level explanatory question.

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We discuss two types of models for social networks. First, there are models accounting for the effects of social networks. Here, assumptions on networks and their characteristics are part of the *explanans*. Such models contribute to the analysis of the diamond markets vignette. Second, there are models with network characteristics as macro-level *explananda* (cf. Borgatti & Foster 2003). Our discussion is mainly by way of example. We 'reconstruct' two paradigmatic cases explicitly as micro-macro models. To ensure complementarity with other *Handbook* chapters and as a contribution to somewhat neglected issues in the sociological literature on networks, we focus on theory formation for research on social networks employing game-theoretic tools. This includes sketching the derivation of testable hypotheses from formal theoretical models. For space restrictions, we do not discuss related empirical studies in detail.

Chapters in this *Handbook* such as those on analytical sociology (Manzo's chapter), on agent-based computational sociology (the chapter by Flache, Mäs & Keijzer; the chapter by Steglich & Snijders), and on rational choice sociology (Diekmann's chapter) reflect that the effects of social networks as well as their formation are key topics in various rigorous sociology research programs. The chapters on experimental sociology (by Gërxhani & Miller) and on stochastic network modeling (by Steglich & Snijders) address empirical designs and statistical modeling, including how empirical methods and statistical modeling are linked to theory formation. The showcase chapters by Burt (see also Vedres' chapter on Burt), by Salganik, Dodds & Watts, and by Van de Rijt offer examples of research employing a range of alternative theoretical assumptions, empirical methods, and statistical approaches.

Our chapter does not aim at a systematic overview of research on social networks. Textbooks and collections offering overviews are plentiful. In sociology, for example, Wasserman & Faust (1994) was an early and influential textbook on concepts and methods. Borgatti et al. (2018) is a more recent textbook with a focus on methodology, including research design, data collection, and data analysis. Kadushin (2012) is complementary by focusing more on concepts and empirical findings. Light & Moody (2020) is a handbook on a wide variety of topics in the social networks literature. Scott (2002) is a collection of seminal studies. Textbooks on network research in other disciplines than sociology include Easley & Kleinberg (2010), Jackson (2008), and Newman (2018). Networks are a topic, too, of popular science literature (for example, Christakis & Fowler 2011; Jackson 2019; Watts 2003).

We first sketch a framework for theory formation on effects and formation of social networks. Subsequently, related to the diamond merchants vignette, our first 'case study' is a model of exogenous network effects on trust in social and economic exchange. Our second example is a model of status hierarchies, with endogenous network formation as the key macro-outcome of the model. A brief discussion concludes the chapter.

2. SOCIAL NETWORKS IN MICRO-MACRO MODELS

Coleman's (for example, 1990) diagram for representing micro-macro explanations is a convenient heuristic device for highlighting how social networks can be researched in rigorous sociology (Figure 9.1). The introduction chapter for this *Handbook* includes a discussion of micro-macro explanations (see also the chapter by Steglich & Snijders).

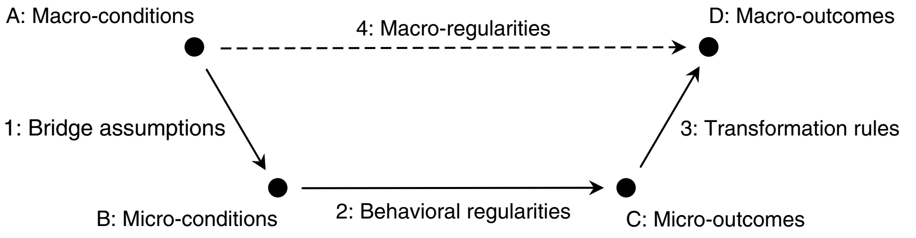

Figure 9.1 Coleman's diagram

Here, we build on that discussion, employing terminology from that chapter (see also Agneessens 2020 for a discussion on different levels in networks research). At the same time, we relate the diamond merchants vignette to nodes and arrows in the figure.

2.1 Network Effects

Social networks and their characteristics can be represented in Coleman's diagram as macro-conditions (Node A) and as macro-outcomes (Node D). When considering the effects of networks, assumptions on network characteristics refer to macro-conditions. In the diamond merchants vignette, the macro-conditions thus include assumptions on a network with extensive ties and frequent interactions between the actors, thus allowing for ease of information exchange. Another set of macro-conditions refers to characteristics of the market for stones. This includes the value of high- and low-quality stones and the necessity of careful inspection of stones to reliably assess their quality. Bridge assumptions then specify how such macro-conditions affect the micro-level of exchange between individual merchants. Micro-conditions include individual incentives for merchants and their information on a potential trading partner. Assumptions on behavioral regularities are that reputational concerns will affect whether or not a potential buyer of stones abstains from substituting inferior stones for valuable ones when inspecting them. In addition, the potential seller is assumed to anticipate whether or not the potential buyer will be trustworthy. Micro-outcomes follow, namely, whether or not buyer and seller engage in a 'smooth' transaction, avoiding malfeasance. Macro-outcomes, then, refer to how efficiently the market functions. In this way, macro-level regularities also follow on how the characteristics of the merchants' network are associated with efficient functioning of the market.

Our diamond merchants vignette indicates that networks have effects on trust in economic and social exchange (Coleman 1990) and more generally on behavior in social dilemmas and on the outcomes of such behavior (Raub & Weesie 1990). Other research on network effects includes, for example, individual behavior on the labor market and labor market outcomes (Granovetter 1973, 1974), individual adoption of innovations and macro-level diffusion processes more generally (Centola 2018; Coleman et al. 1966), and social inequality (Coleman 1988; Lin 2001).

An overall implication of research on network effects is that actors benefit from certain network structures and also from their individual positions in such structures. For example, dense networks may be beneficial for solving trust and cooperation problems.

In competitive settings, access to and control of information provide individual advantages (Burt 1992 and his showcase chapter; Granovetter 1973; see also Vedres' chapter).

2.2 Network Formation

At times, actors can adapt their individual positions in a network, at least to some degree. They can do so by establishing, maintaining, or severing relations with others. For example, actors can often choose with whom to exchange goods or information and with whom to collaborate. The notion that networks have important consequences for them suggests that actors have incentives for 'networking'. Namely, goal-directed behavior, represented as a micro-level behavioral regularity in Coleman's diagram (Arrow 2) and sometimes referred to as 'agency', 'intelligible action', and the like in sociology, would then imply that actors try to form relationships to improve their individual network benefits: they invest in establishing and maintaining beneficial relations, while ending relations that are not beneficial. These are then relevant micro-outcomes (Node C). This is in line with the social capital notion that goal-directed actors benefiting from resources embedded in networks would choose their network ties purposively (Flap & Völker 2013). Then, the network structure is the emergent and endogenous macro-outcome (Node D) of the combined choices of all actors involved (Corten 2014). In this way, endogenous network formation fits in Coleman's diagram. Network structure, rather than being 'one-shot', may of course develop over time in a dynamic process (see the chapters by Flache, Mäs & Keijzer and by Steglich & Snijders). From a more empirical perspective, ignoring that networks may be due to forming and severing ties with similar others ('selection') may lead to biased estimation of the importance of, for example, influence processes (Steglich et al. 2010).

Of course, when network structures are the results of actors' decisions, it does not necessarily follow that network structures will also be socially beneficial (Buskens & Van de Rijt 2008). After all, since the network structure is the result of the combined choices of all actors, relational choices of one actor have consequences for other actors. For instance, by breaking just one relation, an actor can interrupt many indirect connections between other pairs of actors, thereby changing the flow of information in the network. Thus, endogenous network structures are possibly unintended and unfavorable consequences of individual action.

For quite some time, the literature on social networks focused primarily on the effects of social networks. Systematic research on the formation and dynamics of social networks is more recent and presumably still more scarce. This is understandable since the emergence and dynamics of networks is inherently due to interdependent behavior of actors, thus complicating theoretical and empirical analysis (Snijders 2011, 2013, and the chapter by Steglich & Snijders). However, since the 1990s, a sizeable literature has studied network formation, often using new data sources (Ackland 2013; Lazer et al. 2009; see the chapter by Flache, Mäs & Keijzer). This literature has roots in sociology (for example, Doreian & Stokman 1997; Stokman & Doreian 2001; Weesie & Flap 1990; see also Borgatti & Foster 2003) but has become very multidisciplinary, with contributions from disciplines such as economics, physics, biology, and mathematics. Scott (2011) shows how such work from other disciplines relates to – often overlooked – prior work in sociology. The example of endogenous network formation discussed below is on status hierarchies emerging from a network of status allocations.

2.3 Theory on Social Networks in Rigorous Sociology

Coleman's diagram directs attention to addressing how micro-outcomes depend on macro-conditions, bridge-assumptions, micro-conditions, and assumptions on behavioral regularities. Furthermore, the diagram directs attention to addressing how assumptions on micro-outcomes together with assumptions on transformation rules allow for deriving macro-outcomes. This induces a focus on the mechanisms through which networks have effects on micro- and macro-outcomes and a focus on the mechanisms producing network dynamics. In this way, the 'theory gap' (Granovetter 1979) that characterized much purely descriptive network research can be avoided.

It deserves mentioning that quite some research on social networks in rigorous sociology could be seen as an alternative to the perfect market model of neoclassical economics (Raub 2021 provides further discussion). For example, in his programmatic pamphlet, Granovetter (1985) argued that one should replace the assumptions of 'atomized' actors on perfect markets by assumptions that include the 'embeddedness' of actors. Here, 'embeddedness' refers to ongoing relations between actors as well as networks of actors and their relations. The interesting and often overlooked feature is that the core difference with the perfect market model lies in assumptions on macro-conditions rather than in micro-level assumptions on behavioral regularities. Even stronger, Granovetter opposes 'psychological revisionism', namely, the 'attempt to reform economic theory by abandoning an absolute assumption of rational decision making' (1985, p. 505). According to Granovetter (1985, p. 506),

> while the assumption of rational action must always be problematic, it is a good working hypothesis that should not be easily abandoned. What looks to the analyst like nonrational behavior may be quite sensible when situational constraints, especially those of embeddedness, are fully appreciated.[1]

This is similar to how Coleman (1994, p. 167) suggested employing rational choice theory in sociology:

> The hallmark of rational choice theory in sociology is the combination of an assumption of rationality on the part of individuals, but replacement of the assumption of a perfect market with social structure, sometimes regarded as endogenous and other times regarded as exogenous, which carries individual actions into systemic outcomes.

It is interesting to see that a research program as proposed by Granovetter and Coleman has meanwhile also developed in economics, with 'games on networks' studying network effects and 'strategic network formation' studying the endogenous dynamics of networks, although the roots in sociology of such a program are often, at best, scarcely noted (for an example, see Jackson et al. 2020).

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[1] Granovetter (2017) is a more recent version of his research program for 'economic sociology' and is more evasive on employing rationality assumptions; Goyal (2019) is a nuanced review by an economist.

3. EXOGENOUS NETWORK EFFECTS: TRUST IN EXCHANGE

Our first example is on network effects, with networks and their characteristics as macro-conditions that are assumed to be exogenous. In terms of the diamond merchants vignette, the model quantifies how large the short-term incentive to abuse trust can be as a function of the network structure in which actors are embedded. Exchange involving trust problems exemplifies social dilemmas and the problem of social order (for example, Buskens & Raub 2013, pp. 113–116). Hence, the model likewise highlights how networks affect cooperation in social dilemmas and how they can contribute to 'solving' the problem of social order.

3.1 Model Assumptions: the Heterogeneous Trust Game

The model is a slightly simplified version of the one in Buskens (2002, Chapter 3). We employ the Heterogeneous Trust Game (HTG, Figure 9.2), an adapted version of the standard Trust Game (Dasgupta 1988). The HTG represents exchange involving trust problems. Assumptions on the game, by defining the interaction situation, include key macro-conditions of the model. In terms of the diamond merchants vignette, these are market features related to characteristics of stones and the necessity of inspecting them. The game is played by two actors, a trustor and a trustee. In our vignette, the trustor would be a seller and the trustee a buyer. A special feature of the HTG is that it starts with determining an incentive θ for the trustee. As is common in game-theoretic modeling, θ is randomly drawn by 'Nature' from a distribution F. 'Heterogeneous' refers to this feature. Trustor and trustee are informed on θ.

Subsequently, trustor and trustee move sequentially. First, the trustor decides between placing or not placing trust. In our vignette, 'placing trust' would be to hand over stones

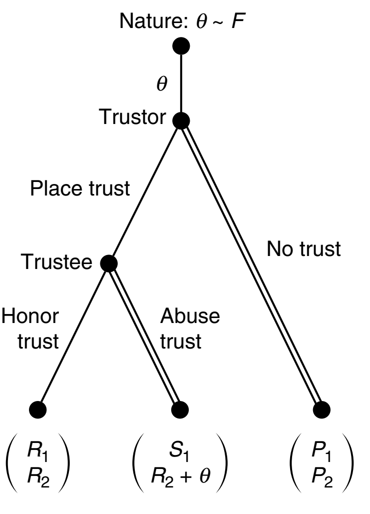

Figure 9.2 Extensive form of the Heterogeneous Trust Game, where $R_i > P_i$, $(i = 1, 2)$, $P_1 > S_1$, $\theta > 0$ (double lines indicate best reply behavior)

to the potential buyer for private inspection without formal insurance against malfeasance. 'Not placing trust' would be to abstain from a transaction. If the trustor does not place trust, the interaction ends and trustor and trustee receive payoffs P_1 and P_2, respectively. If the trustor places trust, the trustee chooses between honoring or abusing trust and the HTG ends. In our vignette, 'abusing trust' would mean substituting low-quality stones for high-quality ones, while not buying any stones. 'Honoring trust' would mean buying the stones for a mutually beneficial price (clearly, other courses of action are conceivable but we abstract away from such complications). If the trustee honors trust, trustor and trustee receive R_1 and R_2, respectively, with $R_i > P_i$ ($i = 1, 2$). If the trustee abuses trust, the trustee receives $R_2 + \theta$, while the trustor receives S_1. Actors are informed on all details of the HTG (in game theory terminology: they know the extensive form of the game).

Because $\theta > 0$, a rational trustee will abuse trust, when trust is placed. In addition, since $S_1 < P_1$, the trustor prefers not to place trust over placing trust that is abused. Hence, since the trustor can anticipate on the trustee's behavior, rational behavior implies that no trust is placed, while trust would be abused in the HTG. Technically, not placing trust, while trust would be abused, is the unique subgame-perfect equilibrium of the game.[2] This leaves both actors with a lower payoff than when trustor and trustee cooperate in the sense that trust is placed and honored so that both actors receive $R_i > P_i$. This shows that the HTG is a social dilemma (Buskens & Raub 2013).

Drawing the incentive θ to abuse trust from a probability distribution F distinguishes the HTG from the standard Trust Game. In the standard Trust Game, abusing trust is associated with payoff $T_2 = R_2 + \theta > R_2$ for the trustee, with θ as a constant. By specifying a probability distribution F, it is possible to represent the mean expected incentive to abuse trust as well as the variation of this incentive and the feature that 'golden opportunities' might occur so that abusing trust is particularly tempting. This is a 'mini example' of making a model more complex in a stepwise fashion, while keeping it tractable, and thus of cumulative growth of knowledge. Below, we show how this feature enriches implications of the model compared with a similar model without heterogeneity in incentives to abuse trust.

3.2 Model Assumptions: the Iterated Heterogeneous Trust Game

We now embed the HTG in an Iterated Heterogeneous Trust Game (IHTG) that allows for analyzing network effects on trust and cooperation. The intuition from our diamond merchants vignette made precise in the model can be summarized as 'trust and cooperation due to network effects'. As we have seen, the trustee has short-term incentives to abuse trust in the HTG. However, given repeated interactions of the trustee with multiple trustors and information exchange between trustors about past behavior of the trustee, the trustee must balance short-term incentives to abuse trust against long-term incentives to honor trust. After all, abusing trust now may imply that trustors in future exchanges will not place trust in the first place.

The IHTG is a sequence of HTGs, played at discrete time points t between a trustee and n trustors. For each time point t, one trustor i is randomly chosen from the set of

[2] See a textbook such as Rasmusen (2007) for details on game-theoretic terminology and assumptions used in this chapter.

trustors, each with equal probability. For the next time point $t + 1$, again a trustor j is chosen (this might be the same trustor as for t). Before the trustor for $t + 1$ plays with the trustee, the trustor for t and the trustor for $t + 1$ may be able to exchange information about past behavior of the trustee. More specifically, the trustors are linked in an information network $\boldsymbol{A}$ that is assumed to be exogenous. Formally, the network $\boldsymbol{A}$ is a weighted matrix with elements α_{ij} (thus, i and j again index trustors). The elements α_{ij} have values between 0 and 1, indicating the probability that i exchanges all information i has on the trustee's past behavior with the next trustor j. We define $\alpha_{ij} = 1$. If trustors do exchange information, j truthfully receives all past information i knows. If the trustors do not exchange information, all information on past behavior of the trustee is lost for all future HTGs to be played. This implies that if i after some time plays again with the trustee, and information has been lost in between, i also does not know what happened in i's own previous interactions with the trustee. Note that information exchange is not due to endogenous choices in the IHTG. Rather, the probability of information exchange is exogenously determined. Finally, with respect to payoffs, we assume that trustor and trustee involved in the HTG at t obtain the payoffs associated with the outcome in that interaction. Trustors not involved in the HTG at t receive payoff 0 at t. Payoffs for the IHTG are discounted exponentially with discount factor w, $0 < w < 1$. Actors are assumed to be informed on all details not only of the HTG but also of the IHTG. They are also assumed to know that everybody has that information (in game theory terminology: the extensive form of the IHTG is common knowledge).

From a game-theoretic perspective, the assumptions specified characterize the extensive form of the HTG and, somewhat roughly, of the IHTG. From the perspective of Coleman's diagram, these assumptions characterize macro-conditions of the social context of interactions. Related to the diamond merchants vignette, we have already seen that HTG models basic features of the market for stones. IHTG specifies features of the network of merchants. In addition, the extensive form also includes bridge assumptions linking macro- to micro-conditions. Namely, assumptions on the IHTG include how an actor's individual payoffs depend on the random events during the game (incentives θ for abusing trust, selection of trustor playing at a given time point, information exchange between time points) as well as on the actor's own behavior and the behavior of the other actors. In addition, assumptions on the IHTG include how the information an actor has at a specific time point on the previous behavior of other actors depends on what has happened previously in the IHTG.

3.3 Model Implications: Micro- and Macro-outcomes

We now turn to model implications. In terms of Coleman's diagram, we focus on how macro-conditions affect micro- and macro-level outcomes. Placing or not placing trust as well as honoring or abusing trust are micro-level outcomes. The macro-outcome is the proportion of interactions such that mutual cooperation – trust placed and honored – is attained. The extensive form of the IHTG shows how this proportion depends on micro-level outcomes. Through the lens of Coleman's diagram, assumptions on the extensive form, therefore, also imply transformation rules.

Game-theoretic analysis permits us to derive model implications by considering equilibria of the IHTG. We thus assume that all actors are strategically rational in the sense that each actor maximizes own payoffs in the IHTG, given the behavior of all other actors. We have already seen that the HTG has an equilibrium such that trust is not placed, while placed trust would be abused. As is pretty much standard in the analysis of iterated games, we consider trigger strategy equilibria (Friedman 1971) of IHTG to see how iterating the HTG and, specifically, how the network of trustors affect equilibrium behavior. For the IHTG, trigger strategies are defined using a vector of trust thresholds $\boldsymbol{\vartheta} = (\vartheta_1, \ldots, \vartheta_n)$, where ϑ_i indicates the maximum incentive θ of the trustee for which trustor i is still willing to place trust. Trigger strategies imply that trustor i always places trust if $\theta \leq \vartheta_i$ and he or she does not have any information about an abuse of trust by the trustee in the past. In all other cases, trustor i will not place trust. The trustee will honor trust if $\theta \leq \vartheta_i$ in interactions with trustor i, provided that trustor i does not have any information about an abuse of trust in the past. Buskens (2002, Chapter 3) shows that the ϑ_i of trustor and trustee in interactions with trustor i need to be the same in equilibrium. Then, conditions can be derived for the maximal values of $\boldsymbol{\vartheta}$ such that these trigger strategies are indeed in equilibrium. In terms of Coleman's diagram, the key assumption on behavioral regularities is then that actors employ trigger strategies with maximal values of $\boldsymbol{\vartheta}$. This assumption on playing a trigger strategy equilibrium mirrors the diamond merchants' reputational concerns that mitigate malfeasance. The trigger strategy equilibrium implies Pareto improvements compared with the no trust-equilibrium of the HTG, since it implies that trust will be placed and honored for sufficiently small incentives θ.[3]

In terms of the diamond merchants vignette, our solution for IHTG implies that a merchant trusts a potential buyer and hands over stones for informal inspection and the buyer abstains from malfeasance if the value of the stones is below a certain threshold value. The threshold depends on the parameters of the game, including characteristics of the network of trustors. However, trust will not be placed when the stones are so valuable that informal inspection would create a 'golden opportunity' for the potential buyer. This feature again corresponds with Wechsberg's (1966) sketch.

One can now derive (Buskens 2002, Chapter 3) testable hypotheses on how macro-conditions affect micro-level behavior in social and economic exchange as well as macro-effects. Such hypotheses follow from properties of trigger strategy equilibria. It can be shown, first, that the maximal trust thresholds $\boldsymbol{\vartheta}$ increase if the costs of withheld trust $(R_2 - P_2)$ for the trustee are larger and decrease if the distribution of incentives to abuse trust F produces larger θs. Second, with respect to the embeddedness of actors and their transactions in the sense of repeated interactions, the maximal trust thresholds $\boldsymbol{\vartheta}$ increase if the discount parameter w is closer to 1 so that long-term effects of present behavior become more important. Third, with respect to network effects, if an element of $\boldsymbol{A}$ increases, say α_{ij}, the thresholds of all those trustors will increase for whom there is a positive probability that the information they send to another trustor will reach trustor i. Because the average of all values in $\boldsymbol{A}$ is the density of the network of trustors, it follows that the proportion of cooperative interactions increases in the density of the network.

[3] As is typical for iterated games (Rasmusen 2007, Chapter 5.2), the IHTG has many equilibria. An often used assumption for the analysis of iterated games, though sometimes left implicit, is 'equilibrium selection based on payoff dominance': actors coordinate on a trigger strategy equilibrium that is a Pareto optimal equilibrium within the set of equilibria (Buskens & Raub 2013, p. 125). Employing such an assumption, trigger strategy equilibria with maximal values of $\boldsymbol{\vartheta}$ can be considered as the solution of the IHTG.

The analysis likewise reveals how the derivation of testable hypotheses employing the IHTG differs from how hypotheses are generated when the iterated standard Trust Game is used (Buskens & Raub 2013, pp. 122–130). Since the payoff for the trustee after abused trust is always the same $T_2 > R_2$ in the standard Trust Game, one can only specify a condition for the iterated standard Trust Game such that an equilibrium in trigger strategies exists that induces that trust will be placed and honored throughout *all* periods of the iterated game. Hypotheses on how macro-conditions affect trust in exchange are then generated by assuming that placing and honoring trust is more likely when the condition for the existence of such a trigger strategy equilibrium becomes less restrictive. By contrast, in the model employing the IHTG, hypotheses follow directly from the comparative statics of the extent to which trust can be placed by the trustor. This shows, too, why it is useful from an empirical as well as a theoretical perspective to assume that incentives for abusing trust are heterogeneous. In this way, replacing the standard Trust Game by the HTG and employing IHTG, while building on earlier game-theoretic models, contributes to systematic and cumulative growth of knowledge.

3.4 A Systematic Summary of the Model

We now summarize the model of network effects on trust in social and economic exchange (Box 9.1). For simplicity, we focus on key assumptions and implications of the game-theoretic model, neglecting various details. We structure our summary in terms of Coleman's diagram. We do so by indicating how assumptions (the *explanans*) and implications (the *explananda*) of the model relate to the nodes and arrows of the diagram. An important point of our summary is, though, that it highlights that the simple diagram in Figure 9.1 is a useful heuristic device but is not itself a theoretical model. Rather, the nodes and arrows of the diagram indicate different kinds of assumptions and implications that have to be specified explicitly, also showing that implications indeed follow from the assumptions.

BOX 9.1 EXOGENOUS NETWORK EFFECTS ON TRUST IN EXCHANGE

Macro-level

Node A: Macro-conditions

- Actors (*n* trustors and a trustee) are involved in the IHTG, including
  - Trust Games with heterogeneous temptation payoffs according to the distribution *F* (HTG, Figure 9.2);
  - trustors are linked in an exogenously given information network *A*, with links α_{ij} indicating probabilities of information exchange between trustors *i* and *j* on past behavior of the trustee;
  - rules on information exchange between trustors and on recall of information;
  - discount parameter *w*;
  - information conditions on what each individual actor knows about the interaction and knows about what other actors know etc. (technically, it is assumed that the extensive form of the IHTG is 'common knowledge').

Node D: Macro-outcomes

- Proportion of interactions such that mutual cooperation is attained (trust is placed and honored).

Arrow 4: Macro-regularities

- Relations between network properties and the proportion of interactions such that mutual cooperation is attained, for example, a positive association between network density and the proportion of interactions such that mutual cooperation is attained.

Arrow 1: Bridge assumptions

- These assumptions follow from the extensive form of the IHTG that show how an actor's individual payoffs and information on what happened in previous HTGs depend on macro-conditions as well as the actor's own behavior and the behavior of the other actors.

Micro-level

Node B: Micro-conditions

- Payoffs for specific actors
- Actors' information on what happened in previous HTGs

Node C: Micro-outcomes

- Individual choices on placing or not placing trust and, respectively, on honoring or abusing trust.

Arrow 2: Behavioral regularities

- Game-theoretic equilibrium behavior based on trigger strategies with maximal trust thresholds ϑ.

Arrow 3: Transformation rules

- These assumptions follow from the extensive form of the IHTG that shows how the proportion of interactions such that mutual cooperation is attained depends on individual choices on placing or not placing trust and, respectively, on honoring or abusing trust.

3.5 Further Model Implications and Discussion

Using approximation methods, Buskens (2002, Chapters 3.5 and 3.6) derives additional implications, particularly with respect to network effects. First, a linearization method is employed to distill more detailed predictions about network effects on the extent to which trust is expected to be placed and honored in a given network. The linearization shows that the outdegree of a trustor (the probability that a trustor sends information to the next trustor) is the main network determinant predicting how much a specific trustor can trust the trustee.

Second, to generalize and extend predictions further, Buskens uses a simulation generating a large number of networks with sufficient variation in a series of relevant network properties. The equilibrium thresholds for all trustors in all these networks were calculated and collected in a dataset. Subsequently, trust thresholds were predicted using a linear regression model with network properties as the predictors for the trust thresholds. Over a large set of networks, this analysis shows how likely it is that a network property or an actor's individual network position changes the trust threshold in a certain direction. In addition, interaction effects of network properties and other parameters in the game can be derived if these other parameters are also varied in the simulation. The simulation reconfirms that trust thresholds increase in a trustor's outdegree. Moreover, trust thresholds increase in the likelihood that the trustors to which a focal trustor sends information, pass the information on to other trustors. At the network level, trust increases with the overall network density, which is implied by the effect of outdegree. In addition, the effect of the centralization of the network is positive if central trustors are again strongly connected to each other, but negative if central trustors are mainly related to peripheral ones. An example of a hypothesis on an interaction effect is that the effects of the network properties become stronger with an increasing discount parameter.

Some limitations related to specific theoretical assumptions of the model merit discussion. It is assumed that all actors know all elements of the structure of the IHTG. This seems unrealistic. For example, why would actors exactly know each other's payoffs? Also, the assumption on actors' complete information about the extensive form affects implications that can be derived. One implication is that trust is never abused in the trigger strategy equilibrium of the IHTG. Consequently, the model implies that there is no effect of the payoff difference $P_1 - S_1$ on placing and honoring trust. Empirically, it is known that trust decreases if $P_1 - S_1$ increases, at least in one-shot standard Trust Games (Snijders & Keren 2001) and in finitely repeated Trust Games with incomplete information (Camerer & Weigelt 1988). Concerning the diamond merchants, Wechsberg and Granovetter mention that malfeasance is a rare exception but not completely absent. In addition, because trust is never abused in equilibrium, information about abused trust is never shared in the network. The effect of outdegree is, thus, purely an effect of the threat of sending information and of deterring the trustee from abusing trust, given this threat, while receiving information is not crucial. This explains why the model predicts no effect of indegree on trust. Buskens (2003) provides a model with incomplete information of trustors on the incentives of the trustee to abuse trust. This model implies hypotheses on the effects of $P_1 - S_1$ and of indegree on trust. It also implies that abuse of trust, while being an exception, can happen when the equilibrium is played.

Deriving analytical results on network effects from game-theoretic models is often a difficult, if at all feasible, task. As we have already seen, simulation, rather than deriving analytical results, can then be an attractive complementary method for theory formation. Also, game-theoretic models are based on strong rationality and information assumptions. Implications of alternative assumptions on behavioral regularities can be explored using agent-based models of network effects, also relying on simulation methods (Flache, Mäs & Keijzer). Rather than employing assumptions on strategic rationality, some such alternative models employ an 'evolutionary' perspective. In such models, agents with predefined strategies are interacting on networks, assuming that 'successful' strategies thrive over time, while less successful strategies are employed less often. Some of these models have been developed in physics. Perc et al. (2017) and Sánchez (2018) review this work, including hypotheses that can be generated, overviews of empirical tests, and overviews of empirical regularities needing further research. Still other simulation models include assumptions on boundedly rational actors by assuming backward-looking learning or myopic best reply behavior (Steglich & Snijders provide an example).

This chapter is on theoretical models for networks effects and network formation. A careful discussion of empirical tests of implications of the model on network effects on trust in exchange is therefore beyond the scope of this chapter. For a systematic review of empirical work on such network effects, with results from survey studies and experiments, including vignette experiments, see Buskens & Raub (2013).

4. ENDOGENEOUS NETWORK FORMATION: STATUS HIERARCHIES

Our second example is Gould's (2002) model of status hierarchies. This is a model of endogenous network formation, with network characteristics as macro-level *explananda*. Status hierarchies are pervasive in both formal and informal human organizations. Traditionally, sociology has offered two different explanations for the existence of hierarchy. According to the first account, individuals end up at different status positions as a result of their individual qualities through a process of social exchange (Blau 1964). The competing view considers status hierarchies as determined externally, and attributes differences in individual outcomes to the positions that these individuals occupy in status hierarchies rather than to differences in intrinsic qualities of the individuals. As an alternative to these 'individualist' and 'structuralist' approaches, Gould's model explains social hierarchies as *emergent*, that is, as a result of how individual actors choose to attribute status to other actors, but without assuming that hierarchies are necessarily a straightforward reflection of individual qualities.

4.1 Status Hierarchies as Networks

Emergent status hierarchies can develop in social networks in the sense that a hierarchical *structure* is implied by the set of actor-to-actor status attributions – the 'connections' in the network. Gould provides a model of endogenous network formation with connections indeed implying status attributions. By conceptualizing status hierarchies as social networks, his model applies the conceptual lens of social network analysis to a fundamental theme of sociology, namely, social inequality and power differentials. In turn, this conceptualization allows us to reformulate questions about status inequalities in network terms. For example, questions about the degree of inequality in status hierarchies straightforwardly translate into questions about degree distributions or centralization in a network.

Two broad intuitions serve as starting points for the model. One is the 'self-fulfilling character of subjective judgements' (Gould 2002, pp. 1147–1148), or, more broadly, the Matthew effect (Merton 1968; see Van de Rijt's showcase chapter for a recent account). In the context of status hierarchies, this implies that, given uncertainty about individual qualities, judgments about individual qualities and, consequently, status attributed to individuals are reinforced by the relative status positions already occupied by these individuals. In terms of social networks, this idea is consistent with the notion of *preferential attachment* (Barabási & Albert 1999): actors who already have relatively many connections will disproportionally attract even more connections.

The second intuition is that attributions of status are the results of actors' goal-directed behavior. In particular, Gould points out that most actors would prefer to connect to actors who represent a certain value to them, and prefer receiving approval or connections over giving them. Again, in social networks terms, this idea is consistent with the – by now mainstream – notion of social capital, referring to the notion that connections in social networks provide actors with resources and that actors therefore decide in a goal-directed fashion about these connections (Flap & Völker 2013).

These two intuitions, at face value, provide reasonable motivation for a theory about the emergence of status hierarchies. They do not, though, provide by themselves clear predictions about emergent hierarchies. Still, the intuitions are consistent with a system that tends towards stability in the sense that everybody's attributions are optimal, given others' choices, and produce stable collective attributes. Then, chosen attributions seemingly constitute an equilibrium in the game-theoretic sense. Gould takes up this theoretical challenge. He reformulates the intuitions in a rigorous fashion as an equilibrium model of network structure. This allows for more specific predictions and insights that are not obvious from the informal intuitions alone. We summarize the model and its implications. Subsequently, we discuss its merits in a broader perspective, also taking into account critique and extensions of the model.

4.2 Outline of the Model and Key Results

The emergence of status hierarchies is conceptualized as a one-shot network game among a population of n actors. We now outline the assumptions characterizing the game. In game-theoretic terminology, we specify the normal form. As in our first case study, this yields macro-conditions related to the interaction situation. First, each actor can create directed weighted ties to any other member of the population, with ties representing status attributions. In principle, tie values are unrestricted, both positively and negatively. Second, each actor is assumed to possess a certain intrinsic quality Q_i. Third, the utility of an actor i from a tie a_{ij} with a given alter j is a function of two components. One component is the intrinsic quality of the alter, the other is the difference in tie strength (the degree of reciprocity). More specifically, the utility of connecting to alters with a certain intrinsic quality is assumed to increase linearly in the strength of the tie and the alter's intrinsic quality. On the other hand, actors experience a greater decrease in utility from differences in tie strength, the stronger their tie to alter. Fourth, *perceived* quality q_{ij}, that is, the quality of j as perceived by i, is assumed to be endogenously determined through social influence in the network. Specifically,

$$q_{ij} = (1 - \omega) Q_j + \omega \sum_{k \neq i, j} a_{kj} \tag{9.1}$$

in which ω represents the weight of social influence. Hence, the perceived quality is a function of the intrinsic quality of the alter Q_j of alter j and the indegree (the total of incoming connections, not counting i's own connection to j) of alter j, with ω determining the relative weight of these components.

The total utility of actor i as a function of all connections and perceived quality (as defined above) is subsequently defined as

$$u_i = \sum_j a_{ij} q_{ij} - s \sum_j a_{ij} \left(a_{ij} - a_{ji} \right) \tag{9.2}$$

in which s is a model parameter (with $s \geq 0$) representing the strength of symmetry considerations, represented by the right-hand side of the equation.[4]

As is common in game theory, actors are assumed to maximize their own utility conditional on the choices of other actors. This is the assumption of equilibrium behavior. The specification of the utility function in terms of Equations 9.1 and 9.2 allows us to characterize equilibria of the network game as dependent on the relative strength of social influence ω and symmetry considerations s. In general, an equilibrium of the game is a network of status allocations that maximizes utility u_i for each actor, conditional on the status allocations by all others. While the precise characterization of equilibrium attachment choices is somewhat cumbersome to interpret, a few more general implications of the equilibria as depending on ω and s are noteworthy. First, with the exception of a corner equilibrium in which all attachments 'cascade' towards a single actor,[5] the model does not predict status inequalities (in network terms: differences in indegree between actors) in the absence of differences in intrinsic qualities Q. Second, for sufficiently low values of s, Gould finds that status inequalities are related to differences in intrinsic qualities Q and the inequalities increase with ω. This implies that social influence indeed tends to exaggerate pre-existing quality differences. However, this is only true if social influence outweighs symmetry considerations: if actors have a sufficiently strong preference for reciprocity, status differences actually understate intrinsic quality differences.[6] Third, the network game of status hierarchies implies a *social dilemma*: even though, from a collective perspective, it would be optimal to maximize the density of the network, reciprocity considerations (with s sufficiently large) motivate actors to avoid connections to alters with low Q. The analysis of the model thereby echoes the tension between stability and efficiency that is often found in the game-theoretic literature on networks (Jackson 2008).

4.3 A Systematic Summary of the Model

Gould's model can be summarized as in Box 9.2. Our summary is once again structured in terms of Coleman's diagram. The overview highlights how the model aims to show how macro-level features of social networks depend on macro-level social conditions. Here, macro-level features of social networks include density, centralization, and the correlation between in- and outdegree. Macro-level social conditions include the distribution of quality differences and group size. The relation between the distribution of intrinsic quality and centralization, a macro-to-macro relation, is the main focus of the model. The mechanisms underlying these relations are specified in terms of goal-directed choices by individual actors. The macro-to-micro and micro-to-macro mechanisms driving the emergent nature of network are specified in the social influence mechanism.

4 There is no upper bound on s in the original formulation of the model. This makes both its substantive interpretation and its use in computational approximations of the model somewhat difficult (Manzo & Baldassarri 2015).

5 Corner equilibria are equivalent to star networks. Gould considers them as 'unrealistic' and therefore mainly focuses on interior equilibria, for sufficiently small values of ω and s.

6 This is a key finding in Gould's analysis. Later elaborations and re-analyses of the model cast doubt on its generality (Manzo & Baldassarri 2015). Below, we return to this issue.

BOX 9.2 STATUS HIERARCHIES AS ENDOGENOUS NETWORKS

Macro-level

Node A: Macro-conditions

- A network game, including
  - a set of *n* actors;
  - feasible strategies of each actor *i*: directed weighted ties (representing status attributions) to any other actor;
  - a distribution of (objective, exogenously determined) quality differences *Q*;
  - weight ω of social influence and strength *s* of symmetry considerations;
  - information conditions on what each individual actor knows about the interaction and knows about what other actors know etc. (technically, it is assumed that the normal form of the network game is 'common knowledge').

Node D: Macro-outcomes

- Features of the emerging hierarchy, such as density and the distributions of status (indegree) and 'gregariousness' (outdegree).

Arrow 4: Macro-regularities

- The extent to which emergent status hierarchies (a macro-level outcome) reflect the distribution of underlying quality differences (a macro-level condition). For example, the model shows that social influence may amplify quality differences as reflected in the hierarchy. In addition, the model provides insights in how this amplification *in itself* depends on other macro-level model parameters.

Arrow 1: Bridge assumptions

- These assumptions follow from the normal form of the network game that shows how an actor's individual utility depends on macro-conditions as well as the actor's own behavior and the behavior of the other actors.

Micro-level

Node B: Micro-conditions

- Payoffs for specific actors
- Individual actors' information on other actors

Node C: Micro-outcomes

- Attachment decisions (that is, status attributions) by individual actors directed at alters.

Arrow 2: Behavioral regularities

- Equilibrium behavior

Arrow 3: Transformation rules

- These assumptions follow from the normal form of the network game that shows how features of the emerging hierarchy, such as density, centralization, and the distributions of status (indegree) and 'gregariousness' (outdegree) depend on individual attachment decisions.

4.4 The Model in a Broader Perspective

Gould's model provides insights on macro-level regularities. However, these are not easily tested empirically because, for example, intrinsic quality is typically difficult to measure. Gould therefore derives a number of additional, more specific hypotheses about emerging network structure. This includes the implication that asymmetry in social relationships will be proportional to the difference in choice status between pairs of actors. A detailed discussion of Gould's tests of hypotheses is beyond the scope of this chapter. It is noteworthy, though, that the hypotheses refer *exclusively* to features of the network structure. They thus do not require the measurement of intrinsic quality differences. Thereby, somewhat counterintuitively, this approach seems to ignore one of the core features underlying status hierarchies. However, this greatly facilitates the testability of the hypotheses. It allows Gould to subsequently test these and other hypotheses on a number of relatively straightforward data sets on small social networks. The data sets include interactions in task groups, between toddlers, and in a fraternity. Overall, the tests provide considerable support for the predictions of the model. For instance, the model predicts the emergence of social roles (or structural equivalence) in terms of social status, and indeed, with the exception of the toddlers, actors in the empirical networks who are more similar in status also tend to have similar connections to others.

From a more meta-theoretical perspective, Gould's analysis provides a good illustration of the merits of a 'rigorous' approach to studying the emergence of social networks. First, the model provides non-trivial insights that are not obvious from the verbal representation of the motivating intuitions. These insights are made possible by the formalization of assumptions. This allows for the application of a rich toolbox of mathematical techniques that would not have been available otherwise.

Second, these insights also lead to precise and testable hypotheses. In his case, the hypotheses tend to be supported by the data examined. However, the important point is that the hypotheses are derived from the assumptions in a verifiable way. Therefore, empirical evidence contradicting the hypotheses is also directly informative about the underlying assumptions. Furthermore, it is noteworthy about the hypotheses that they provide predictions on relatively easily observable structural features of networks. Hence, testing does not require empirical information on relatively hard-to-observe individual traits such as intrinsic quality, even though these traits do play a crucial role in the model. This illustrates the more general point of the difference between assumptions on the one hand, specifying underlying causal mechanisms, and hypotheses on the other hand, as testable statements about patterns in empirical data.

Third, while the model builds on common sociological intuitions regarding the role of social influence on quality judgements, preferential attachment, and reciprocity, the analysis goes beyond verbal representations of such intuitions. The formal representation forces the modeler to make assumptions on the underlying mechanisms explicit, and thereby also more vulnerable to critique and falsification. Indeed, while Gould's model was an innovative and important step in understanding the emergence of status hierarchies, it has also sparked discussion and criticism. Critics pointed out flaws in the analysis of the model, questioning the generality of Gould's results, or the realism of some of the assumptions underlying the model (Lynn et al. 2009; Manzo & Baldassarri 2015). Engaging in this debate is beyond the scope of this chapter. Our point is that the debate itself demonstrates the merits of a modeling approach: implicit assumptions that are easily 'brushed over' in a verbal representation, must be made explicit and precise in order to be implemented in a model. Subsequently, implications of these assumptions can (and must) be derived in a systematic and transparent fashion. Precisely these features also make a model more vulnerable to targeted critique.

Finally, and related to the previous point, as opposed to the verbal intuitions that motivated the model, Gould's model provides a useful 'platform' for further theory construction. For example, the formalization of intuitions in the model now allows for a precise comparison, both in terms of assumptions and implications, with alternative models of hierarchy in networks (for example, Barabási & Albert 1999). In addition, taking the model as a starting point, it has been extended further by introducing alternative, more complex, and possibly more realistic assumptions (Lindenberg 1992). This includes assumptions on a more dynamic process of network formation as opposed to Gould's 'one-shot' equilibrium approach (Gould 2002, p. 1156; Lynn et al. 2009), alternative outcome measures, and alternative decision heuristics (Manzo & Baldassarri 2015). Such extensions, as well as the critique and debate that motivated these extensions, demonstrate that the rigorous approach to theory building that underlies both Gould's model and its extensions allows for cumulative growth of knowledge.

5. CONCLUSION AND DISCUSSION

This chapter focused on theoretical work on social networks in rigorous sociology that addresses two kinds of questions, namely, the effects of networks on individual behavior as well as on the macro-outcomes of behavior and how networks are themselves affected by behavior. Whether one wants to consider the effects of networks or their formation, the interdependence of actors requires systematic model building to understand the micro- and macro-implications of assumptions on the social context on the one hand and on individual properties and regularities of individual behavior on the other. In particular, network models need to incorporate macro-to-micro (bridge assumptions) and micro-to-macro links (transformation rules). This is necessary because one tries to understand how macro-conditions such as network structures affect behavior and how individual behavior in turn shapes macro-outcomes, including the emergence and dynamics of networks. We have employed two examples to illustrate in some detail, although selectively, how network models can be specified and analyzed along these lines. One of these examples has been on exogenous network effects on trust and cooperation in social and economic exchange, the other one on endogenous network formation related to status hierarchies.

Models of social networks like those discussed in this chapter have obvious strengths. Assumptions are clearly specified, with an eye on systematic distinction between assumptions on macro- and micro-conditions, assumptions that relate macro- and micro-levels of analysis, and assumptions on behavioral regularities. The explicit focus on macro-to-micro as well as micro-to-macro links is an appealing feature of the models. In these ways, progress has been made in closing Granovetter's (1979) 'theory gap'.

Both our examples of network models employed assumptions from game theory – basically on equilibrium behavior in non-cooperative games – as assumptions on behavioral regularities. In general, assuming goal-directed behavior seems quite natural in research on social networks, certainly in line with rigorous sociology research à la Granovetter and Coleman (see above). Game theory provides prominent specifications of such assumptions for situations with interdependence between actors. Such interdependence is typical for social settings with network effects as well as for social settings with network formation. These models often lead to implications, including testable hypotheses, via analytical methods. Our examples likewise revealed another advantage of game-theoretic models in the field of social network analysis: as we have seen, these models require explicit specifications of interaction situations in terms of the normal or extensive form of a game. In turn, the normal or extensive form typically yields well-specified bridge assumptions and transformation rules linking micro- and macro-levels of analysis, thus providing key elements of micro-macro-models (Coleman 1987, 1993).

Of course, assumptions on goal-directed behavior can be specified in ways that provide alternatives to game-theoretic equilibrium assumptions. For example, a variety of models of bounded rationality as well as models assuming myopic behavior and backward-looking learning have been suggested and are meanwhile often also used in models of social networks. Agent-based modeling is often used to derive testable hypotheses when working with such assumptions on goal-directed behavior (Macy & Flache 2009; see the chapter by Flache, Mäs & Keijzer), although, in principle, agent-based modeling is a 'tool' for theory construction that is neutral with respect to the assumptions on behavioral regularities used. In addition, the demarcation between analytical game-theoretic models and simulation models employing myopic behavior and backward-looking learning is often ambiguous, for example, because learning may lead to game-theoretic equilibria via evolutionary dynamics (see Buskens et al. 2015 for further discussion of analytical and simulation models for network effects and network formation).

Much of the literature on network formation and dynamics is on causes that lie solely in the network structure itself. It is often likely, though, that the choice of network relations also depends on the 'content' of those relations and on actual behavior in relevant interactions. After all, one of the reasons to study social networks in the first place is that networks affect behavior. For example, when facing cooperation problems, actors may want to avoid defectors. In other settings, actors may simply want to avoid those who behave differently and prefer relations with those who behave similarly (McPherson et al. 2001). Thus, on the one hand, networks influence the way people behave in their interactions. On the other hand, individual behavior in interactions also affects the network such that actors 'themselves constitute each other's changing environment' (Snijders 2001, p. 363; see also Snijders 2013 and the chapters by Flache, Mäs & Keijzer as well as by Steglich & Snijders). Hence the co-evolution of networks and behavior has become the object of study in a new research program still *in statu nascendi* (see Eguíluz et al. 2005 and Pujol et al. 2005 for early examples in sociology; Buskens et al. 2015 for a brief overview and Corten 2014 for a more detailed survey).[7]

Goldthorpe (2007, Chapter 6) has advocated an alliance of rational actor models and quantitative survey research in rigorous sociology. We conclude this chapter with three remarks on Goldthorpe's program. First, in line with his own research domain, Goldthorpe

[7] See Raub et al. (2013) and Frey et al. (2019) for examples of theoretical and empirical work on co-evolution of networks and trust in exchange, integrating network formation in models of network effects on trust.

considered such an alliance specifically for research on education, social mobility, and inequality. The program, however, can be and actually has been applied in other domains as well, including research on social networks. Second, with respect to theory, a variety of rational actor models can be used. These include those discussed in Goldthorpe (2007, Part Two) as well as alternative assumptions on behavioral regularities that fit into micro-macro models such as those discussed in this chapter. Quite some theoretical work on the effects and the formation of social networks then fit into the program, too. Finally, on the empirical dimension, work along the lines of Goldthorpe's program need not exclusively employ survey research. Rather, in addition to and possibly complementing survey designs, other designs can also be used. These can be experiments, both lab and field, as well as quasi experimental designs (Buskens & Raub 2013; Jackson & Cox 2013; see the chapter by Gërxhani & Miller). Certainly in research on social networks, new digital data sources have become important (Ackland 2013; Salganik 2018; for general discussion and see the chapter by Flache, Mäs & Keijzer). In addition, digital data can be linked with survey data for the same study (Hofstra et al. 2017 is an example). The showcase chapters by Salganik, Dodds & Watts and by Van de Rijt highlight, by way of example, how 'digital experiments' can be implemented. In these ways, much of empirical research on networks is well in line with Goldthorpe's program, broadly conceived.

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