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Social network capital, economic mobility and poverty traps

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Abstract This paper explores the role social network capital might play in facilitating poor agents' escape from poverty traps. We model and simulate endogenous link formation among households heterogeneously endowed with both traditional and social network capital who make investment and technology choices over time in the absence of financial markets and faced with multiple production technologies featuring different fixed costs and returns. We show that social network capital can either complement or substitute for productive assets in facilitating some poor households' escape from poverty. However, the voluntary nature of costly link formation also creates exclusionary mechanisms that impede some poor households' use of social network capital. Through numerical simulation, we show that the ameliorative potential of social networks therefore depends fundamentally on the broader socio-economic wealth distribution in the economy, which determines the feasibility of social interactions and the net intertemporal benefits resulting from endogenous network formation. In some settings, targeted public transfers to the poor can crowd-in private resources by inducing new social links that the poor can exploit to escape from poverty.

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1 Introduction

The persistent poverty widely observed in developing countries has motivated much research on poverty traps. Most poverty trap models rely on the existence of financial market imperfections that impede investment in productive assets or technology, thereby preventing households with poor initial endowments from reaching higher-level equilibria in systems characterized by multiple equilibria.[1] Meanwhile, a parallel literature emphasizes multiple pathways through which social network capital might facilitate productivity growth, technology adoption and access to (informal) finance.[2] Various studies also document the existence of exclusionary mechanisms that can effectively prevent some poor from utilizing social networks to promote growth.[3] Advances in understanding the nature and limits of social network capital formation could offer insights into whether and how poor households might avoid or escape poverty traps. There have been some notable recent efforts to make these links explicit.[4]

This paper explores mechanisms by which endogenous social network capital can facilitate or impede poor households' escape from persistent poverty and the conditions that affect such mechanisms. While some empirical studies (e.g., Narayan and Pritchett [52]) find that social network capital effectively serves as a substitute for real capital in mediating economic mobility, others suggest that accumulation of social network capital proves ineffective for households at the bottom of the economic pyramid in highly polarized economies [1]. How might social network capital foster or impede the poor's economic mobility? Why might endogenous social network formation help some poor households but not others? What determines the poverty reduction potential of social networks? We develop a stylized household optimization model with endogenous network formation and use numerical simulations to elicit the mixed effects of social network capital on poor households' well-being dynamics.

The basic structure and intuition of our model runs as follows. We consider an economy with multiple production technologies with different fixed costs and returns but no financial market, which may prevent some households from accumulating capital to afford the high-return technology. Households heterogeneously endowed

[1]See Azariadis and Stachurski [7] or Carter and Barrett [15] for helpful reviews. Note that in the poverty traps literature the multiple equilibrium concept refers to situations in which different initial conditions lead to different outcomes. This differs from some alternative uses of the term in multi-agent game theoretic models where a given set of initial conditions can lead to several distinct final outcomes, e.g., because of strategic complementarities in agents' actions.

[2]Dasgupta and Serageldin [22] and Durlauf and Fafchamps [27] offer excellent reviews.

[3]For example, Adato et al. [1], Mogues and Carter [47] and Santos and Barrett [56].

[4]See, for example, the volumes by Barrett [9, 10] and Bowles et al. [13] and the December 2005 special issue of the *Journal of Economic Inequality* on "Social Groups and Economic Inequality".

(by their parents) with privately owned capital assets and social network capital choose production technologies, consumption, and investment in capital assets and in social relationships with others in the economy so as to maximize their discounted lifetime utility. Social links are costly to establish and have no intrinsic value; they merely provide access to partners' capital that can be used in the high-return technology. Social links between two individuals form endogenously based on mutual consent and result from optimal strategic interaction among all households in an economy. We simplify by assuming perfect information.

Analogous to other poverty traps models, some initially poor households are caught in a low-level equilibrium because they lack access, through endowments, markets or social mechanisms, to the productive assets needed in order for the most productive technology to be the households' optimal choice. Initially poor households without such access must resort to autarkic savings if they are to finance later adoption of the improved technology. Some find such investment attractive and thereby climb out of poverty of their own accord. Others find the necessary sacrifice excessive and optimally choose to remain relatively unproductive and thus poor. A third subpopulation might find bootstrapping themselves out of poverty unattractive, but will make the necessary investment if they receive some help from others, i.e., social network capital becomes necessary for escape from persistent poverty. A fourth subpopulation is able and willing to make the necessary investment autarkically, but will find it more attractive to invest in social relations that offer a lower cost pathway to higher productivity. The initially poor are thus quite a heterogeneous lot, some enjoying independent growth prospects, others with socially mediated growth prospects, with social relations either complementing or substituting for own capital in economic mobility, while still others have no real growth prospects at all.

The tricky part of the analysis stems from the fact that (1) social networks represent complex sets of dynamic interpersonal relationships ("links") established non-cooperatively between mutually consenting agents, and (2) a given relationship or link's net value to any agent depends on the set of other links operational at the same time. Because the social network structure formed by the set of individual links evolves endogenously and depends fundamentally on the socio-economic wealth distribution of the underlying economy, the partitioning of the initially poor among the four subpopulations just identified will vary in both cross-section and time series.[5] This complex interdependency in a setting with multiple and heterogeneous households poses an analytical challenge, which we address using numerical simulations.

2 Poverty traps and social network capital

The growing literature on the microeconomics of poverty traps commonly employs a non-convex livelihood technology exhibiting locally increasing returns that arise from the implicit costs of uninsured risk associated with a high-return livelihood option [23, 61] or the explicit costs or capital requirement for adopting a high-return livelihood [8, 46, 48, 49]. Where markets fail to provide the poor with adequate access to necessary capital, multiple dynamic equilibria of long-term well being therefore

[5] Note that we use the term "link" to denote a bilateral relationship between two individuals and the term "network" to represent an individual's set of links or the set of individuals' networks.

arise, characterized by at least one critical asset threshold below which households tend to fail to accumulate enough assets to adopt a high-return livelihood and thereby remain trapped in persistent poverty. Households' initial asset endowments are thus a key determinant of their long-term well being [15].

A rapidly growing, parallel literature on "social capital" emphasizes its potential to obviate market failures in low-income communities. Durlauf and Fafchamps [27] distinguish between two broad concepts of social capital identifiable in the literature. First, social capital is sometimes referred to as a stock of trust and associated attachment(s) to a group or to society at large that facilitate coordinated action and the provision of public goods [18, 54]. A second conceptualization treats social capital as an individual asset conferring private benefits [19, 31, 35, 50]. We employ the second conceptualization, which is sometimes referred to as "social network capital" so as to emphasize that household's gain from linking with others for mutual benefit [35, 41].

The literature identifies various pathways through which social networks might mediate economic growth: improved information flow and informal access to finance for technology adoption, market intelligence or contract monitoring and enforcement, access to loans or insurance, or provision of friendship or other intrinsically valued services. For simplicity, this paper assumes the sole function of a social network is to provide access to link partners' (at least partially nonrivalrous) productive assets, which reduce the cost of the high-return technology. Intuitively, this can be understood as sharing or borrowing tools, equipment or even skilled animal or human labor, obtaining nonrivalrous capital-specific information, etc., which are costly, productive inputs in high-return production.[6] For example, a farmer's social link to another farmer might afford free access to the latter's tractor or at least to information that reduces tractor acquisition or operating costs if the farmer opts to buy a tractor himself. The social network in our setting thus has purely instrumental value in allowing one to accumulate social network capital, naturally defined as socially mediated access to others' productive assets.

Social network capital is assumed to be productive only in the high-return production technology, in which it is (imperfectly) substitutable for private capital. The prospective benefits of social network capital create material incentives to establish social relations with others, even when it is costly to establish and maintain such relationships. Social network formation is thus akin to more conventional capital investment.

Social networks necessarily evolve endogenously. A small but growing literature demonstrates this empirically in the case of poor agrarian communities [19, 24, 32–34, 57]. Because social networks are (at least partly) the consequences of individual's cost–benefit calculus with respect to prospective links with others, and those costs and benefits depend on social distance and the underlying structure of the economy, network structure is highly variable. Theorists have modeled endogenous network formation, building on seminal works by Aumann and Myerson [5], Myerson [51] and Jackson and Wolinsky [43]. Development economists have begun applying formal theoretical models of network formation [14, 19, 39, 47]. Nonetheless, most social

[6]Note that such access does not need to be equivalent to that of the asset owner. It merely needs to be superior to that of others who do not have similar social access so that socially-mediated capital access reduces fixed costs of operating the high-return technology. We develop this further in Section 3.1.

networks studies related to economic development are empirical, and in aggregate strongly suggest that not everyone benefits from social networks and that there exist patterns to failures to form links [27]. Carter and May [16] and Adato et al. [1] show that the voluntary and involuntary exclusion of poorer black households from the social networks of wealthier whites in South Africa has prolonged the legacy of apartheid and minimized the prospective benefits of social capital to the poor via obviating barriers to entry into remunerative livelihoods. Vanderpuye-Orgle and Barrett [59] find that socially isolated households in southern Ghana are unable to smooth consumption in the face of idiosyncratic shocks, while the socially connected pool risk effectively. Santos and Barrett [57] find that asset transfers in southern, systematically exclude poorer households, corroborating insights from anthropologists and historians studying similar systems across rural Africa.

Nonrandom patterns of unformed latent social links within a society reflect choices made by individuals to forego prospective relationships. We refer to the situation where an individual opts not to seek out partners as "social isolation", reflecting voluntary self-selection out of prospective networks.[7] In other cases, individuals desire links with others but are rebuffed by prospective partners, resulting in involuntary "social exclusion".[8] We demonstrate below how patterns of social exclusion and isolation may turn fundamentally on the wealth distribution in an economy, with significant consequences for the poor's growth prospects.[9] Models of endogenous social network capital as an input into productivity growth provide a natural link between the social networks literature and that relating income distribution to economic growth.[10]

3 A simple household optimization model with endogenous network formation

Assume n heterogeneous households exist in an economy, $N = (1,2,\ldots n)$. Each lives for two periods, $t = 0,1$.[11] Each household i is initially endowed with two types of assets: traditional productive capital, denoted A_{i0}, representing a one-dimensional aggregate index measure of physical, natural, human and financial capital, and social network capital, denoted S_{i0}, referring to the traditional capital that might be acquirable from others in the initial social network. There is thus just one type of individually owned asset, but people can have access to it directly

[7]Postlewaite and Silverman [53], Kaztman [45], Barry [11], Wilson [60], among others, similarly use the concept and term "social isolation" to reflect voluntary non-participation in a society's institutions.

[8]Note that we use the term "social exclusion" very precisely, especially as compared to the literature on social exclusion as, more generally, "inability of a person to participate in basic day-to-day economic and social activities of life" (Chakravarty and D'Ambrosio [17], p. 397), as the term is used by, among others, Room [55], Atkinson et al. [4], and Bossert et al. [12].

[9]We only directly refer to social isolation and social exclusion with respect to those agents who remain poor over time and do not establish social networks. Extension to those non-poor who similarly do not link with others is straightforward, but omitted in the interest of focus on the paper's core poverty traps theme.

[10]See Aghion et al. [2], Galor and Zeira [38] or Mookherjee and Ray [48].

[11]Population growth is assumed zero for both periods.

through private ownership or indirectly through their social network. The economy's initial endowment distribution is denoted by $\lambda(A_0, S_0)$. Households' preferences are identical, with utility derived solely from consumption, as is the set of available production technologies.

3.1 Non-convex production technology

The available production technology set in this economy consists of two technique-specific production functions that generate low and high income at any period t, Y_t^L and Y_t^H, respectively, through

$$Y_t^L = f_L(A_t) \tag{1}$$

$$Y_t^H = f_H(A_t - F(S_t)) \quad ; \quad F(S_t) \geq 0,\ -1 < F'(S_t) < 0,\ F(\infty) = 0. \tag{2}$$

Technology L is a low-cost, low-return technique that everyone can afford. Technology H is a high-return technology with a fixed cost entry barrier, $F(S_t) \geq 0$. Greater capital is thus required to make technology H attractive because one has to cover the fixed cost of operation. Social network capital reduces the fixed cost of using the high-return technology and is thus an imperfect substitute for privately owned capital.

Each technology fulfills standard curvature conditions. For net productive assets, $NA_t^H = A_t - F(S_t) \geq 0$ and $NA_t^L = A_t \geq 0$, concave, (almost everywhere) twice-differentiable functions $f_H\left(NA_t^H\right)$ and $f_L\left(NA_t^L\right)$ follow Inada conditions with

$$\left.\frac{\partial f_H\left(NA_t^H\right)}{\partial NA_t^H}\right|_{NA_t=\alpha} \geq \left.\frac{\partial f_L\left(NA_t^L\right)}{\partial NA_t^L}\right|_{NA_t=\alpha} \geq 0 \quad \forall \alpha. \tag{3}$$

Thus, in each period t a household i's aggregate production function can be described as

$$Y_{it} = Max\left(Y_{it}^H, Y_{it}^L\right) = Max\left(f_H\left(A_{it} - F(S_{it})\right), f_L\left(A_{it}\right)\right) \tag{4}$$

which yields a non-convex production set, with locally increasing returns in the neighborhood of $\underline{A}(S_{it})$, the asset threshold beyond which a household will optimally switch to the high-return technology, i.e., $f_H\left(\underline{A}(S_{it}) - F(S_{it})\right) = f_L\left(\underline{A}(S_{it})\right)$. Figure 1 presents this aggregate production function as an outer envelope of the two specific production functions, with the threshold asset stock $\underline{A}(S_{it})$.[12] Social network capital thereby reduces the private asset stock necessary to make technology H optimal. As Sit increases, the high-return production function shifts in, lowering the minimum asset threshold needed to make high-return production optimal, i.e., $\underline{A}'(S_{it}) < 0$, which follows implicitly from the assumption that $F(\cdot)$ is decreasing in S_{it}.

The value of social network capital necessarily varies across households. For those with sufficient private assets, $A_{it} \geq \underline{A}(S_{it})$, adoption of H is always optimal, but S_{it}

[12] This is in the spirit of Cooper [20] or Azariadis and Drazen [6], each of whom exploits similar technologies to analyze multiple equilibria. Durlauf [26] explores the role of complementarities and incomplete markets in economic growth under such non-convexities and shows that localized technological complementarities can produce long-run multiple equilibria.

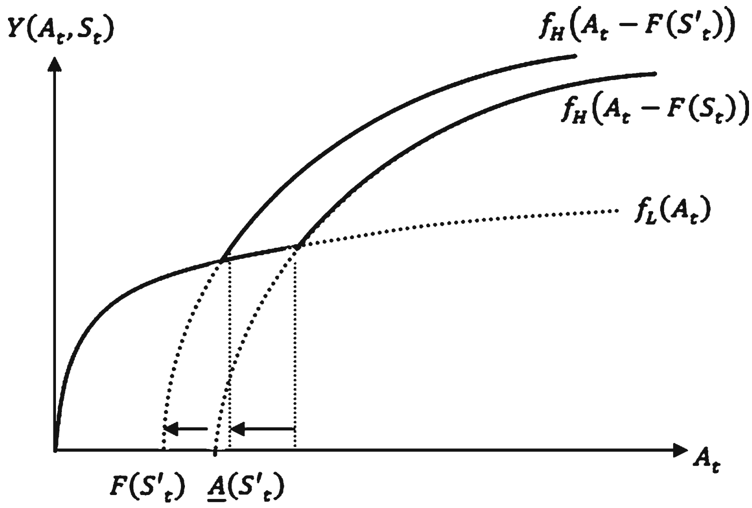


Fig. 1 Locally increasing return production technology when acquiring more social networking capital ($S'_t > S_t$)

reduces their fixed costs, increasing the productivity of their assets. Their investment incentives turn on the relative costs of social network capital and traditional, privately held assets. Social network capital is potentially most valuable for those households k, who possess insufficient assets themselves to adopt H, $A_{kt} < \underline{A}(S_{kt})$, but who are "not too far" in some sense from $\underline{A}(S_{kt})$ so that investment in building social network capital can lower the critical threshold they face to the point that the high-return technology becomes optimal in the future. Because social network capital has no value for those who do not employ technology H, however, as one's distance from $\underline{A}(S_{kt})$ increases the benefit from increased future social network capital falls once it will not suffice to bring the threshold down far enough, given the household's current and prospective asset stock. For such households, there is no incentive to invest in social network capital, thus they will rationally self-select out of costly social relations, thereby becoming socially isolated.

3.2 Household utility maximization problem

A household i derives utility solely from consumption each period, maximizing

$$U_i = u(C_{i0}) + \rho u(C_{i1}) \tag{5}$$

where ρ is the discount factor. The household faces a subsistence constraint such that for any level of consumption necessary for survival $\overline{C} > 0$;

$$u(C_{it}) = -\infty \ \forall t \geq r \text{ if } C_{ir} < \overline{C}. \tag{6}$$

This limits the intertemporal consumption tradeoff available to the household by permanently penalizing extremely low consumption in any period.

In period 0, household i with endowments (A_{i0}, S_{i0}) optimally chooses a production technology and allocates the resulting income from production among consumption (C_{i0}), investment in productive assets (I_{i0}) and investment in its social network ($X_{i0}K_i$), which is the product of its network (X_{i0})—the binary (0,1) vector reflecting the combination of social relationships ("links") it establishes during period 0—and the column vector of costs the household has to incur to establish or maintain[13] these relationships (K_i).[14]

Note that the household incurs costs in period 0 for establishing network X_{i0}, from which it derives no immediate benefits. The laws of motion mapping initial endowments into stocks at the beginning of period 1 depreciate A_{i0} and S_{i0} at rates δ_A and δ_S, respectively, while period 0 investments add to the stock of both assets. The new stock of social network capital is a function of the household's social network at the end of period 0 and the benefit function (B_i) that maps proportion of assets held by members of its established network into social network capital. In period 1, the household again chooses the optimal production technology and consumes all resulting income.[15] Social network capital is non-transferable and there are no financial markets. Autarkic saving is thus the only investment strategy so that holdings of both assets must be nonnegative.

A key distinction between A_{i0} and S_{i0} is that the household unilaterally decides the stock of traditional capital it will own, but it does not unilaterally decide on its social network because each social link involves bilateral decisions by both prospective partners. The household's social network is therefore the product of optimal social interactions, taking into consideration everyone in the economy's network preferences. A household's utility maximizing network might therefore prove infeasible because its preferred link partners do not have reciprocal desires for an active link. In modeling the household's decision, we thus define $X_{i0}^u = X_{i0}(X_{-i0})$ as household i's desired, unilateral network choice conditional on others' choices, denoted by X_{-i0}.

Specifically, the indirect utility that household i with endowments (A_{i0}, S_{i0}) derives from a possible network choice X_{i0}^u is simply

$$V_t^*\left(X_{i0}^u\right) = \max_{\{C_{i0}(X_{i0}^u), I_{i0}(X_{i0}^u), C_{i1}(X_{i0}^u)\}} u\left(C_{i0}\right) + \rho u\left(C_{i1}\right) \tag{7}$$

$$\begin{aligned} \text{subject to:} \quad & C_{i0} \le Y_{i0}\left(A_{i0}, S_{i0}\right) - I_{i0} - X_{i0}^u K_i \\ & A_{i1} = \left(1-\delta_A\right) A_{i0} + I_{i0} \\ & S_{i1} = \left(1-\delta_S\right) S_{i0} + X_{i0}^u B_i \\ & C_{i1} \le Y_{i1}\left(A_{i1}, S_{i1}\right) \\ & A_{i1}, S_{i1} \ge 0\ ,\ C_{i0}, C_{i1} \ge \overline{C}. \end{aligned}$$

Each household evaluates their network choices conditional on the choices of others. We now detail the specifications for the endogenous network formation and the suitable equilibrium concept in order to resolve this intertemporal optimization problem.

[13] Because, realistically, some agents begin with inherited social network capital—e.g., familial ties with biological relatives and parents' close associates—we assume that household's endowed social network capital exists independent of its de novo network link choices, subject only to a uniform rate of depreciation of the social network capital. Think of this as mortality or out-migration of pre-existing ties.

[14] Both K_i and X_{i0} are described in more detail in the next section.

[15] Zero investment in the terminal period is obviously an artifact of our simplifying assumption of a known, finite lifetime with no subsequent generations.

3.3 Endogenous network formation

We model network formation as a non-cooperative game in which links arise through a binary process of mutual consent between individuals who costlessly observe the current wealth distribution. Due to the multiplicity of equilibria, we reduce the range of feasible equilibria by imposing two restrictions. The first follows from the well-established fact that active social networks are primarily formed among individuals already acquainted with one another. This implies a central role for social distance in determining the net benefits of active link formation. We let social distance affect the individual-specific costs and benefits of link formation in a way that helps limit the range of prospective links to a domain over which they are most likely. Second, we model network formation using an extensive form game of link formation with perfect information, which allows us to find a subgame perfect Nash equilibrium (SPNE) social network in this economy.

3.3.1 Social distance, feasible interactions and link-specific cost–benefit analysis

A broad literature suggests there exist boundaries to prospective social interactions and therefore models network formation within prescribed neighborhoods [28, 29, 36]. In our model, each household is characterized by its universally observable (A_{i0}, S_{i0}) endowment. As in Akerlof [3] or Mogues and Carter [47], we use the geometric distance between households' endowments to reflect social distance, which reflects the degree of discomfort in their social interaction

$$d\,(i,\,j) = \sqrt{\left(A_{i0} - A_{j0}\right)^2 + \alpha\left(S_{i0} - S_{j0}\right)^2} \quad ; \ \alpha \geq 0 \tag{8}$$

for any pair of households, i and j, where α establishes the relative weight of pre-existing social network capital in determining social distance. It can thus serve as a proxy for the cost of establishing and maintaining a social relationship.[16]

Formally, a household $i$incurs total costs $X_{i0}K_t$ to establish its network of links, X_{i0}, where K_t is a column vector of costs they have to incur to establish each active link in the network. The cost to household i to establish a link with household j can be written as

$$K_i\,(j) = k\,(d\,(i,\,j)) \cdot \left(\frac{A_{j0}}{A_{i0}}\right) \ ; \ k'\,(\cdot) > 0 \ \text{ for } \ d\,(i,\,j) \leq \overline{d}, \ \ k'\,(\cdot) = \infty \,\text{otherwise.} \tag{9}$$

The idea is that it is easier to establish a link with people who are socially proximate, hence the cost function $k(d(i,\,j))$ increases in social distance. Further, we allow for asymmetric costs such that the poorer partner incurs more costs in link formation.

[16] Mogues and Carter [47] consider a similar social distance function incorporating wealth (or economic class) as one dimension of individual's intrinsic identity and ethnicity as another. An interesting extension of our model would include ethnicity (or other visible social markers) as another dimension that determines the social distance between households.

The constant $\overline{d}$ reflects a social distance threshold beyond which social interaction is infeasible.[17] It implicitly reflects physical and social barriers on the probability that individuals meet and interact. A low $\overline{d}$ can represent an economy in which households cluster into many small groups of shared characteristics with low inter-group connectivity or an economy characterized by significant ethnic, racial or religious discrimination or physical isolation. A high $\overline{d}$, on the other hand, allows for greater social interactions.

The benefits to household i from the active links in its social network are reflected in the column vector B_i, mapping some proportion of its partners' asset endowments into its social network capital next period. Specifically, a link with household j yields

$$B_i(j) = b\left(A_{j0}\left|A_{i0} - A_{j0}\right|\right) \quad ; \; 0 < b'_1(\cdot) < 1\,,\; -1 < b'_2(\cdot) < 0. \tag{10}$$

Implicitly, $0 < b'_1(\cdot) < 1$ emphasizes the nature of access to link partners' capital.[18] Some components of the composite asset are nonrivalrous (e.g., equipment-specific knowledge). Others, such as tools and equipment, can be shared and thus used at different time without materially affecting the owner's (or other borrowers') use, but perhaps with degraded performance for the borrower (e.g., due to imperfect timing). Whether one considers this unfettered, occasional or probabilistic access, the key is that i's access to socially mediated capital is increasing in the stock of links' privately held assets.

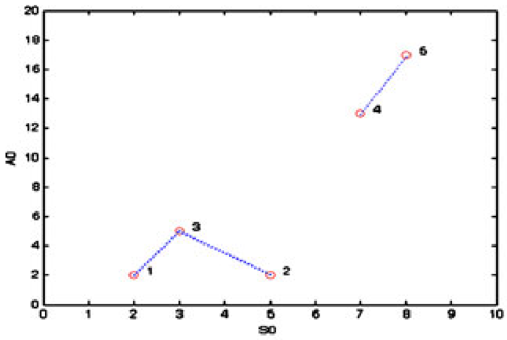
Social network capital benefits are link-specific and independent of all other links the household establishes. The social network capital gained from a link may not be symmetric to both members of the dyad for the simple reason that a poorer household can call on more resources from their richer partner than vice versa. Extreme differences in wealth, however, may hinder mutual benefits, as reflected in the second argument in (10). Intuitively, the specific capital of one partner might be inappropriate to a partner employing quite different practices due to stark wealth differences. This benefit asymmetry fits the empirical pattern that wealthy households are more likely to opt out of links with much poorer partners than vice versa [57]. In similar spirit, very poor households might not find it attractive to link with far richer ones with whom they share little [47].

Two fundamental points distinguish our network formation model from others. First, costs and benefits of links are realized intertemporally.[19] Preferences over possible networks therefore rely on realized net intertemporal utility gains. Second, household i's decision to link with household j is interdependent with its decision to link with others. A link with one household might complement or substitute for links with others. The multiple equilibria in our setting accentuate this interdependency because only those households that can accumulate enough resources to make the high-return production technology optimal benefit from social network capital. Therefore, many households' valuation of a given link is conditional on their success in establishing other links as well. Households' strategies therefore involve choosing

[17] The parameter $\overline{d}$ distinguishes between local and global interactions. It is economy-specific but universal to each household in the economy.

[18] Note that benefits are only generated from direct links, not indirectly through one's direct links.

[19] In existing network formation models, relationship payoffs occur within the period [14, 40, 43, 44].



$\Omega_1^{Ranked} = \{(x(12)\ x(13))\} = \{(1\ 1), (0\ 1), (1\ 0), (0\ 0)\}$

$\Omega_2^{Ranked} = \{(x(21)\ x(23))\} = \{(0\ 1), (1\ 1), (1\ 0), (0\ 0)\}$

$\Omega_3^{Ranked} = \{(x(31)\ x(32)\ x(34))\} = \{(1\ 0\ 1), (0\ 1\ 1), (0\ 0\ 1), (1\ 1\ 1), (1\ 1\ 0), (1\ 0\ 0), (0\ 1\ 0), (0\ 0\ 0)\}$

$\Omega_4^{Ranked} = \{(x(43)\ x(45))\} = \{(0\ 1), (1\ 1), (0\ 0), (1\ 0)\}$

$\Omega_5^{Ranked} = \{x(54)\} = \{1, 0\}$

The progress of interaction procedure is shown below
"⇒" stands for "propose to"

	Round 1	Round 2	
Household 1	⇒ 2 *No* ⇒ 3 *Match*	⇒ 2 *No*	$X_1^* = (0\ 1)$
Household 2	⇒ 3 *No*	⇒ 3 *Match*	$X_2^* = (0\ 1)$
Household 3	⇒ 1 *Match* ⇒ 4 *No*	⇒ 2 *Match*	$X_3^* = (1\ 1\ 0)$
Household 4	⇒ 5 *Match*	$X_4^* = (0\ 1)$	
Household 5	⇒ 4 *Match*	$X_5^* = 1$	

Therefore, the subgame perfect Nash equilibrium yields the set of links at equilibrium: $g^* = \{13, 23, 45\}$

Fig. 2 Example of endogenous network formation

among possible networks of links, instead of just myopically considering each link separately.

Let ij describe the binary link between households i and j. The network of household i, reflecting the combination of its binary links is represented by the vector:

$$X_i = \left(x\,(ij)\,|\,j \in N,\ j \neq i, d\,(i,\ j) \leq \overline{d}\right) \quad ; \ x\,(ij) \in \{0, 1\}\,. \tag{11}$$

The binary index $x(ij)$ reflects joint agreement to establish a link, $x(ij) = 1$, otherwise $x(ij) = 0$. Household i's set of all feasible networks is then $\Omega_i = \{X_i\,|x\,(ij) \in \{0, 1\}\}$. By way of illustration, consider an economy with $N = \{1, 2, 3, 4, 5\}$ and the endowment distribution $\lambda(A_0,\ S_0)$ illustrated in the left panel of Fig. 2. At $\alpha = 1$, $\overline{d} = 9$, for example, 3's network can be generally represented by $X_3 = (x\,(31)\,x\,(32)\,x\,(33))$ with $x\,(3k) \in \{0, 1\}$ for all $k = 1, 2, 4$. Clearly interaction between 3 and 5 is not feasible because $d\,(3, 5) > \overline{d} = 9$. Hypothetically, $X_3 = (1\ 0\ 0)$ represents 3's network that consists of only a link with 1. $X_3 = (1\ 1\ 1)$ arises when 3 establishes links with everyone with whom interaction is feasible, while $X_3 = (0\ 0\ 0)$ presents the case where household 3 has no links. $\Omega_3 = \{(0\ 0\ 0), (1\ 0\ 0), (0\ 1\ 0), (0\ 0\ 1), (1\ 1\ 0), (1\ 0\ 1), (0\ 1\ 1), (1\ 1\ 1)\}$ thus represents the set of all feasible networks.

We use the indirect utility $V_i^*\,(X_i)$ associated with the network choice X_i[20] to compare among household i's feasible networks. Strategic interactions among all households in the economy then involve households choosing their network of social links from the set of feasible ones using the resulting set of ranked networks, Ω_i^{Ranked} as their reaction function in an extensive form game of link formation, which we now describe.

[20]The time index $t = 0$ is dropped here. In the next section, however, the optimal network is denoted as X_{i0}^*.

3.3.2 Linking game with perfect information

We model link formation as a non-cooperative game. The mutual consent requirement poses a hurdle, however, to the use of any off-the-shelf solution technique, especially due to the multiplicity and stability of equilibria. Reviewing models of link formation, Jackson [42] concludes that the mutual consent requirement for link formation implies either some sort of coalitional equilibrium concept or an extensive form game with a specific protocol for proposing and accepting links in some sequence. As this paper aims not to study the nature of link formation per se, but rather to use a sensible equilibrium network concept to analyze how the resulting social networks mediate economic mobility, we opt for the latter approach and develop a reasonable extensive form game of network formation with perfect information that yields a unique SPNE network.

We model households interacting over multiple rounds of link proposing, accepting and rejecting, using Ω_i^{Ranked} as their best response function. This extensive form game involves an algorithm for proposing and accepting links that yields a sequential matching process.[21] As the game begins there are no pre-established links between any player households.[22] Households first consider their top-ranked network. They simultaneously propose a link to each of the other households with which they wish to link. The link between two households is established if and only if (1) both agents propose to each other, and (2) at least one of the two partners optimizes its network (i.e., has all of its proposals accepted). Once a household optimizes its network, its game is concluded. For any of its partners that do not likewise optimize their networks, these established links are binding. All households that do not optimize their networks in a proposal round move on to the next round, when they again simultaneously propose to each of those households still active in the game with whom they wish to link in their top-ranked still-feasible network (which must include any pre-existing link commitments from prior rounds with households that have concluded play). The same link formation rule is followed. The game then repeats itself if there remain households without optimized networks. The entire history of offers, acceptances and rejections is known to all.

If no household can optimize its network in a specific stage, and thus no binding link can be established, we assume that the poorest household (i.e., lowest A_{i0}) foregoes its top-ranked network and instead use its second-best network while the rest still play their top-ranked networks. If still no one can optimize, the second poorest household then sacrifices its first-best network, and so on. The process of sequential matching continues until everyone optimizes their networks following the protocol outlined above.

The perfect information assumption, finite number of households and the specific sequential matching process ensure that this process results in a unique SPNE set of established links in pure strategies [58]. Our specific protocols for sequential link proposing and accepting and for compromising the process (with respect to wealth)

[21] This specification is in the context of a matching game in the domain of a coalitional game, in which each household may be matched with many others. Our matching specification differs greatly from Gale and Shapley [37], which considers a two-sided one-to-one matching game. It also differs from marriage models and the roommates problem in which individuals can match with only one partner.

[22] S_0 reflects inherited links with an older generation while, X_i, captures links within one's own generation.

in the stage when no binding link can be established have automatically ruled out the possibility for any household to deviate from their equilibrium and achieve welfare improvement. We denote this unique SPNE set of established links by g. Household i's social network derived from this resulting set of link g can then be denoted $X_i(g)$. The payoff to each household i is then defined by the corresponding indirect utility $V_i^*\left(X_i\left(g\right)\right)$.

The right panel of Fig. 2 offers a numerical illustration of this algorithm and its SPNE for the five-player economy considered earlier. Note three interesting aspects of this game. First, even if proposals are matched, this does not guarantee the establishment of a link. Binding links are established only if (at least) one partner optimizes its network. This follows from the fact that households' preferences over individual links are governed by their preferences over their broader networks, as reflected in Ω_i^{Ranked}. Second, households' optimal networks in equilibrium are not necessarily their first-best ones, due to the interactive nature of the link formation process and the spillovers inherent to the process. This contrasts with the optimality conditions that would result from unilateral decisions over social network structure. Third, the game's SPNE network favors those households able and/or preferring to link with a small number of others.[23]

4 Analytical results

Due to the mutual consent requirement, household i's optimal network in the SPNE of the extensive form game just described constrains the optima for each household in the economy. At a SPNE set of link g, the equilibria of this model are characterized by every household's accumulation decisions, $\left\{X_{i0}^*\left(g\right), I_{i0}^*\left(X_{i0}^*\left(g\right)\right)\right\}_{i=1,\ldots,n}$, which determine their current and future technology choice, consumption, and thus household's well being. The complexity of the multi-agent social network formation process precludes generating formal analytical results. This section describes the expected household equilibria and patterns of economic mobility that result from this model. Section 5 then uses numerical simulations to illustrate these patterns with heterogeneous households and to explore variation in those patterns across different wealth distributions.

4.1 The possibilities presented by social networks and their limitations

We concentrate on the setting in which high-return production is always preferable to the lower return technology. Without the borrowing constraint, every household

[23]Formal examination of other properties of this extensive form game with large number of heterogeneous players is difficult and beyond our objectives. The simulation statistics in Appendix C use 100 randomly generated economies to explore simple properties of this endogenous network formation. Those for whom no links are feasible or who do not wish to establish any social links (i.e., socially isolated households) necessarily always get their first-best network. Thereafter, the proportion of households attaining their first-best network in equilibrium is declining monotonically in desired network size and non-monotonically in feasible network size. This merely reflects that more complex networks are harder to establish.

would gradually converge to this superior equilibrium. The assumptions of constrained autarkic savings and no borrowing in (7) generate multiple equilibria, one of which is the poverty trap associated with continued use of the low-return technology. The economic mobility of interest here is the movement of the initially poor into the high-level equilibrium associated with use of the high-return technology.

The non-convex technology set in (4) thus implies an asset threshold $\underline{A}(S_{it})$ such that, at any period t, those with $A_{it} \geq \underline{A}(S_{it})$ can optimally undertake high-return production. Assume those who choose the low return technology generate income that leaves them poor while those who choose the high-return technology earn income that renders them non-poor. Thus threshold $\underline{A}(S_{it})$ represents a static asset poverty line, which distinguishes the *current* poor from non-poor. In our model, the poor are, therefore, those households with $A_{it} < \underline{A}(S_{it})$, i.e., those currently undertaking low-return production.

For any optimal social network X_{i0}, household i's first-order conditions for an interior optimum of (7), resulting from equating the lifetime utility loss due to foregone present consumption with the discounted utility gain from investment in the next period technology, yields two equilibria of long-term well being[24]

$$C_{i1}^{*} = \begin{cases} C_{i1H}^{*} = Y_{i1}^{H}(A_{i0}, S_{i0}, X_{i0}) & \text{if } C_{i0H}^{*} \geq \overline{C} \text{ solves } u'\left(C_{i0H}^{*}\right) = \rho u'\left(C_{i1H}^{*}\right) f_{H}'(\cdot) \\ C_{i1L}^{*} = Y_{i1}^{L}(A_{i0}, S_{i0}, X_{i0}) & \text{if } C_{i0L}^{*} \quad\quad \text{ solves } u'\left(C_{i0L}^{*}\right) = \rho u'\left(C_{i1L}^{*}\right) f_{L}'(\cdot) \end{cases} \tag{12}$$

These distinguish extremely low lifetime utility associated with a poverty trap, for households that can only afford the low-return technology, $U_{iL}^{*} = U_{i}^{*}(C_{i0L}^{*}, C_{i1L}^{*})$, from the higher utility attained by the initially non-poor or households that eventually escape from poverty, $U_{iH}^{*} = U_{i}^{*}(C_{i0H}^{*}, C_{i1H}^{*})$.

According to (12), an initially poor household i (with $A_{i0} < \underline{A}(S_{i0})$) can gradually accumulate resources toward the high-level equilibrium, and thereby escape future (but not current) poverty, if it can save and establish a productive network X_{i0} such that

$$\begin{aligned} C_{i0H}^{*}(A_{i0}, S_{i0}, X_{i0}) = Y_{i0}^{L}(A_{i0}, S_{i0}) - X_{i0}, K_{i} \\ - \left(A_{i1H}^{*}(A_{i0}, S_{i0}, X_{i0}) - (1-\delta_{A}) A_{i0}\right) \geq \overline{C} \end{aligned} \tag{13}$$

where $A_{i1H}^{*}(A_{i0}, S_{i0}, X_{i0})$ represents the optimal capital necessary use the high-return technology in period 1.

In the absence of social network capital, the household's optimal welfare depends solely on its autarkic savings. (13) suggests the existence of a dynamic asset threshold A_{0}^{*} at which optimal household asset accumulation bifurcates, i.e., $C_{i0H}^{*}(A_{0}^{*}, S_{i0} = 0, X_{i0} = \underline{0}) = \overline{C}$. Those initially poor households with $A_{i0} > A_{0}^{*}$ save and escape poverty in the future (but not initially), while other poor with $A_{i0} < A_{0}^{*}$ are

[24] To ensure the existence of the equilibria, our assumptions in Appendix A assure that accumulation toward U_{iL}^{*} is at least feasible, i.e., for every household i, $C_{i0L}^{*} \geq \overline{C}$ and that the high-return equilibrium is always preferable for household able to afford autarkic savings, i.e., $U_{i}^{*}(C_{i0H}^{*}, C_{i1H}^{*}) > U_{i}^{*}(C_{i0L}^{*}, C_{i1L}^{*})$ if $C_{i0H}^{*} \geq \overline{C}$.

trapped in long-term poverty. This dynamic asset threshold is analogous to the dynamic asset poverty line proposed by Carter and Barrett [15]. In the absence of social network capital, a household's initial endowment of productive assets determines its long-term equilibrium well-being.[25]

More interestingly, household i's ability to establish and utilize network X_{i0} may affect the dynamic asset poverty line. Relation (13) implies three distinct avenues by which the initially poor can reach the high-level equilibrium. First, a poor household can undertake autarkic savings without social network capital. Second, an initially poor household can establish social links that generate enough social network capital to drive $\underline{A}(S_{i1})$ to the point that the high-return technology becomes optimal in the next period, without having to accumulate capital itself. Third, the household can invest in both social links to lower the asset threshold and private capital to let it attain this lowered threshold.

These latter two avenues indicate that the dynamic asset poverty threshold depends not only on household's initial endowments (A_{i0}, S_{i0}), but also on the poor's opportunity to establish a social network, X_{i0}, that could generate the social network capital necessary to graduate from poverty. Thus factors that determine the poor's ability to establish a productive social network, such as the broader wealth distribution in the economy and the maximum social distance over which links are feasible in a given society, also influence the initially poor's economic mobility. Unlike standard poverty traps models in which one's initial conditions determine one's growth prospects, when social interactions condition investment behavior, the initial conditions of the entire economy matter.

Among the initially poor households (whose $A_{i0} < \underline{A}(S_{i0})$), we can further identify initial asset positions for which social network capital complements or substitutes for productive assets in facilitating upward economic mobility. Because those endowed with $A_0^* \leq A_{i0} < \underline{A}(S_{i0})$ can escape from poverty even without inheriting or building social network capital, investment in X_{i0} is only optimal if it efficiently substitutes for productive asset accumulation, i.e., if establishing links is cheaper than capital investment for the household. For such households, social network capital reduces the savings required to reach the high-level equilibrium, making social network capital a substitute for traditional capital in facilitating productivity and welfare growth.

For initially poor households endowed with $A_{i0} < A_0^*$, however, social network capital is a complement to traditional capital accumulation, in that it is needed in order to lower the asset poverty threshold and thereby enable the household to escape from poverty in the future. With a dynamic asset threshold conditional on a given endowed network structure, $A_0^*(S_{i0}|X_{i0} = \underline{0})$ that satisfies $C_{i0H}^*(A_0^*(S_{i0}|X_{i0} = \underline{0}), S_{i0}, X_{i0} = \underline{0}) = \overline{C}$, we can further distinguish two distinct subpopulations among those for whom social network capital is a complement to traditional capital in mediating economic mobility. First, those with $A_0^*(S_{i0}|X_{i0} = \underline{0}) \leq A_{i0} < A_0^*$ are endowed with sufficient social network capital in period 0 that, even with depreciation rate δ_s, their extant social network capital, S_{i0}, is already sufficient to enable enough capital asset accumulation to reach the high-level equilibrium in period 1 without needing to

[25]Note that initially non-poor households (whose $A_{i0} > A_0^*$) can always achieve the high-return equilibrium. This rules out the possibility of downward mobility of the initially non-poor, as there is no uncertainty in the model.

establish a new social network X_{i0}. Second, households with $A_{i0} < A_0^*(S_{i0}|X_{i0} = \underline{0}) < A_0^*$ need to form new social links—i.e., invest in X_{i0}—to augment their initial social network capital endowment in order to complement asset accumulation necessary to escape future poverty. Their potential to escape poverty thus relies on the capacity and possibility to establish productive social network.

4.2 Patterns of social network-mediated economic mobility and immobility

So far we have treated households' optimal social networks as if they are exogenously given. Now we consider what happens as one inserts households into a broader economy in which the mutual consent requirement governs social network formation, yielding an optimal network structure, X_{i0}^*. Four distinct patterns of economic mobility and immobility emerge among the initially poor upon realization of their optimal network X_{i0}^*.

4.2.1 Households who escape from poverty without forming social networks

One subpopulation of the initially poor enjoy sufficient initial endowments, $A_{i0} > A_0^*(S_{i0}|X_{i0} = \underline{0})$, that they can accumulate resources autarkically, pulling themselves up to the high-level equilibrium in period 1 by their own bootstraps without investing in accumulating further social network capital. They can be characterized as

$$X_{i0}^* = \underline{0} \quad \text{and} \quad U_i^* = U_{iH}^*\left(X_{i0}^* = \underline{0}\right). \tag{14}$$

Among this group, some households never consider establishing a new network, as all of their possible networks would yield non-positive net intertemporal utility gain, i.e., $U_{iH}^*(\overleftarrow{X}_{i0}) < U_{iH}^*(X_{i0} = \underline{0}), \forall \overleftarrow{X}_{i0} \in \Omega_{i0}$. Other households may be regrettably autarkic in their climb out of poverty, having failed to establish any preferred network, $\overrightarrow{X}_{i0} \in \Omega_{i0}$ such that $U_{iH}^*(\overrightarrow{X}_{i0}) > U_{iH}^*(X_{i0} = \underline{0})$. This latter subgroup's first-best arrangement proves socially infeasible, leaving them worse off than they might have been under a different equilibrium social network configuration, but still able to exit poverty in time.

4.2.2 Households who form social networks and thereby escape from poverty

A second subpopulation of the initially poor successfully establishes networks with others, utilizing their accumulated productive social network capital so as to graduate from poverty. Their optimality condition can be characterized as

$$X_{i0}^* \neq \underline{0} \quad \text{and} \quad U_i^* = U_{iH}^*\left(X_{i0}^*\right). \tag{15}$$

This group's socially mediated climb out of poverty excites the imagination of the most ardent fans of social capital as an instrument for poverty reduction. Among this group, there are likewise two distinct subgroups. Those initially poor households with $A_{i0} > A_0^*(S_{i0}|X_{i0} = \underline{0})$ find it cheaper to use social network in mediating economic mobility, but they can escape the poverty trap regardless. Social capital improves their welfare but it does not fundamentally alter the qualitative path they follow over time.

By contrast, the crucial subpopulation is those with $A_{i0} < A_0^*(S_{i0}|X_{i0} = \underline{0})$. Their escape from poverty will not be possible if they cannot build a productive social network. Their initial endowment of both assets and social network capital is insufficient for them to climb out of poverty in time unless they can find other households willing to link with them. The underlying wealth distribution, which determines the feasibility of social interactions and the net benefits of social network formation, generates sufficient social proximity that others are willing to link with them in the equilibrium social network.

4.2.3 Households involuntarily excluded from social networks and trapped in poverty

Others are less fortunate. Another subpopulation of the initially poor could escape from poverty if they established one of their preferred social networks. However, they are rebuffed by those to whom they propose links and, as a result, they cannot accumulate enough traditional capital to climb out of poverty. Involuntary social exclusion thus conspires with meager initial asset endowments to trap these households in long-term poverty. Although there exists at least one network $\widetilde{X}_{i0} \in \Omega_{i0}$ such that $C^*_{i0H}(\widetilde{X}_{i0}) > \overline{C}$, no such network arises in equilibrium. Thus they resort to $X^*_{i0} = \underline{0}$, although this is not their preferred network. Their optimality condition is represented by

$$X^*_{i0} = \underline{0},\ U^*_i = U^*_{iL}\left(X^*_{i0} = \underline{0}\right) \quad \text{and} \quad \exists \widetilde{X}_{i0} \in \Omega_{i0} \quad \text{with} \quad C^*_{i0H}\left(\widetilde{X}_{i0}\right) > \overline{C}. \tag{16}$$

This constrained optimum best illustrates how social networks can fail the poor because of the mutual consent condition that underpins the formation of social links.

4.2.4 Households who choose social isolation and remain trapped in poverty

The final subpopulation comprises those with especially meager endowments, $A_{i0} < A_0^*(S_{i0}|X_{i0} = \underline{0})$, who have no possibility to escape poverty no matter the social networks they create. None of their feasible networks, $X_{i0} \in \Omega_{i0}$, would generate sufficient social network capital to complement traditional capital accumulation in fostering upward economic mobility. Since links are costly to establish and only yield welfare gains if one employs the high-return technology they will never optimally choose, this subpopulation does not value social network capital and therefore does not establish any links in equilibrium. Their optimality condition can be characterized as

$$X^*_{i0} = \underline{0}\,,\ U^*_i = U^*_{iL}\left(X^*_{i0} = \underline{0}\right) \quad \text{and} \quad C^*_{i0H}\left(\check{X}_{i0}\right) < \overline{C}\ \forall \check{X}_{i0} \in \Omega_{i0}. \tag{17}$$

Since $X^*_{i0} = \underline{0}$ is their top-ranked network choice in Ω^{Ranked}_{i0}, they self-select out of social networks, rejecting any proposals made to them by others in the economy. The result is socially isolated, long-term poverty.

These household equilibria and distinct mobility patterns are a product of the underlying distribution of endowments in society, which governs opportunities and limits to social network formation. Appendix A describes key specifications of the stylized model we use in the simulations along with its comparative statics.[26]

5 Numerical simulations of households' equilibria and patterns of economic mobility

We now simulate households' long-run equilibria for randomly generated economies. The numerical simulation assumes 17 heterogeneous households,[27] each endowed with randomly generated (A_0, S_0), cumulatively representing the economy's endowment distribution, $\lambda(A_0, S_0)$. We stylize our generalized model with (1) non-convex Cobb Douglas production functions, where high-return technology is always preferable to the low-return one if agents could borrow, which they cannot in our model, and (2) a linear utility function, which maximizes households' willingness to sacrifice current consumption for future investment.[28] Our goal is to illustrate the distinct roles of social network capital in fostering or impeding the economic mobility of the initially poor.

5.1 Role of social network in households' economic mobility and escape from poverty

One core result is that mobility and immobility and the potential for social network capital to mediate economic growth vary with the initial structure of the economy. Two otherwise identical households, dropped into two quite different economies, can follow markedly different patterns. Economic mobility is thus, at least in part, socially constructed. To illustrate this, we first explore varying equilibria and patterns of mobility of identical households placed in economies with various wealth distributions, $\lambda(A_0, S_0)$, simulated from various statistical distributions (e.g., uniform, truncated bivariate normal, bi-modal, etc.) with $A_0 \in [0, 20]$ and $S_0 \in [0, 10]$.

Figures 3, 4, 5, 6 and 7 depict some key interesting patterns found in the larger set of our randomly generated economies. Households are represented by initial endowment positions plotted on the (A_0, S_0) plane. Their long-run equilibria (either high- or low-level) are represented by the shapes in the plots. A dot represents a

[26] With endogenous network formation, results of the comparative statics (with respect to endowments, production technology and preferences) for the initially poor household with $A_{i0} < A_0^*(S_{i0}|X_{i0} = \underline{0})$—whose escape from poverty is only possible if they successfully form new productive social network in the economy—tend to be ambiguous (and sometime counterintuitive). For example, increases in endowments will not always foster escape from poverty unless the endowment increase allows them to grow out of poverty regardless of new social network formation. Generally, improvement in the value of social links and/or feasibility of social interaction yield ambiguous effects on household's potential to use social network to escape poverty, though at best, the former could reduce incidence of social isolation.

[27] This arbitrary number was chosen for computational and presentational reasons, to generate a big enough population to demonstrate the complex interlinkages, but small enough to display visually and to remain tractable in solving the complex matching and optimization problem.

[28] Appendix B reports the details of parameterization of our stylized model. Appendix C discusses detailed statistics of endogenous network formation and sensitivity analysis resulted from exploring the impact of deviations from the baseline parameterization in 100 randomly generated economies.

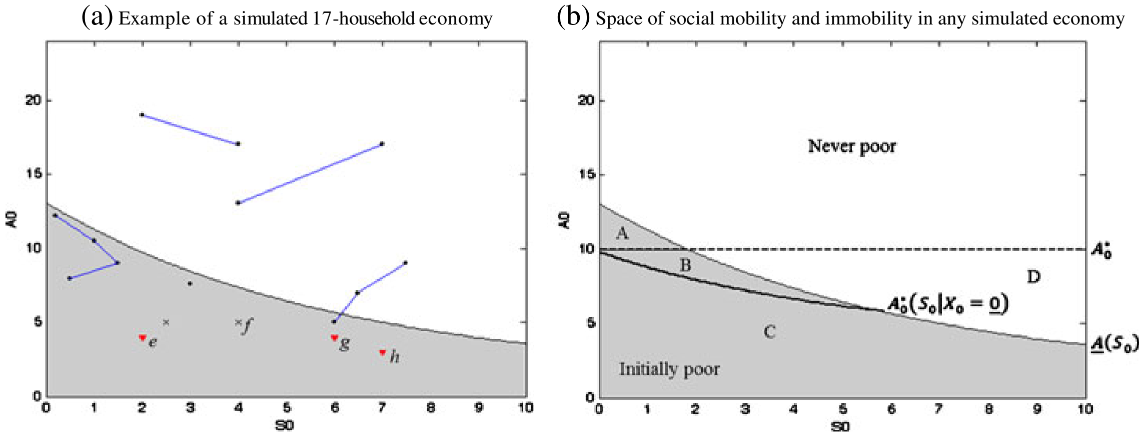


Fig. 3 Basic simulation results

household that enjoys the high-level long-term well-being in period 1, a triangle represents a socially isolated household, and an "x" represents a socially excluded one. The equilibrium bilateral links are represented by lines connecting two households. In each figure, a downward sloping curve reflects the static asset poverty threshold $\underline{A}(S_0)$. All those to the southwest of that line (shaded in blue) initially (in period 0) choose the low-productivity technology. We focus our discussion on this subpopulation, on the economic mobility of the initially poor.

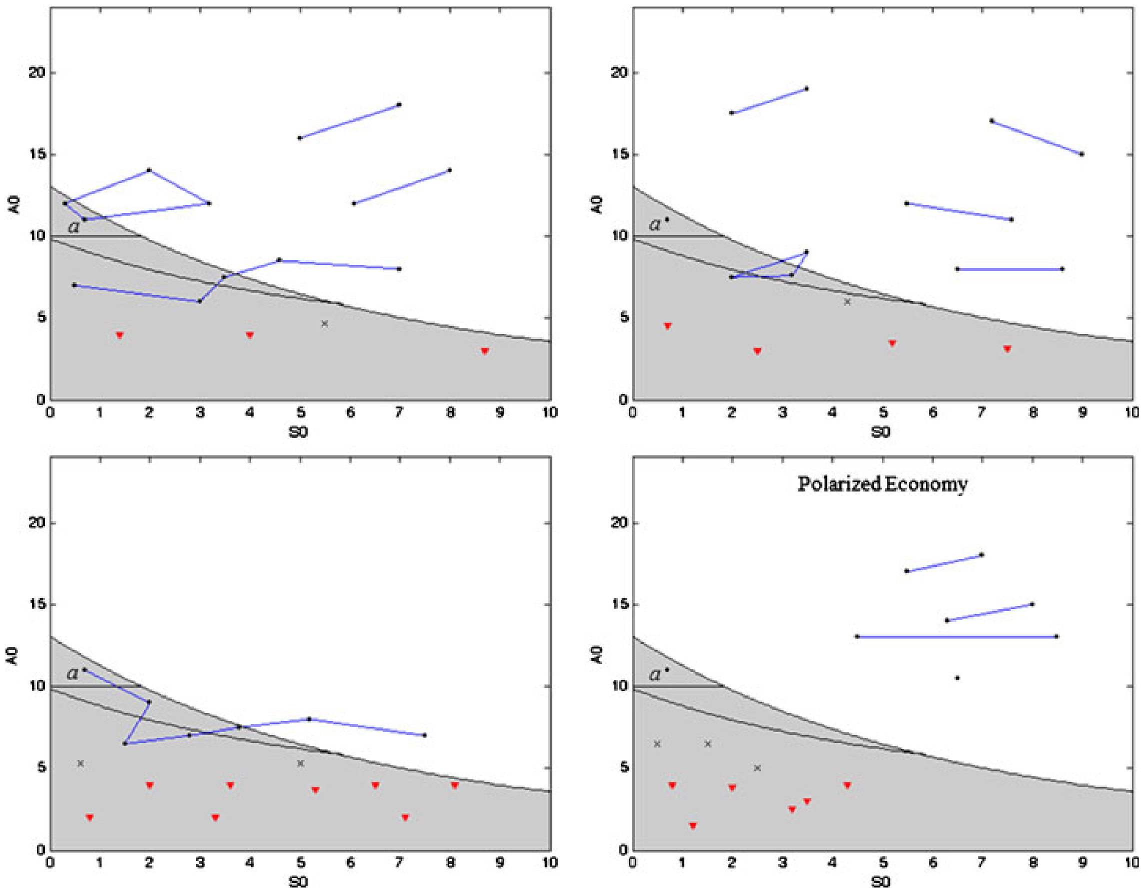


Fig. 4 Different patterns for an autarkically mobile household

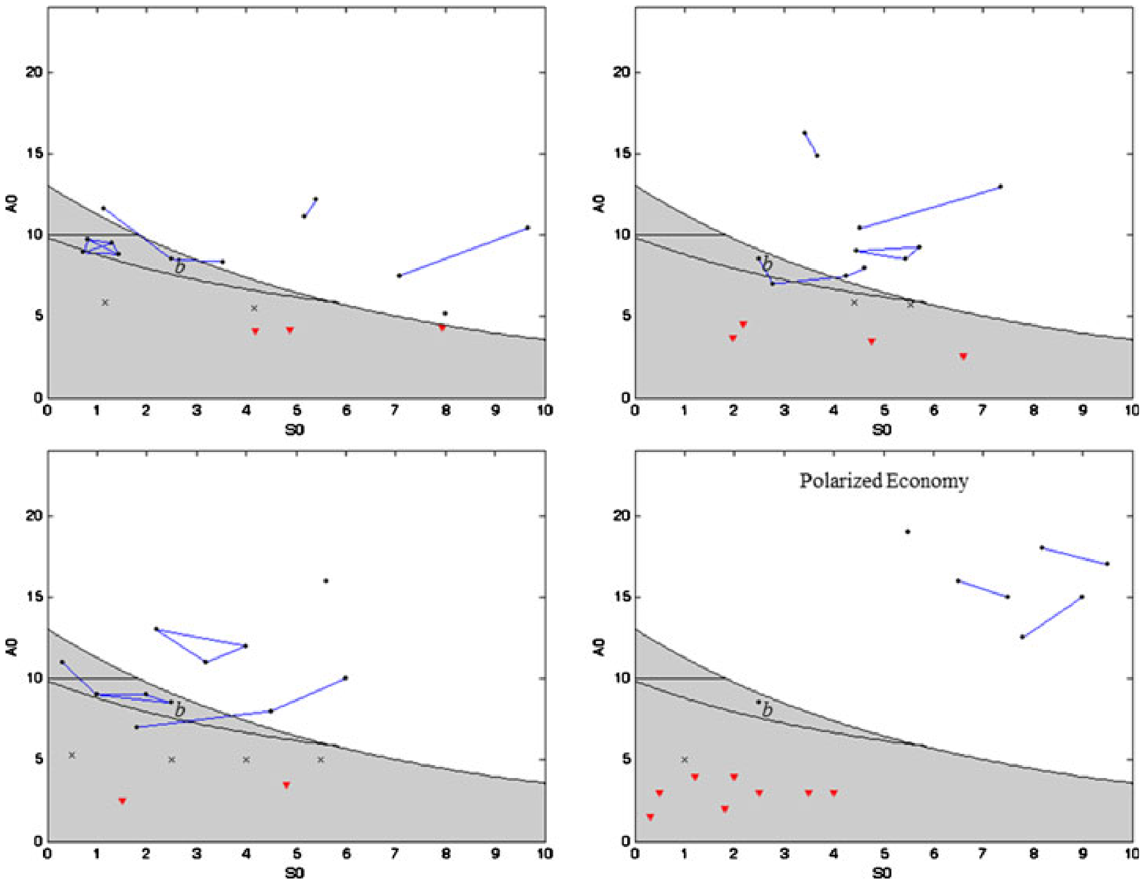


Fig. 5 Different patterns for a household autarkically mobile given its S_0

Figure 3a provides a simple illustration of the distinct patterns that emerge from the baseline model. The initially poor who escape from poverty without forming new social networks are represented by the household with initial endowment $(A_0, S_0) =$ (7,3). Those who form social networks and escape poverty fall into two sub-groups. Some climb out of poverty through solidarity among the initially poor (the cluster of the four households with the lowest S_0 endowments), while others successfully link to the initially non-poor (the household initially endowed with (5,6)). Then there are those who remain trapped in poverty, either due to social exclusion (the two households marked "x") or to self-imposed social isolation (the three households marked with triangle).

Though these households' (im) mobility results may vary with model parameterization, the qualitative patterns associated with these distinct outcomes are quite robust. Figure 3b then abstracts from the specific households and their links to map the space of these different mobility and immobility patterns. The horizontal line at the dynamic asset threshold A_0^* represents the dynamic asset poverty line in the absence of social network capital, as in Carter and Barrett [15]. Those households in area A have a large enough endowment of productive assets, A_0, to save in the first period and thereby accumulate sufficient traditional capital to reach the high-level equilibrium without recourse to social network capital. Some households in region A might nonetheless establish social links as a more cost effective substitute for savings and traditional capital accumulation. But households in region A are all independently economically mobile.

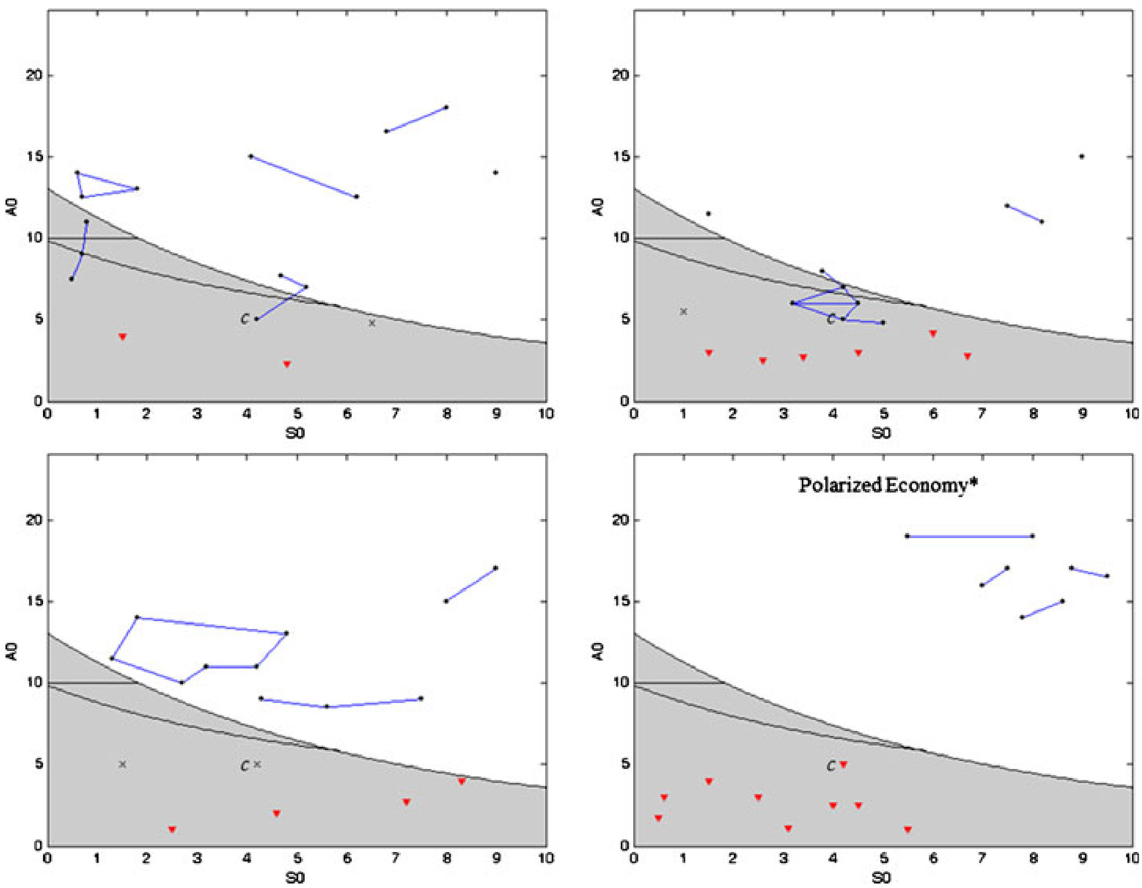


Fig. 6 Different patterns for a household whose mobility depends on social links

Those households beneath the dynamic asset threshold A_0^* all require social network capital to complement existing capital in order to exit poverty. They can be divided into three distinct groups. Those in area D, whose initial endowments place them above the static asset poverty line with social network capital, $\underline{A}(S_0)$, are initially non-poor because of their social network capital endowment in spite of their otherwise-insufficient endowment of traditional capital. Not only do they enjoy the high-level equilibrium in period 1, but they are able to reach the high-level equilibrium in period 0, unlike those with somewhat greater traditional capital but lesser social network capital endowments.

The dynamic asset threshold $A_0^*(S_0|X_0 = \underline{0})$ distinguishes among the final two groups. Those in area B are endowed with sufficient social network capital to complement productive asset accumulation and escape from poverty, even without forming new social links. While social network capital is necessary for their economic mobility, their initial endowment suffices to shelter them from depending on others' willingness to establish new links with them. By contrast, others (in area C) can only make it out of poverty if they successfully establish new social links and thereby augment their initial social network capital endowment as a complement to traditional capital accumulation. This group's economic mobility thus depends fundamentally on the underlying structure of the economy, in particular on their social distance from others and the feasible distance over which links can form within the economy. This mapping of endowment space thus underscores the multiple roles social network capital can play in conditioning household economic growth paths,

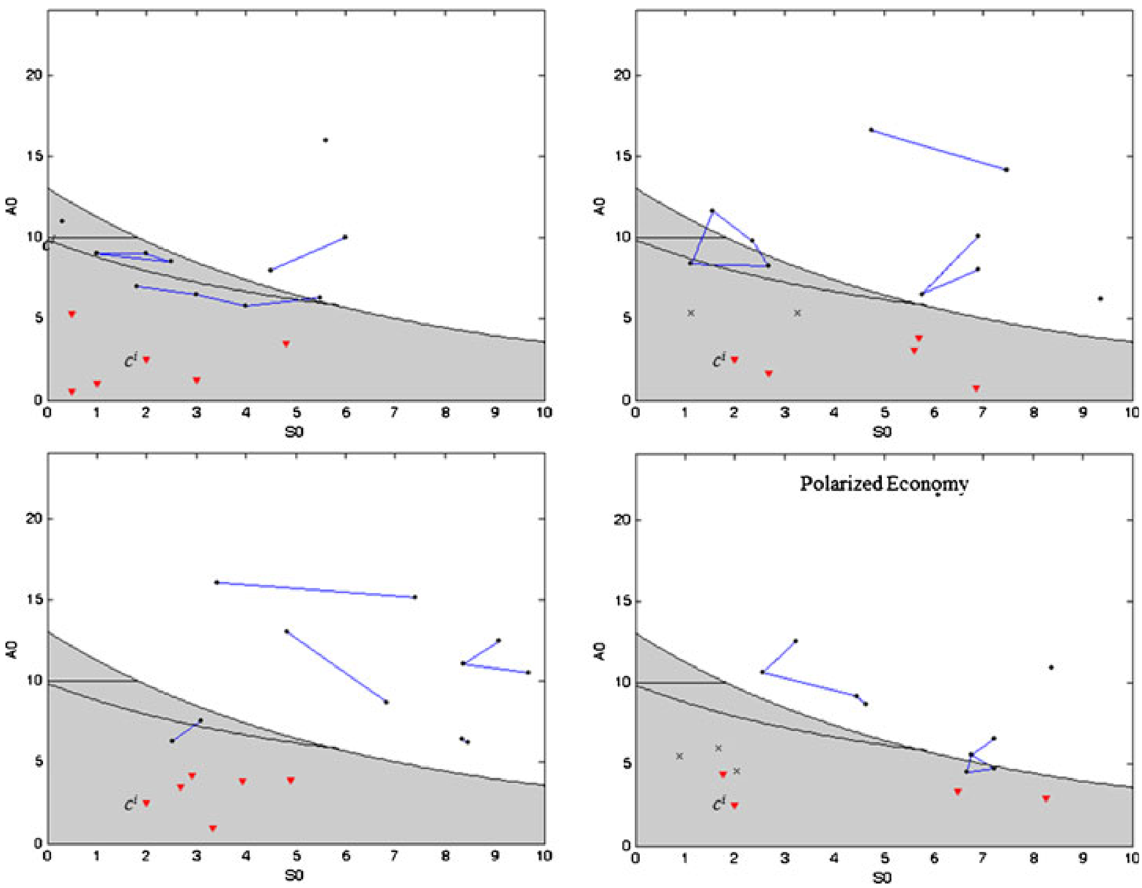


Fig. 7 Different patterns for a destitute, economically immobile household

either serving as a substitute for or a complement to traditional productive assets, enabling immediate or delayed exit from poverty, and ensuring independent, albeit social network-mediated mobility, or requiring the establishment of new social links non-cooperatively.

Figures 4, 5, 6 and 7 illustrate the impact of the initial socio-economic structure of the economy on the mobility of the initially poor. Each figure focuses on a distinct type of initially poor household—from group A, B or C in Fig. 3b—and displays four panels that differ solely by the initial distribution of households in the economy. The southeastern panels show the case of a highly polarized economy,[29] underscoring the impact of socio-economic polarization on the economic mobility of the poor [47].

Figures 4 and 5 depict the initially poor who are autarkically mobile, in the former case irrespective of social network capital, and in the case of Fig. 5, thanks to their initial endowment of social network capital. Neither household *a* in Fig. 4 nor household *b* in Fig. 5 need to establish social links in order to climb out of poverty from period 0 to period 1. Their ability to reach the high-level equilibrium is thus not

[29]Two-dimension polarization equals $P = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} d(i,j)\lambda(A_{i0},S_{i0})\lambda(A_{j0},S_{j0})dA_{i0}dS_{i0}$ $dA_{j0}dS_{j0}$, as proposed by Mogues and Carter [47] and modified from Esteban and Ray [30] and Duclos et al. [25]. In the case where $\lambda(\cdot)$ belongs to the family of additive normal distributions, Mogues and Carter [47] show that P increases (1) with the shrinking of the middle class, (2) as population becomes increasingly concentrated around discrete poles, (3) as the poles become further apart and (4) as the correlation between economic and social characteristics increases.

affected by structure of economy. But their choice as to whether or not to form new links with others varies with the underlying structure of the economy in which they find themselves. In the (southeastern) case of the polarized economy, neither has any incentive to invest in links with others and thus climbs out of poverty without any new social relationships. In the southwestern case in each Figure, they choose to link with other initially poor households only, while in the northwestern case in each Figure they choose to link also with initially non-poor households. Their social arrangements are the byproduct of the underlying endowment distribution in the economy even though they in no sense depend on further social relations to reach the high-level equilibrium. This has an important implication for empirical studies. The presence in a sample of independently economically mobile households who may or may not find it optimal to build social networks can generate considerable cross-sample differences in the correlation between household-level economic mobility and social network density.

Figure 6 illustrates perhaps the most interesting case. Here we see how the underlying structure of the economy conditions economic mobility for the initially poor (such as household *c*) who fall into what Fig. 3b labeled area C. In the northwestern panel, a link with a socially proximate household that is initially non-poor enables socially mediated exit from poverty. In the northeastern panel, economic mobility is achieved through multiple links with other, similarly initially poor households in area C. In the lower two panels of Fig. 6, however, household *c* gets trapped in poverty. In the southwestern case, there are socially proximate households with which it would like to link, but it is rebuffed in its proposal to form a network. The result is social exclusion in equilibrium. In the polarized economy case, there is no socially proximate household with whom a connection would be beneficial, so the household prefers no links and thus settles into a socially isolated low-level equilibrium. The subpopulation represented by C in Fig. 6 is thus the group for whom social networks and the underlying structure of society fundamentally shape economic mobility (or immobility).

Finally, as shown in Fig. 7, some households are so destitute initially that they almost never find social relations sufficiently beneficial to enable a climb out of poverty. They are thus socially isolated in almost all configurations of the economy. The key thing to note about social isolation is that, at least under the parameterization we employ, it depends primarily on a household's initial endowment of traditional, productive capital. Those who begin too poor simply cannot leverage their meager endowments no matter how skillfully they interconnect themselves with others.[30]

5.2 Network endogeneity, socio-economic structure and socially mediated growth

A key implication from the simulations just discussed is that the wealth distribution in the economy is a key determinant of households' capacity to enjoy socially

[30]This is highlighted in Appendix C which plots the results from 100 randomly generated economies. There emerges a clear asset threshold below which individuals lose any incentive to establish social networks with others. Social exclusion and socially mediated climbs out of poverty are, however, generally quite difficult to predict due to the fact that those patterns depend so heavily on the underlying structure of the economy.

mediated growth. We now briefly explore further how wealth distributions affect the economic mobility patterns of initial poor households in the presence of social network endogeneity.

Table 1 reports the number of equilibrium links formed in the economy and patterns of economic mobility of the initial poor in economies with varied socio-economic structures, as represented by different dispersion and polarization relative to the base case characterized by a truncated bivariate normal distribution. Results for each distribution are based on 100 17-household economies simulated from the indicated distribution.[31] Appendix B describes the specifications of these distributions in detail.

The results clearly indicate that, in this model, increasing dispersion in the wealth distribution increases social distance among households, which decreases the feasibility of social interaction and increases the costs of social links. Holding mean assets constant, cases 2 and 3 in Table 1 show that economies with greater wealth dispersion tend to exhibit fewer social links in equilibrium, both overall and among the initially poor. As a result, fewer of the initially poor enjoy socially mediated growth and so a higher proportion of them remain trapped in poverty. A 50% increase in the dispersion of A_0 leads to a 18% decrease in the expected number of links formed in the economy, and a reduction (from 39% to 18%) in the proportion of the initially poor who escape poverty using a social network and an increase (from 34% to 53%) in the proportion of those trapped in poverty due to social isolation.

The bivariate normal distribution in the base case allows us to explore further how varying degrees of socio-economic polarization (P)—e.g., with larger correlations (ρ) in socio-economic wealth (A_0, S_0) while preserving marginal distributions of wealth—affect households' economic mobility. Cases 4 and 5 show that in economies with a higher degree of socio-economic polarization (e.g., with $\rho = 0.6$ relative to $\rho = 0$ in the base case 1), far fewer links are formed in the economy, especially by the initially poor, which results in sharply lower proportion of the initially poor who achieve socially mediated growth and a far greater proportion trapped in poverty due to social isolation. Increasing the correlation between physical and social assets implies a higher cost of and less benefit from investing in productive links. This naturally induces reduced connectivity.

There may, however, be cases where polarization can prove beneficial for socially mediated growth. While varying ρ in these bivariate normal distributions captures one type of increasing socio-economic polarization that is independent of one-dimensional economic and social asset polarization, it may not fully capture the sort of multi-modal polarization that characterizes some economies (e.g., South Africa, Brazil). Using the numerical method of Mogues and Carter [47], we construct bi-modal distributions holding constant the marginal wealth distributions, where for $x = A_0, S_0$, the marginal distribution $h(x)$ is first partitioned numerically into $h^{lo}(x)$ and $h^{hi}(x) = h(x) - h^{lo}(x)$ with $E_x^{hi} > E_x^{lo}$. This then allows us to reconstruct the two-dimensional bi-modal distribution, each mode or group of which—$k =$ high

[31] Note that these results do not turn on the asymmetric structure of the cost–benefit ratio of social links proposed in (9) and (10). Some simple symmetric structures, e.g., $K_i(j) = k(d(i, j))$ and $B_i(j) = b(A_{i0} + A_{j0}, |A_{i0} - A_{j0}|)$, yield similar results to those in Table 1. The key implication is that relatively rich households are less inclined to link with poorer households regardless of such asymmetry.

Table 1 Socio-economic distributions and patterns of socially mediated growth

	Number of links formed in the economy	Number of links formed by the initially poor	% of initially poor households: Economically mobile via social networks (%)	Trapped in poverty: social exclusion (%)	Trapped in poverty: social isolation (%)
Socio-economic wealth distributions					
(1) Base case: ($P = 8.6$) BVN ($\mu_A, \mu_S, \sigma_A, \sigma_S, \rho$) = (10, 5, 4, 2, 0)	8.2	4.8	39	20	34
Varying dispersion holding mean assets constant					
(2) BVN: $\sigma_A = 5$	6.9	3.4	24	22	46
(3) BVN: $\sigma_A = 6$	5.7	2.5	18	21	53
Varying degrees of polarization holding marginal distributions constant					
(4) BVN: $\rho = 0.3$ ($P = 9.0$)	7.1	2.8	21	18	57
(5) BVN: $\rho = 0.6$ ($P = 10.5$)	5.4	1.6	13	17	66
(6) Bimodal: ($P = 15.8$) Disperse the poor, concentrate the non-poor	7.6	4.6	36	17	39
(7) Bimodal: ($P = 16.1$) Concentrate the poor, disperse the non-poor	3.7	0.2	6	13	80

The degree of polarization $P = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} d(i, j)\, \lambda (A_{i0}, S_{i0})\, \lambda \left(A_{j0}, S_{j0}\right) dA_{i0} dS_{i0} dA_{j0} dS_{j0}$. Results are based on 100 randomly generated 17-household economies based on respective distributions wealth (*hi*) or low wealth (*lo*)—can then be characterized by the joint density of $h^k(A_0)h^k(S_0)$ The resulting bimodal distribution can therefore be characterized by two density groups: the low wealth group with $h^{lo}(x) \sim (E_x^{lo}, \sigma_x^{lo})$ and the high wealth group with $h^{hi}(x) \sim (E_x^{hi}, \sigma_x^{hi})$ for $x = A_0,\ S_0$. Appendix B describes this in more detail. This method allows us to explore the implications of two seemingly different polarized wealth distributions while preserving the marginal wealth distributions of the base case for purposes of comparison. The bi-modal distribution in case 6 can be characterized by a dispersed poor group with $[h^{lo}(A_0) \sim (6, 3), h^{lo}(S_0) \sim (3, 2)]$ and a concentrated group of higher wealth agents with $[h^{hi}(A_0) \sim (14, 2), h^{hi}(S_0) \sim (7, 1)]$. In contrast, in case 7 we concentrate the poorest group with very low mean wealth $[h^{lo}(A_0) \sim (4, 2), h^{lo}(S_0) \sim (2, 1)]$ and increase the within-group dispersion of the higher wealth group $[h^{hi}(A_0) \sim (13, 3), h^{hi}(S_0) \sim (6, 2)]$.

As illustrated by case 6 in Table 1, despite the greater degree of polarization ($P = 15.8$) relative to the base case ($P = 8.6$)—and even relative to the other cases (e.g., $P = 10.5$)—the poor in the bi-modal polarized economy can form solidarity links that foster their economic mobility if there is sufficient heterogeneity among the initially poor. Although the initially poor tend not to establish social links with the non poor in such a polarized economy, they can band together, forming essentially the same number of links within the initially poor sub-population, and achieving effectively the same rate of upward mobility through productive social networks, as in the non-polarized base case. By contrast, the lowest rate of link formation and the highest rate of social isolation arises when the poor are homogeneous, with assets are too meager to help each other out, as in case 7. Concentrating the poor does not help build solidarity networks if there is not a reasonable subpopulation of the initially poor with sufficient assets to make investment attractive.

Endogenous social networks also condition the effects of changes in household assets, technological productivity and conditions for network formation on patterns of households' economic mobility. In particular, for those who depend on social links for economic mobility, the comparative statics can be counterintuitive when what seem like advances happen to isolate an initially poor agent. For example, an increase in a household's asset (or in the productivity of the low-return technology used by the initially poor) may decrease economic mobility for some by degrading their prospects for making essential social links. Conversely, increasing the asset holdings or technological productivity for some agents can also foster the economic mobility of others by sparking new, productive social links between households. We now briefly explore this possibility.

6 Crowding-in possibilities created by endogenous social networks

The endogeneity of social networks can quite fundamentally affect prospective interventions by governmental or non-governmental agencies. We illustrate this with reference to one specific problem of particular relevance to poverty reduction programs: transfers to the poor. Under the maintained (implicit) hypothesis that agents' social networks are exogenously fixed, Cox et al. [21], among others, argue that public transfers can crowd out private transfers because the altruistic or insurance motivation for a transfer is diminished by public support. Attempts to aid the poor could thus be thwarted by induced private responses to public interventions. If, however, households' networks of social relationships form endogenously, then transfers can change network configuration. Indeed, if social networks are endogenous, well-targeted public transfers may have the opposite effect to that posited in the existing literature. Transfers can crowd in private support by reducing the social distance between individuals and thereby encouraging the creation of new social links, enabling recipients to access newfound social network capital and to escape from poverty. Such crowding-in effects depend, however, on the structure of the underlying economy, reinforcing a core point of the preceding section.

We illustrate this crowding-in possibility by repeating the previous simulations, but now adding targeted transfers to specific households. We first use Fig. 3a as our base case without transfers, considering four specific households—*e*, *f*, *g* and *h*—in region C identified in Fig. 3b. The upper two rows of Fig. 8 then illustrate the possible crowding-in effects for four distinct cases of transfers to these four households using exactly the same initial endowments as in economy 3a. The bottom row of Fig. 8 presents two different cases of transfers to every poor household in a polarized economy (previously depicted without transfers in the southeastern quadrant of Fig. 6).

The upper left example in Fig. 8 shows the case of a household (*e*) that was previously too poorly endowed with capital to make costly formation of social networks attractive. In the absence of a transfer, it therefore chooses social isolation and persistent poverty. But with the benefit of a modest transfer,[32] and given the social proximity of other households, this transfer encourages *e* to link to others, enabling it to leverage social network capital to escape poverty. Moreover, the induced re-formation of social networks also permits two other households to escape from poverty. These households were socially excluded in the no-transfer economy but now are able to band together, using newly created social network capital to access the high-level equilibrium in period 1. The central left graphic in Fig. 8 shows a qualitatively similar result, this time with a 20% smaller transfer (0.8 units of A) because the recipient (household *g*) is more proximate to other households than household *e* was, ex ante. It therefore requires less of a transfer to induce the creation of new social links, and thus an expansion of social network capital that not only lifts the transfer recipient out of poverty, but also two other households that would otherwise remain persistently poor. Targeting plainly matters, as we emphasize below.

The upper right example in Fig. 8 shows a similar effect, in this case through a one unit transfer to household *f*, which was socially excluded in the no-transfer setting but now links to three other households. One of those was already able to climb out of poverty through autarkic savings. Another was, like *f*, socially excluded but can leverage its new social link to accumulate enough social network capital to climb out of poverty. The third expands its pre-existing social network. Lest it seem that transfers have an automatic beneficial effect in inducing the creation of new social network capital, the right central graphic in Fig. 8 illustrates how even relatively large transfers—1.5 units of A to household *h*—can fail to generate poverty reduction gains when they are poorly targeted. Although the transfer brings household *h* right

[32] This transfer is just one unit of A, worth one-quarter of the poor recipient household's initial capital stock and just 0.6% of the wealth of this 17-person economy.

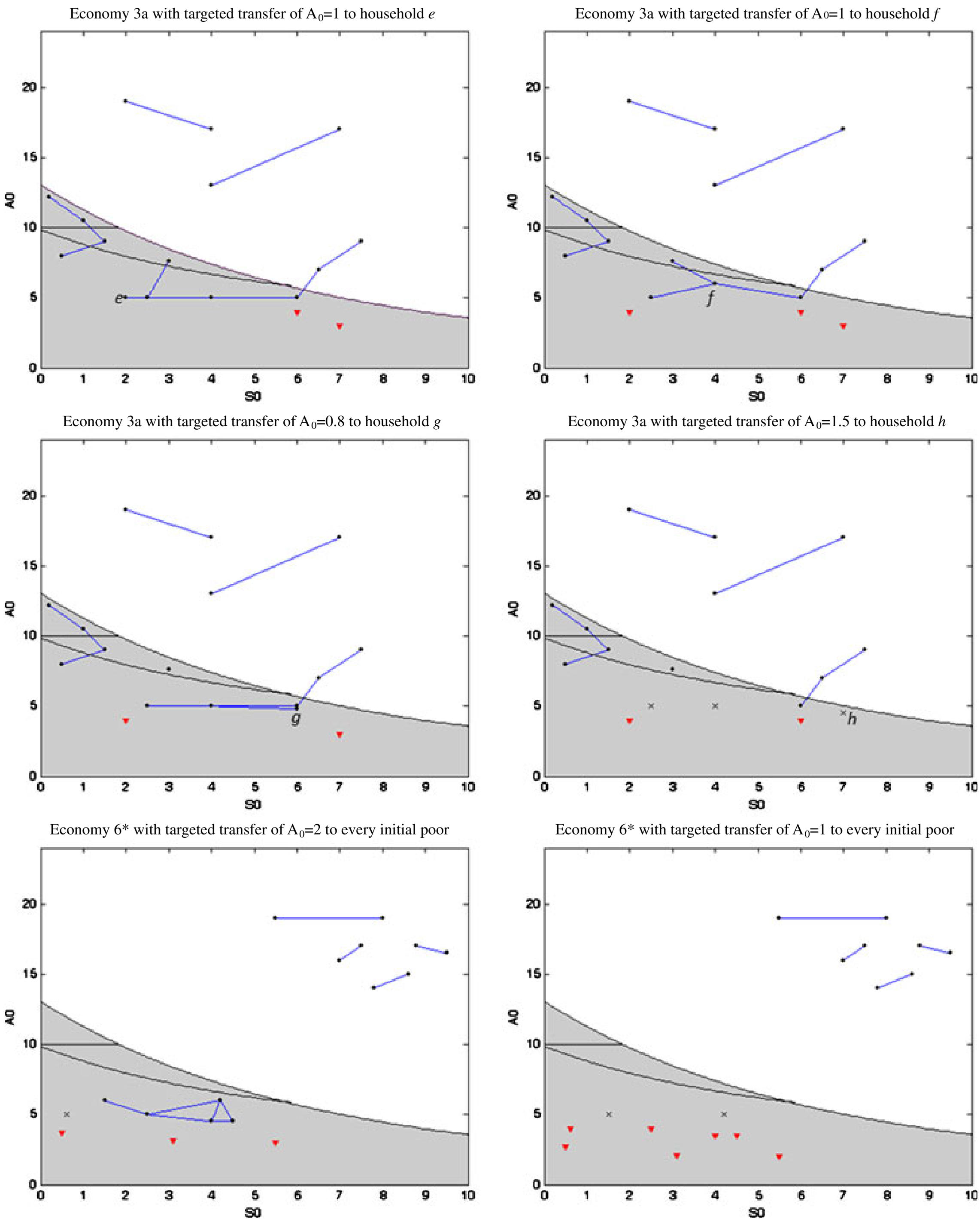


Fig. 8 Targeted transfers and "crowding in" effects

to the threshold of autarkic escape from poverty, makes social linkages attractive to it and clearly leaves it better off than it would have been without the transfer, *h*'s relative social distance from other households leave it socially excluded and persistently poor even in the wake of a relatively large transfer.

Transfers do not have to induce the creation of social links with those who are already able to climb out of poverty in order to generate crowding-in effects. As already discussed, even in a highly polarized economy, transfers to multiple poor households can stimulate the emergence of a solidarity network among the poor that enables several of them to escape poverty. This effect is shown in the lower left portion of Fig. 8, which simulates the transfer of two units of A to each ex-ante poor household. This transfer is clearly welfare-improving for all, but only facilitates an exit from poverty for some, the five households who establish a solidarity network from which they optimally exclude one other poor beneficiary household and which three other poor beneficiaries do not wish to join, preferring social isolation to costly linkage to the new network.

However, the induced social network capital creation effect that stimulates economic mobility for some ex-ante poor households is by no means automatic. Too meager a transfer can improve recipients' welfare but fail to generate the bigger gains associated with a leap to the high-level equilibrium, as illustrated in the lower right graphic in Fig. 8, which shows the result of transfers to all poor households of just one unit of A. Collectively, these examples underscore how important core targeting questions—who? how much?—are to the poverty reduction effects of transfer programs and how endogenous social network formation fundamentally affects the efficacy of such programs. Well-targeted transfers can lift even non-recipients out of long-term poverty, while poorly targeted transfers can fail to facilitate economic mobility even for recipients.

7 Conclusions

Social network capital can be an important facilitator of mobility to escape persistent poverty. But costly social networking is no panacea. Not all households find it worthwhile to link to others and some will be rebuffed in their efforts to build a network. Moreover, the usefulness of social networks depends fundamentally on the underlying structure of the economy in which agents reside. In some settings, well-targeted public transfers to selected poor households can catalyze the creation of new social network capital, thereby multiplying the poverty reduction effects of interventions.

We illustrate these points by developing a highly stylized model of heterogeneous households that make consumption, investment and social networking decisions in a dynamic, interlinked setting. Depending on their initial endowment positions, social network capital substitutes for productive assets for some, while for others it complements their productive assets in facilitating productivity growth and economic mobility.

One fundamental point that emerges from this exercise is that the exclusionary mechanisms necessary for people to be trapped in poverty may arise endogenously due to the inherent costliness of establishing and maintaining social links. In our setting, with multiple technologies that create locally increasing returns to productive capital but no credit market to permit individuals to borrow the capital necessary to exit poverty in time, costless access to social network capital would provide an alternate pathway out of poverty, a socially mediated solution to a market failure. When establishing social links is costly, however, some households may opt out of networks, choosing social isolation and persistent poverty. When the net benefits of social links are asymmetric, other households may desire social links that would help them climb out of poverty, but are rebuffed by prospective links and thus left in a state of social exclusion and persistent poverty.

These exclusionary mechanisms are economy-specific, depending fundamentally on the underlying socio-economic conditions that determine feasibility of social interaction and the net benefits to agents of social links. As a result, four distinct mobility and immobility patterns may co-exist among the initially poor: (1) exit from poverty through autarkic saving, (2) socially mediated exit from poverty, (3) a poverty trap due to social exclusion, and (4) a poverty trap associated with self-imposed social isolation. Although in many ways this model is kept quite artificially simple, it suffices to illustrate that the causal links between social network capital and economic mobility are highly context specific and need not be empirically identifiable in a way that is generalizable across economies.

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Appendix A: Stylized model and analysis for simulation

We study a setting where each household i initially endowed with (A_{i0}, S_{i0}), faces the unilateral intertemporal utility maximization problem (7) with the instantaneous utility:

$$u\left(C_{it}\right) = \frac{C_{it}^{1-\theta}}{1-\theta}\ ;\ 0 \leq \theta < 1 \tag{A1}$$

where θ determines the household's willingness to shift consumption between periods. The smaller is θ, the more slowly marginal utility falls as consumption rises, and so the more willing the household is to allow its consumption to vary over time. The non-convex production technology set described in (4) is with the general Cobb-Douglas form:

$$Y\left(A_{it}, S_{it}\right) = \max\left(k_1 A_{it}^{\alpha_1}, k_2\left(A_{it} - F\left(S_{it}\right)\right)^{\alpha_2}\right) \quad ;\ 0 < \alpha_1 < \alpha_2 < 1, k_1, k_2 > 0. \tag{A2}$$

In this setting, household would gradually converge to the high-return production technology (the second argument on the right-hand side of (A2)) in the long run, whether through autarkic savings, borrowing or both. With the assumption of constrained autarkic savings and borrowing constraint thus lead to the existence of multiple equilibria, one of which is the poverty trap associated with continued use of the low-return technology.

The benchmark case without a social network

The case where $S_{it} = 0 \forall t$, implying no functioning social network, replicates a traditional poverty traps model, in which the household's optimal welfare depends solely on its autarkic savings and accumulation capacity. The non-convex production set in (A2) implies an asset threshold $\underline{A}$ such that, at any period t, those with $A_t \geq \underline{A}$ can optimally undertake high-return production, i.e., $k_1 \underline{A}^{\alpha_1} = k_2(\underline{A} - F(0))^{\alpha_2}$. As we assume those who choose the low return technology generate income that leaves them poor while those who choose the high-return technology earn income that renders them non-poor, $\underline{A}$ represents a static asset poverty line, which distinguishes *current* poor from non-poor. In any period t, the poor in our context are, therefore, those households with $A_{it} < \underline{A}$.

Household i's first-order conditions for an interior optimum thus yield two equilibria. First, household achieves the high-level equilibrium $U^*_{iH}(S_{i0} = 0, X_{i0} = \underline{0})$ when they can optimally produce at the high-return technology in the last period:

$$\left(C^*_{i0H}\right)^{-\theta} = \rho\left(C^*_{i1H}\right)^{-\theta} \cdot \alpha_2 k_2 \left(A^*_{i1H} - F(0)\right)^{\alpha_2 - 1}, \tag{A3}$$

where the second term on the right side represents the marginal return of the high-return production evaluated at the optimal net asset in the last period. Analogous to the Euler equation, this equation describes the household's equilibrium behavior such that the accumulated asset stock in equilibrium is

$$A^*_{i1H} = \left((\rho\alpha_2 k_2)\left(\frac{C^*_{i0H}}{C^*_{i1H}}\right)^{\theta}\right)^{\frac{1}{1-\alpha_2}} + F(0). \tag{A4}$$

This yields optimal first period consumption of

$$C^*_{i0H} = Y(A_{i0}) - \left(\left((\rho\alpha_2 k_2)\left(\frac{C^*_{i0H}}{C^*_{i1H}}\right)^{\theta}\right)^{\frac{1}{1-\alpha_2}} + F(0) - (1-\delta_A)A_{i0}\right) \tag{A5}$$

where the second term on the right-hand side represents the optimal investment requirement to achieve the high-level equilibrium. Only those households who can afford the corresponding autarkic savings (i.e., $C^*_{i0H} \geq \overline{C}$) will converge to this superior equilibrium. They derive the high-level optimal consumption in the terminal period, $C^*_{i1H} = k_2(A^*_{i1H} - F(0))^{\alpha_2}$.

Those who could not afford this autarkic accumulation will end up in the low-level equilibrium (poverty trap) $U^*_{iL}(S_{i0} = 0, X_{i0} = \underline{0})$ producing at the low-return technology in both periods. The Euler equation describing household behavior implies optimal asset holdings and first period consumption such that

$$C^*_{i0L} = Y(A_{i0}) - \left(\left((\rho\alpha_1 k_1)\left(\frac{C^*_{i0L}}{C^*_{i1L}}\right)^{\theta}\right)^{\frac{1}{1-\alpha_1}} - (1-\delta_A)A_{i0}\right). \tag{A6}$$

To ensure the existence of the equilibria, our parameterization assures that accumulation toward U^*_{iL} is at least feasible, i.e., for every household i, $C^*_{i0L} \geq \overline{C}$.

Therefore, an initially poor household (with $A_{it} < \underline{A}$) graduates to the high-level equilibrium, and thereby escapes poverty, through autarkic savings if and only if

$$C^*_{i0H} = k_1(A_{i0})^{\alpha_1} - \left(\left((\rho\alpha_2 k_2)\left(\frac{C^*_{i0H}}{C^*_{i1H}}\right)^{\theta}\right)^{\frac{1}{1-\alpha_2}} - F(0) - (1-\delta_A)A_{i0}\right) \geq \overline{C}. \tag{A7}$$

Equating A8 to $\overline{C}$ thus allows us to recover a dynamic asset threshold A_0^*—analogous to the *dynamic asset poverty line* proposed by Carter and Barrett [15]—at which optimal household savings bifurcates.[33]

The possibilities presented by social networks and their limitations

With the possibility of social network capital that reduces the fixed cost associated with using the high-return production technique, the static asset poverty line $\underline{A}(S_t)$ can be generalized according to

$$k_1\left(\underline{A}\left(S_{i0}\right)\right)^{\alpha_1}=k_2\left(\underline{A}\left(S_{i0}\right)-F\left(S_{i0}\right)\right)^{\alpha_2} \tag{A8}$$

with $\underline{A}'\left(S_{i0}\right)<0$, so that greater social network capital lowers the static asset poverty line. In this way, one's inherited social network capital can make high-return production technologies, and thus a higher equilibrium standard of living, immediately attainable when one's private stock of capital would not otherwise suffice. Further, those endowed with adequate social network capital might not need to invest in building further social links so as to accumulate social network capital.

For any optimal social network X_{i0} that household i establishes, the superior equilibrium of well being can be described by

$$\begin{aligned}
U_{iH}^*\left(X_{i0}\right)&=\frac{\left(C_{i0H}^*\right)^{1-\theta}}{1-\theta}\left(1+\rho^{\frac{1}{\theta}}\left(\alpha_2k_2\right)^{\frac{1-\theta}{\theta}}\left(A_{i1H}^*-F\left(\left(1-\delta_S\right)S_{i0}+X_{i0}B_i\right)\right)^{\frac{(1-\alpha_2)(1-\theta)}{\theta}}\right)\\
A_{i1H}^*\left(X_{i0}\right)&=\left(\left(\rho\alpha_2k_2\right)\left(\frac{C_{i0H}^*\left(X_{i0}\right)}{C_{i1H}^*\left(X_{i0}\right)}\right)^{\theta}\right)^{\frac{1}{1-\alpha_2}}+F\left(\left(1-\delta_S\right)S_{i0}+X_{i0}B_i\right)\\
C_{i0H}^*\left(X_{i0}\right)&=Y\left(A_{i0},S_{i0}\right)-X_{i0}K_i\\
&\quad-\left(\left(\left(\rho\alpha_2k_2\right)\left(\frac{C_{i0H}^*\left(X_{i0}\right)}{C_{i1H}^*\left(X_{i0}\right)}\right)^{\theta}\right)^{\frac{1}{1-\alpha_2}}+F\left(\left(1-\delta_S\right)S_{i0}+X_{i0}B_i\right)-\left(1-\delta_A\right)A_{i0}\right).
\end{aligned} \tag{A9}$$

Household i with optimal social network X_{i0} can achieve the high-level equilibrium $U_{iH}^*\left(X_{i0}\right)$ if and only if $C_{i0H}^*(X_{i0})\geq\overline{C}$. Otherwise, they will converge slowly to the poverty trap equilibrium $U_{iL}^*(X_{i0})$ with

$$C_{i0L}^*\left(X_{i0}\right)=Y\left(A_{i0},S_{i0}\right)-X_{i0}K_i-\left(\left(\left(\rho\alpha_1k_1\right)\left(\frac{C_{i0L}^*\left(X_{i0}\right)}{C_{i1L}^*\left(X_{i0}\right)}\right)^{\theta}\right)^{\frac{1}{1-\alpha_1}}-\left(1-\delta_A\right)A_{i0}\right). \tag{A10}$$

[33] Given our assumptions, it is necessarily true that $A_0^*\leq\underline{A}$. By way of proof, suppose instead that $A_0^*>\underline{A}$ and consider an individual endowed with $\underline{A}<A_{i0}<A_0^*$. As $\underline{A}<A_{i0}, k_1(A_{i0})^{\alpha_1}<k_2(A_{i0}-F(0))^{\alpha_2}$, and so the household can initially adopt high-return production technology. Thus, $Y<(A_{i0})=k_2(A_{i0}-F(0))^{\alpha_2}$. But as $A_{i0}<A_0^*$, $C_{i0H}^*<\overline{C}$ implies $k_2(A_{i0}-F(0))^{\alpha_2}+(1-\delta_A)A_{i0}-(\rho\alpha_2k_2)^{\frac{1}{1-\alpha_2}}-F(0)<\overline{C}$. This, however, contradicts (A7).

An initially poor household (whose $A_{i0} < \underline{A}(S_{i0})$) thus can gradually accumulate resources toward the high-level equilibrium, and thus escape future poverty, if it establishes a productive network X_{i0} such that[34]

$$C^*_{i0H}(X_{i0}) \geq \overline{C} \quad \Leftrightarrow \quad k_1 (A_{i0})^{\alpha_1} - X_{i0} K_i - \left(\left((\rho\alpha_2 k_2)\left(\frac{C^*_{i0H}(X_{i0})}{C^*_{i1H}(X_{i0})}\right)^{\theta}\right)^{\frac{1}{1-\alpha_2}} + F((1-\delta_S) S_{i0}) - (1-\delta_A) A_{i0}\right) \geq \overline{C}. \quad \text{(A11)}$$

This implies that the dynamic asset poverty threshold depends not only on household's initial endowments (A_{i0}, S_{i0}), but also on the poor's opportunity to establish a social network, X_{i0}, that could generate the social network capital necessary for them to graduate from poverty. (A11) suggests that there exists a dynamic asset threshold conditional on a given endowed network structure, $A^*_0(S_{i0}|X_{i0} = \underline{0})$, such that for initially poor households with $A^*_0(S_{i0}|X_{i0} = \underline{0}) \leq A_{i0} < \underline{A}(S_{i0})$,

$$C^*_{i0H}(X_{i0} = \underline{0}) \geq \overline{C} \quad \Leftrightarrow \quad k_1 (A_{i0})^{\alpha_1} - \left(\left((\rho\alpha_2 k_2)\left(\frac{C^*_{i0H}(X_{i0} = \underline{0})}{C^*_{i1H}(X_{i0} = \underline{0})}\right)^{\theta}\right)^{\frac{1}{1-\alpha_2}} + F((1-\delta_S) S_{i0}) - (1-\delta_A) A_{i0}\right) \geq \overline{C}. \quad \text{(A12)}$$

Such households gradually escape poverty without needing to establish a new social network X_{i0} to accumulate their (already sufficient) social network capital. For them, new social links are attractive if and only if the feasible network X_{i0} increases welfare by reducing the fixed costs of production enough to (at least) offset the costs of establishing the links—i.e., if it permits positive net intertemporal welfare gains. Therefore, the feasible network X_{i0} they will consider needs to follow

$$C^*_{i0H}(X_{i0}) > C^*_{i0H}(X_{i0} = \underline{0}) \quad \Leftrightarrow \quad \left(\left((\rho\alpha_2 k_2)\left(\frac{C^*_{i0H}(X_{i0} = \underline{0})}{C^*_{i1H}(X_{i0} = \underline{0})}\right)^{\theta}\right)^{\frac{1}{1-\alpha_2}} + F((1-\delta_S) S_{i0})\right) - \left(\left((\rho\alpha_2 k_2)\left(\frac{C^*_{i0H}(X_{i0})}{C^*_{i1H}(X_{i0})}\right)^{\theta}\right)^{\frac{1}{1-\alpha_2}} + F((1-\delta_S) S_{i0} + X_{i0} B_i)\right) > X_{i0} K_i. \quad \text{(A13)}$$

The intuition is that a household will invest in social network formation if the associated cost savings on physical capital investment outweigh the costs of establishing such a network.

Other initially poor households with $A_{i0} < A^*_0(S_{i0}|X_{i0} = \underline{0}) < \underline{A}(S_{i0})$ cannot reach the high-level equilibrium without establishing new social links so as to accumulate

[34]If there exists a network $X_{i0} \neq \underline{0}$ such that $C^*_{i0H}(X_{i0}) > 0$, then $U^*_{iH}(X_{i0}) > U^*_{iL}(X_{i0} = \underline{0})$ if $C^*_{i0H}(X_{i0}) > C^*_{i0H}(X_{i0} = \underline{0})$ by assumptions. Thus the benefit of reaching the high-level equilibrium induces the household to make costly links, if it can afford to do so. Of course, if $C^*_{i0H}(X_{i0} = \underline{0}) > C^*_{i0H}(X_{i0}) > \overline{C}$, then it is optimal for the household to graduate from poverty through autarkic savings.

additional social network capital and thereby make future adoption of the high-return technology optimal. For them, factors that determine the poor's ability to establish a productive social network, such as the broader wealth distribution in the economy and the maximum social distance over which links are feasible in a given society, therefore serve as the key determinants for their potential to use social network to escape poverty.

A still different equilibrium emerges for any household that fails to meet condition (A12), either because it has inadequate endowments (A_{i0}, S_{i0}) or because there is no feasible network $X_{i0} \in \Omega_{i0}$ that would generate sufficient social network capital to let it reach the high-level equilibrium. Because establishing social links is costly and the household will never benefit from these, very poor and socially distant households optimally self-select out of social networks, choosing instead self-imposed social isolation. For these households, thus $U^*_{iL}(X_{i0} = \underline{0}) > U^*_{iL}(\widehat{X}_{i0}), \forall \widehat{X}_{i0} \neq \underline{0}$. For other households, whose feasible network X_{i0} that would let them reach the high-level equilibrium are, at equilibrium, rebuffed by others in the economy, they are also unfortunately trapped in poverty due to involuntarily social exclusion.

Basic comparative statics

Like general asset accumulation model, (A11) implies that the potential of initially poor household i to escape poverty depends on its initial endowment, (A_{i0}, S_{i0}), the parameters of the production technology $(k_1, k_2, \alpha_1, \alpha_2, F(S_{it}))$, depreciation rates on both types of capital (δ_A, δ_S) and preferences (ρ, θ). The key interesting characteristics of this model is that with endogenous network formation as part of household's accumulation, results of the model's comparative statics could vary across households depending on the role social network capital plays in their economic mobility.

For some initial poor households endowed with enough capital and social assets, $A^*_0(S_{i0}|X_{i0} = \underline{0}) < A_{i0} < \underline{A}(S_{i0})$ that allow achieving economic mobility regardless of the social network formation in equilibrium, these comparative static results are all quite intuitive. A household's initial endowment of both physical and social network capital contributes unambiguously toward its potential to grow out of poverty. Lower asset depreciation rates decrease the savings required to adopt the high return production technology and graduate from poverty. Therefore, they unambiguously increase household's upward mobility possibility by enhancing household's capacity to meet this saving requirement autarkically or to find social network a relatively more productive mechanism for growth. Increased productivity of the low-return production technology (k_1, α_1) unambiguously increases household's initial income, which then increases its ability to save and to accumulate its way out of poverty in the next period. Improved productivity of social network capital in reducing fixed cost associated with high-return production, $|F'(S_{it})|$, unambiguously reduces capital requirement to adopt high-return production and so increases its potential to move out of poverty. Improved productivity of the high-return technology (k_2, α_2) implies greater savings incentives. This effect could be amplified (or muted) by household intertemporal preferences, as reflected in either its time discounting (ρ) or its degree of elasticity of intertemporal substitution (θ). All else equal, the higher a household's future discounting, the more required investment it needs in order to converge to the high-level equilibrium. The Euler equation meanwhile suggests that the higher θ, the higher the return on investment in equilibrium, which implies less investment needed to reach the high-level equilibrium. Therefore, all else equal, higher θ increases a household's potential to escape poverty either by making the necessary autarkic savings affordable or by making social network construction attractive and productive for mediating growth.

The more interesting, but perhaps not obvious, implication is that these effects could well be ambiguous and sometime counterintuitive for those initial poor household with $A_{i0} < A_0^*(S_{i0}|X_{i0} = \underline{0})$, whose escape from poverty is only possible if they successfully form new productive social network in the economy. If the increase in socio-economic endowment is not enough to allow household to achieve economic mobility regardless of new social network formation, the resulting change in their potential to grow out of poverty could be ambiguous depending on how these changes affect the new social network established in the equilibrium. The increases in assets that allow household to successfully form productive network in equilibrium will increase their potential to escape poverty for those, who, in the equilibrium without these changes, could not form any productive network or form relatively less productive network. On the other hand, the increases in assets that lead to the increase in socio-economic distance from their prospective link partners and so impede their ability to form a productive social network in equilibrium would not change mobility potential for those initially trap in poverty. Counter intuitively, for those who could form social network in the initial economy, this possibility could well be detrimental as it now traps them in poverty. In our model, therefore, increases in assets will not always be a panacea for improving potential to escape poverty of some poor households (whose economic mobility requires formation of productive social network) unless the asset increase yields them the new socio-economic position that allows them to grow out of poverty regardless of new social network formation. By the same token, the effect of improvement in production technologies or changes in preference will likely be ambiguous for these unfortunate initial poor households.

In this model with endogenous network formation, the potential for household i to escape poverty also depends on the conditions that govern its feasibility and opportunity to establish productive social networks in equilibrium, ($\mathrm{K_t}$, B_t, $\overline{d}$) as well as their position relative to the socio-economic wealth distribution in the economy, $\lambda(A_0, S_0)$. Ceteris paribus, a household will place greater intertemporal value on a social link the lower the cost of establishing it (K_i) and the higher the benefits the link generates (B_i). Decrease (increase) in the cost (benefit) of link thus tend to unambiguously (though non-monotonically) increase the number of link partners in household's top ranked networks. Their effects on total number of links formed in equilibrium and on initial poor households' potential to use (relatively more productive) social network for economic mobility, however, are ambiguous for all initial poor households. On the one hand, as we show through simulations in Appendix C, the first-best networks with larger number of partners are very hard to be fulfilled in equilibrium. So, for some, the decrease (increase) in the cost (benefit) of link could reduce number of prospective links formed in equilibrium, which then result in a reduction in their potential to use (relatively more productive) social network to escape poverty. On the other hand, because all households in the economy tend to increase the number of partners among their top-ranked networks, for others, these improvements in link value could result in fewer poverty trapped households because social network formation becomes more attractive, as well as more use of social networks as a cheaper substitute for autarkic physical capital accumulation by mobile households. Despite these ambiguous effects, the decrease (increase) in the cost (benefit) of link, however, unambiguously result in reduction in the unilateral social isolation as households find social links more valuable.

Ceteris paribus, the increase in $\overline{d}$ will unambiguously increase the number of feasible link partners for household in the economy. But as increasing in $\overline{d}$ does not imply anything about household's ranking of all their possible networks, its impact on equilibrium social network still relies fundamentally on the socio-economic distribution of wealth in the economy. We should as well expect the extreme case such that there exists a very low level of $\overline{d}$, below which constrained social interaction could unambiguously lead to reduction in number of links formed in equilibrium and so households' potential to use social network to escape poverty.

Overall, improvement in the value of social links and/or feasibility of social interaction largely result in ambiguous effects on household's potential to use social network to escape poverty, though at best, the former could reduce incidence of social isolation. The effects of socio-economic on the equilibrium social networks in the economy with multiple and heterogeneous households—which fundamentally governs these earlier ambiguous effects—are intractable. Therefore, we use numerical simulations to explore these points. A sensitivity analysis of our points is reported in Appendix C.

Appendix B: Parameterization for the numerical simulations

Base case

1. Utility: $\theta = 0$, $\rho = 0.95$, $\overline{C} = 2$
2. Production technology: $F(S_{it}) = k_3 k_4^{-S_{it}}$, $k_1 = 9$, $k_2 = 8.5$, $k_3 = 9$, $\alpha_1 = 0.25$, $\alpha_2 = 0.5$, $F = 9$
3. Social interaction: $\alpha = 1$, $\overline{d} = 5$
4. Cost/benefit of link: $K_i(j) = \theta_1 d(i, j)(\frac{A_{j0}}{A_{i0}})$, $Bi(j) = \theta_2 A_{j0} - \theta_3 |A_{j0} - A_{i0}|$, $\theta_1 = 0.125$, $\theta_2 = 0.4$, $\theta_3 = 0.33$
5. Asset accumulation: $\delta_A = \delta_S = 0.05$
6. Endowment: $A_0 \in [0, 20]$, $S_0 \in [0, 10]$

Socio-economic distributions (Table 1)

Cases 1–5 consider a truncated bivariate normal distribution:

$$\lambda\left(A_0, S_0\right) \sim \begin{cases} k_{A_0 S_0, 1}\; N\left(\mu_A, \mu_S, \sigma_A, \sigma_S, \rho\right) \text{ for } A_0 \in \left[0, 2\mu_A\right], S_0 \in \left[0, 2\mu_S\right] \\ 0 \;\text{ otherwise} \end{cases}$$

where $k_{A_0 s_0,1}$ normalizes the distribution so that the area under it in the truncated plane x, y equals 1. Case 1 is the base case with $\mu_A = 10$, $\mu_S = 5$, $\sigma_A = 4$, $\sigma_S = 2$, $\rho = 0$. Cases 2–3 vary the dispersion of A_0 holding $\rho = 0$ and the mean of both assets constant. The parameters considered in Table 1 have been chosen so that the above truncated distribution is nearly normal.

Cases 4–7 deviate from case 1 while holding the marginal distributions of wealth $x = A_0, S_0$ constant at

$$h(x) \sim \begin{cases} N(\mu_x, \sigma_x) & \text{for } x \in [0, 2\mu_x] \\ 0 & \text{otherwise} \end{cases}.$$

As a result, inequality and one-dimension economic polarization [25, 30] are also held constant relative to the base case (1). Cases 4–5 use a bivariate normal distribution deviating from case 1 with $\rho > 0$. Cases 6–7 consider economies characterized by bi-modal distributions. To generate bi-modal distributions that hold constant the marginal distributions of wealth $x = A_0, S_0$ for purposes of comparison, we follow the numerical method used by Mogues and Carter [47]. First, we partition the marginal distributions $h(x)$ into two parts: $h^{lo}(x)$ and $h^{hi}(x) = h(x) - h^{lo}(x)$. To do so, we use a (relatively flexible) gamma function to generate $h^{lo}(x)$, whose density covers most of the lower mode (and the left tail) of $h(x)$, such that $h^{lo}(x) < h(x) \forall x \in [0, 2\mu_x]$. This allows us then to recover $h^{hi}(x)$ numerically from the rest of the density, which is now shifted to cover the higher mode (and the right tail) of $h(x)$, such that $E^{hi}(x) > E^{lo}(x)$. We then expand these into a two-dimension bivariate distribution for $x = A_0, S_0$ such that

$$\lambda(A_0, S_0) \sim k_{A_0 S_0,1} \begin{cases} h^{hi}(A_0)\, h^{hi}(S_0) \text{ if } A_0 + S_0 > \mu_A + \mu_S;\ A_0 \in [0, 2\mu_A],\, S_0 \in [0, 2\mu_S] \\ h^{lo}(A_0)\, h^{lo}(S_0) \text{ if } A_0 + S_0 \le \mu_A + \mu_S;\ A_0 \in [0, 2\mu_A],\, S_0 \in [0, 2\mu_S] \\ 0 \text{ otherwise} \end{cases}$$

where $k_{A_0 s_0,1}$ normalizes this toward a density function in the truncated x, y plane. Cases 6–7 vary by the generated gamma distribution $h^{lo}(x)$ and so by the resulting $h^{hi}(x)$ and their group moments of both assets.

The generalized gamma distributions considered for $h^{lo}(x)$ are characterized by

$$g(x) = \frac{\kappa x^{\kappa\alpha - 1} e^{-\left(\frac{x}{\beta}\right)^{\kappa}}}{\beta^{\kappa\alpha}\Gamma(\alpha)};\ \text{shape parameters } \kappa > 0, \alpha > 0 \text{ and scale parameter } \beta > 0.$$

For case 6:

$$h^{lo}(A_0) : \kappa = 4.75, \alpha = 0.55, \beta = 8.95 \text{ and } h^{lo}(S_0) : \kappa = 5.45, \alpha = 0.65, \beta = 3.65.$$

For case 7:

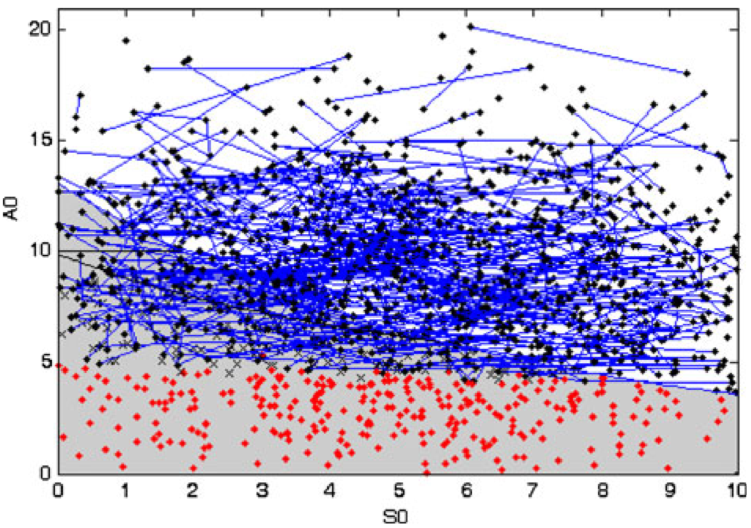
$$h^{lo}(A_0) : \kappa = 15.52, \alpha = 0.24, \beta = 5.51 \text{ and } h^{lo}(S_0) : \kappa = 16.51, \alpha = 0.23, \beta = 2.85.$$

Appendix C: Network simulation statistics and sensitivity analysis

Network simulation statistics

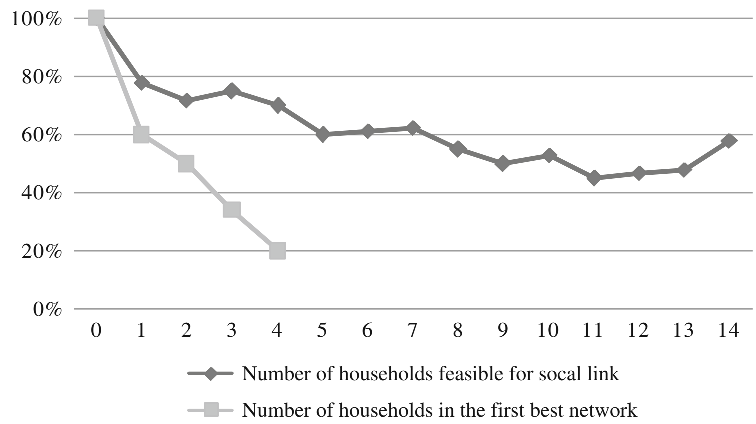
The plot of equilibrium networks and long-run equilibria for 100 randomly simulated baseline economies shows that there emerges a clear asset threshold below which households lose any incentive to establish social networks with others. Social exclusion and socially mediated climbs out of poverty are, however, generally quite difficult to predict as those patterns depend so heavily on the underlying structure of the economy.

Equilibrium social networks and long-run equilibria



Households for whom no links are feasible or who do not wish to establish any social links (i.e., socially isolated households) necessarily always get their first-best network. Thereafter, we show from 100 randomly simulated baseline economies of 17 households that the proportion of households attaining their first-best network in equilibrium is declining monotonically in desired network size and non-monotonically in feasible network size. This reflects that more complex networks are harder to establish.

Sample proportion (%) of households getting their first best network conditional on



Sensitivity analysis

This section describes the effects of deviating several key household- and economy-specific parameters from the baseline parameterization on equilibrium social network and mobility patterns of the initial poor in the economy. Imposing a case by case parameter deviation (holding everything else constant), the summary table below reports the proportion of 100 randomly simulated economies that experience changes in the number of links formed in economy and by the initial poor, the potential of an initially poor household and the percentage of the initial poor households in the economy that are (1) economically mobile through autarkic savings, (2) economically mobile utilizing successfully established social network, (3) trapped in poverty due to social exclusion, and (4) trapped in poverty due to social isolation. The simulated results confirm the likely tendencies we describe earlier in our model's basis comparative statics.

First, we explore how changes in endowment of a household will affect their potential to achieve upward mobility. We consider two specific household: b, whose endowments are sufficient to allow them to enjoy upward mobility autarkically and c, who requires successful establishment of productive social network to escape poverty. As shown in case (1)–(6), while increase in asset endowment will only affect the mean for upward mobility for those initial poor household autarkically mobiled without social network capital, it also lead to counterintuitive results for those whose upward mobility requires newly established productive social network. The case (4)–(5) shows that one (two) units increase in asset for household c could also lead to the increase in its potential to be trapped in poverty due to social exclusion in 22% (16%) of the simulated economies despite the resulting increase in its tendency to form productive social links and escape poverty in 25% (21%) of the time. Therefore, unless the increase in asset endowment is large enough to sustain the initial poor's autarkic mobility, e.g., at a position above $A_0^*(S_{i0}|X_{i0} = \underline{0})$, the improvement in asset endowment will not be a panacea for economic mobility. The results rely fundamental on the underlying distribution of socio-economic endowment that condition endogenous network formation in equilibrium of this model.

Next we explore how the changes in overall economy-specific parameters will affect the patterns of economic mobility of initial poor households in the economy using 100 simulated economies with 17 households, whose endowments are randomly drawn from the uniform distributions similar to the earlier case. Case (7)–(10) show how the change in overall asset endowment of households in the economy could lead to ambiguous effects on the potential to exit poverty of the initial poor in the economy. Everything else equal, though percentage increase (decrease) in asset will unambiguously lead to lower (greater) incidence of unilateral social isolation, it will not always lead to lower (greater) overall percentage of household trapped in poverty. The percentage reduction in asset (thus at progressive rate relative to the initial level) could result in lower social distance among potential link partners, which, in turn, could promote socially mediated growth for some. Case (11)–(14) provide similar results from changes in productivity of the low-return technology with ambiguous effects arise due to endogenous nature of network formation in this model.

Case (15)–(26) explore the effects of changes in the conditions that govern the feasibility and opportunity for households to establish productive social networks in equilibrium, $(K_i, B_i, \overline{d})$, which echo our comparative statics analyzed in Appendix A. The changes in cost and/or benefit of social links will have ambiguous effect on the number of links formed among the initial poor and their potential to escape poverty as the resulting social network established in equilibrium still rely fundamental

Table 2 Effects on equilibrium social network and mobility patterns

Deviation from baseline	Proportion of economies (in 100 simulated economies) experiencing change in											
	Number of links formed in the economy		Number of links formed by initial poor household		% of initial poor households: Economically mobile via autarkic saving		Economically mobile via social networks		Trapped in poverty: social exclusion		Trapped in poverty: social isolation	
	+	−	+	−	+	−	+	−	+	−	+	−
Effects on individual household[a]												
For b: $(A_{i0}, S_{i0}) = (9, 1)$												
(1) 1 unit increase in A_{i0} (11%)	0.19	0.12	0.18	0.11	0.09	0.16	0.16	0.09	0.00	0.00	0.00	0.00
(2) 2 unit increase in A_{i0} (22%)	0.31	0.10	0.27	0.08	0.06	0.21	0.21	0.06	0.00	0.00	0.00	0.00
(3) 3 unit increase in A_{i0} (33%)	0.19	0.22	0.19	0.17	0.15	0.17	0.17	0.15	0.00	0.00	0.00	0.00
For c: $(A_{i0}, S_{i0}) = (5, 4)$												
(4) 1 unit increase in A_{i0} (20%)	0.28	0.25	0.29	0.26	0.00	0.00	0.25	0.22	0.22	0.17	0.00	0.08
(5) 2 unit increase in A_{i0} (40%)	0.20	0.23	0.22	0.19	0.00	0.00	0.21	0.16	0.16	0.08	0.00	0.13
(6) 3 unit increase in A_{i0} (60%)	0.31	0.24	0.35	0.29	0.33	0.00	0.32	0.12	0.00	0.26	0.00	0.21
Effects on households in the economy												
Level of asset endowment A_{i0}												
(7) 20% Increase	0.13	0.28	0.22	0.14	0.22	0.10	0.21	0.26	0.18	0.13	0.00	0.11
(8) 40% Increase	0.07	0.39	0.25	0.21	0.46	0.15	0.20	0.36	0.29	0.19	0.00	0.23
(9) 20% Decrease	0.42	0.11	0.29	0.19	0.08	0.35	0.33	0.16	0.17	0.23	0.18	0.05
(10) 40% Decrease	0.27	0.09	0.20	0.08	0.02	0.59	0.19	0.28	0.31	0.09	0.44	0.02
Productivity of low-return technology: α_1												
(11) 50% Increase	0.23	0.15	0.18	0.18	0.14	0.09	0.16	0.12	0.11	0.08	0.00	0.09
(12) 75% Increase	0.28	0.17	0.19	0.23	0.25	0.11	0.23	0.24	0.18	0.10	0.00	0.22
(13) 50% Decrease	0.22	0.26	0.23	0.12	0.13	0.18	0.25	0.29	0.14	0.17	0.12	0.00
(14) 75% Decrease	0.15	0.29	0.16	0.09	0.07	0.27	0.16	0.23	0.18	0.15	0.29	0.00

Network Costs: $K_i(j)$												
(15) 50% Increase in θ_1	0.28	0.64	0.45	0.36	0.10	0.36	0.44	0.28	0.18	0.31	0.18	0.00
(16) 75% Increase in θ_1	0.09	0.73	0.18	0.45	0.18	0.09	0.09	0.36	0.18	0.18	0.20	0.00
(17) 50% Decrease in θ_1	0.64	0.18	0.55	0.36	0.18	0.18	0.27	0.39	0.52	0.13	0.00	0.27
(18) 75% Decrease in θ_1	0.85	0.10	0.73	0.09	0.00	0.23	0.59	0.09	0.16	0.10	0.00	0.35
Network Benefits: $B_i(j)$												
(19) 50% Increase in θ_2	0.21	0.57	0.45	0.27	0.07	0.20	0.37	0.19	0.27	0.10	0.00	0.27
(20) 75% Increase in θ_2	0.27	0.64	0.73	0.27	0.10	0.27	0.64	0.10	0.20	0.29	0.00	0.32
(21) 50% Decrease in θ_2	0.18	0.55	0.15	0.73	0.18	0.10	0.10	0.59	0.37	0.20	0.32	0.00
(22) 75% Decrease in θ_2	0.18	0.82	0.12	0.72	0.18	0.22	0.20	0.64	0.18	0.36	0.68	0.00
Social Interaction: $\overline{d}$												
(23) 20% Increase	0.42	0.15	0.28	0.27	0.18	0.09	0.10	0.27	0.18	0.10	0.00	0.00
(24) 40% Increase	0.36	0.27	0.25	0.36	0.00	0.09	0.19	0.36	0.28	0.04	0.00	0.00
(25) 40% Decrease	0.63	0.27	0.90	0.10	0.10	0.35	0.45	0.20	0.20	0.36	0.27	0.09
(26) 80% Decrease	0.00	1.00	0.00	1.00	0.81	0.00	0.00	1.00	0.09	0.69	0.78	0.00

Results for each of the deviating cases 1–26 are based on 100 randomly simulated 100 economies of 17 households with $\lambda(A_0, S_0)$ randomly drawn from uniform wealth distributions with: $A_0 \in [0, 20]$, $S_0 \in [0, 10]$. Proportions do not always add up to one as there are economies with no change in some categories

[a]Household b (in area B in Fig. 3b) is autarkically mobile household without forming new link, while household c (in area C in Fig. 3b) whose mobility depends on social links

on the wealth distribution in the economy. Also clearly shown in this table, as household's the intertemporal value of social link increases (decreases), the lower (higher) the cost of establishing social link and the higher (lower) the benefits the link generates, these tend to unambiguously increase (decrease) the number of initial poor households trapped in poverty due to social isolation.

Social link formation obviously responds to changes in the maximal distance permitting social interaction, $\overline{d}$. Case (23)–(26) present the effects of different directions and magnitudes of change in $\overline{d}$. Intuitively, as the space for social interaction shrinks radically, by 80%, there is of course a universal sharp reduction in equilibrium links formed, including by the initially poor. This also leads to an increase in autarkically mobile households in 81% of the economies, as social network capital is less commonly feasible as a substitute for physical capital accumulation, and to an increase in incidence of social exclusion (isolation) in most (all) economies. Less intuitively, for a smaller decrease (40%) in $\overline{d}$, link formation may actually increase. In 63% of the economies, the number of links formed grows; this figure is far higher among the initially poor (90%). One possible reason is that a narrower domain of feasible social interaction induces more reciprocity of desired links among socially proximate clusters of households. With fewer feasible or desired links, households are more likely to seek, and in equilibrium make, links with those with whom they wish to form a network (see the preceding figure). Somewhat lower $\overline{d}$ encourages more links among the poor, as they become less likely to seek out—and be rejected by—better-off households within the domain of socially feasible interactions. The results from this end contribute to greater economic mobility using social networks and less using autarkic savings. These are especially interesting and somewhat counterintuitive results. On the other hand, a small reduction in $\overline{d}$ could as well lead to lower number of links formed in economy and among the initial poor as to some extent it impedes feasibility of social interactions with prospective link partners for some. With these two opposing results, the net effects on initial poor household's economic mobility are thus ambiguous. Increasing $\overline{d}$ also generates corresponding results. Increasing the social distance across which individuals can feasibly connect does not guarantee more links or mobility in an economy. It may merely lead to greater unsuccessful attempts to link, with adverse consequences for some initially poor, whose aspirations go unfulfilled (Table 2).

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