Social Network Capital, Economic Mobility and Poverty Traps

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Comments greatly appreciated

Abstract

The paper explores the role social network capital might play in facilitating poor agents' escape from poverty traps. We model endogenous network 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 serve as either a complement to or a substitute for productive assets in facilitating some poor households' escape from poverty. However, the voluntary nature of costly social network formation also creates both involuntary and voluntary exclusionary mechanisms that impede some poor households' efforts to exit poverty. The ameliorative potential of social networks therefore depends fundamentally on the underlying wealth distribution in the economy. 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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Keywords: social network capital, endogenous network formation, poverty traps, multiple equilibria, social isolation, social exclusion, crowding-in transfer

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Social Network Capital, Economic Mobility and Poverty Traps

1. Introduction

The persistent poverty widely observed in developing countries has motivated much research on poverty traps into which households may fall and have difficulty escaping. The fundamental feature of most poverty trap models centers on the existence of financial market imperfections that impede investment in productive assets or technology, and thus prevent 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] However, various studies also document the existence of exclusionary mechanism 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 further explores the intersection between poverty traps and social network by studying the mechanisms by which endogenous social network capital can facilitate or impede poor households' escape from persistent poverty. We especially seek to provide a theoretical foundation for the quite mixed empirical effects of social network capital on poor households' well-being. While some empirical studies – e.g., Narayan and Pritchett (1999) – find that social network capital effectively serves as a substitute for real capital in mediating economic mobility in many economies, others, such as Adato et al. (2006) and Mogues and Carter (2005), suggest that accumulation of social network capital proves ineffective for households at the bottom of the economic pyramid in highly

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[1] Examples include Loury (1981), Banerjee and Newman (1993), Galor and Zeira (1993), Dercon (1998), and Mookherjee and Ray (2002, 2003). See Azariadis and Stachurski (forthcoming) or Carter and Barrett (2006) for helpful reviews of key threads in the poverty traps literature.

[2] Dasgupta and Serageldin (2000) and Durlauf and Fafchamps (2004) offer excellent reviews.

[3] For example, Adato et al. (2006), Mogues and Carter (2005) and Santos and Barrett (2006), among others.

[4] See, for example, the recent volumes by Barrett (2005) and Bowles et al. (2006) and the December 2005 special issue of the *Journal of Economic Inequality* on "Social Groups and Economic Inequality".

polarized economies. Why might endogenous social network formation help some poor households but not others?

The basic structure and intuition of our model runs as follows. Households heterogeneously endowed with privately owned capital assets and social network capital – from endowed (e.g., parents') social networks – choose production technologies, consumption, and investment in assets and in social relationships with others in the economy (that confer future social network capital) over multiple periods so as to maximize their lifetime utility. We assume that social networks are costly to establish and maintain, have no intrinsic value and only function to provide access to partners' (at least partially nonrivalrous) capital that reduces the fixed cost of a high-return technology. Social networks form endogenously based on mutual consent and result from optimal strategic interaction among all households in an economy. We simplify the setting by assuming perfect information and no financial markets.

In this setting, analogous to other poverty traps models, some initially poor households will be caught in a low-level equilibrium because they lack access, through either endowments, market or social mechanisms, to the productive assets needed in order for the most productive technology available to be the households' optimal choice, albeit perhaps after a period of initial investment. Initially poor households without such access must resort to autarkic savings if they are to finance 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 an 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 (i) social networks represent complex sets of dynamic relationships established non-cooperatively between mutually consenting agents, and (ii) a given link's net value to any agent depends on the set of other links operational at the same time. Because the social network structure thus evolves endogenously and depends fundamentally on the 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. This complex interdependency in a setting with multiple and heterogeneous households poses an analytical challenge. We advance one reasonable technique for addressing this challenge in numerical simulation.

The remainder of the paper is structured as follows. In section 2, we briefly summarize the relevant economics literatures on social networks in low-income economies and social network formation and relate them to the concept of social network capital used in this paper. In section 3, we develop a dynamic optimization model with endogenous network formation among heterogeneous households, describe the simple non-convex production technology set we use and explain household's unilateral decision concepts. Section 4 studies the optimal social network structure. We illustrate a stylized noncooperative game of network formation and introduce the concept of pairwise stability, which we use to characterize the stable social network in our context. In section 5, we then describe household's equilibria for any stable network that may arise in this stylized economy and the resulting patterns of economic mobility. Specifically, we first distinguish between static and dynamic asset poverty thresholds as a function of asset and social network capital. We then describe heterogeneous patterns of economic mobility, how social networks can mediate household-level welfare dynamics and how exclusionary mechanisms can arise in equilibrium, effectively barring some of the poor from reaching the high-level equilibrium, thereby yielding a poverty trap consistent with the existence of social networks. We illustrate these results in section 6, first developing an implementable network formation protocol to generate a unique pairwise stable network, then simulating randomly generated economies to demonstrate different mobility patterns of households in any economy and of households with identical initial endowments in different economies. The simulations also allow us to show, in section 7, how endogenous social network formation can overturn familiar policy implications generated by models without endogenous social interactions, as when public transfers to the poor no longer crowd-out private transfers but can, instead, crowd them in by inducing the creation of new social links. Section 8 concludes.

2. Social network capital

Despite its elusive definitions and applications, a rapidly growing literature on "social capital" emphasizes its potential to obviate market failures in low-income communities. Durlauf and Fafchamps (2004) 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 (Coleman 1988, Putnam et al.1993). A second conceptualization treats social capital as an individual asset conferring private benefits (Onchan 1992, Berry 1993, Townsend 1994, Foster and Rosenzweig 1995, Fafchamps 1996, Ghosh and Ray 1996, Kranton 1996, Barr 2000, Bastelaer 2000, Carter and Maluccio 2002, Conley and Udry 2002, Fafchamps and Minten 2002, Isham 2002, Fafchamps 2004, Bandiera and Rasul 2006, Moser and Barrett 2006). We employ the second conceptualization, which is sometimes referred to as "social network capital" so as to emphasize that households gain from linking with others to form social networks for mutual benefit (Granovetter 1995a, Fafchamps and Minten 2002).

The literature discusses many prospective mechanisms through which social network capital might operate: improved information flow 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's sake, however, we assume the sole function of a social network is to provide access to link partners' (at least partially nonrivalrous) productive assets. Intuitively, this can be understood as sharing or borrowing tools, equipment or even animal or human labor, obtaining nonrivalrous capital-specific information, etc.[5] The social network thus has

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[5] 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 former opts to buy a tractor himself. Note that such access does not need to be equivalent to that of the asset owner, it merely needs to

purely instrumental value in allowing one to accumulate social network capital – socially-mediated access to others' productive assets. Social network capital is thus (imperfectly) substitutable for traditional, privately possessed capital.

The prospective benefits of social network capital thus create material incentives to establish social relations with others, even when it is costly to establish and maintain such relationships. The formation of a network of bilateral relationships is thus a form of investment, akin to more conventional investment in traditional financial, natural or physical capital.

Social networks necessarily evolve endogenously. A small but growing literature demonstrates this empirically in the case of poor agrarian communities (Conley and Udry 2001, DeWeerdt 2004, Santos and Barrett 2005, Fafchamps and Minten 2001, Fafchamps and Gubert forthcoming). 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 developed insightful strategic models of endogenous network formation, building on seminal work by Aumann and Myerson (1988) and Myerson (1991) to model network formation in a cooperative game settings, and on Jackson and Wolinsky (1996) to concretize the notion of a stable network based on pairwise stability in links and "strong stability" among larger coalitions of agents. Recent advances in the literature, nicely reviewed by Jackson (2005), emphasize dynamic perspectives on network formation (Watt 2001, Jackson and Watt 2002a, Dutta et al. 2002, Watt 2002) and refinement of stability concepts (Dutta and Mutuswami 1997, Jackson and van den Nouweland 2000, Konishi and Ünver 2003), but have focused to date almost entirely on applications in industrial organization and labor economics. The application of formal models of network formation in development economics remains relatively rare.[6]

This is an unfortunate lacuna, especially because the literature strongly suggests that not everyone benefits from social networks and that there exist patterns to these gaps

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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.

[6] Calvó-Armengol and Jackson (2004), Conley and Udry (2005), Genicot and Ray (2005),Mogues and Carter (2005) and Bloch et. al (2006) are important exceptions.

(Durlauf and Fafchamps 2004). For example, Figueroa et al. (1996) point out that social exclusion has become a very active subject of debate concerning poverty in Europe. Carter and May (2001) and Adato et al. (2006) 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 to the poor of social capital in obviating barriers to entry into remunerative livelihoods. Santos and Barrett (2006) find that asset transfers through social networks in southern Ethiopia 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 initial wealth distribution in an economy, with significant consequences for the growth prospects for the poor.[9] In this way, 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] Having situated this paper in the broader literature and laid out the core intuition and concepts, we now explain our stylized model in detail.

[7] Postlewaite and Silverman (2005), Kaztman (2001), Barry (1998), Wilson (1987), 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 2006, p.397), as the term is used by, among others, Room (1995), Atkinson (1998), Atkinson et al. (2002), and Bossert et al. (forthcoming).

[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, for example, Galor and Zeira (1993) or Mookherjee and Ray (2000), as well as the excellent review by Aghion et al. (1999).

3. A dynamic optimization model with endogenous network formation

Assume n households exist in an economy, $N = (1,2,...,n)$. Each lives for two periods,[11] $t = 0,1$. 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 endowed (e.g., parents') social network. There is thus just one type of individually owned asset, but people can have access to it directly through private ownership or indirectly through their social network. The economy's initial endowment distribution is denoted by $\phi(A_0, S_0)$. Households' preferences are identical, with utility derived solely from consumption, as is the set of available production technologies to generate income from one's capital stock.

3.1 Production technology set

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

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

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

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 (i.e., this is not a one-time sunk cost of adoption). Social network capital reduces the fixed cost of using the high-return technology and is thus an imperfect substitute for owned capital.

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

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

$$f_H(0) = f_L(0) = 0 \tag{3}$$

$$\frac{\partial f_H(0)}{\partial NA_t^H} = \frac{\partial f_L(0)}{\partial NA_t^L} = \infty \quad \text{and} \quad \frac{\partial f_H(\infty)}{\partial NA_t^H} = \frac{\partial f_L(\infty)}{\partial NA_t^L} = 0 \tag{4}$$

$$\frac{\partial^2 f_H(NA_t^H)}{\partial (NA_t^H)^2} \leq 0 \quad \text{and} \quad \frac{\partial^2 f_L(NA_t^L)}{\partial (NA_t^L)^2} \leq 0 \tag{5}$$

$$\frac{\partial f_H(NA_t^H)}{\partial NA_t^H}\Big|_{NA_t=j} \geq \frac{\partial f_L(NA_t^L)}{\partial NA_t^L}\Big|_{NA_t=j} \geq 0 \;\; \forall j\,. \tag{6}$$

In each period *t*, therefore, a household *i*'s aggregate production function can be described as

$$Y_{it} = Max[\,Y_{it}^H, Y_{it}^L\,] = Max[\,f_H(A_{it} - F(S_{it})),\; f_L(A_{it})\,] \tag{7}$$

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 production technology. $\underline{A(S_{it})}$ thus satisfies

$$f_H[\,\underline{A(S_{it})} - F(S_{it})\,] = f_L[\,\underline{A(S_{it})}\,]. \tag{8}$$

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 S_{it} 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 (8) and the assumption that $F(\cdot)$ is decreasing in S_{it}. This effect is depicted in Figure 2.

[12] This is in the spirit of Cooper (1987), Murphy, Shleifer and Vishny (1989) or Azariadis and Drazen (1990), each of whom exploits similar technologies to analyze multiple equilibria. Milgrom and Roberts (1990) discuss how this type of non-convexity can arise as firms internally coordinate many complementary activities. Durlauf (1993) explores the role of complementarities and incomplete markets in economic growth under non-convexities of this type and shows that localized technological complementarities, when strong enough, produce long-run multiple equilibria.

An obvious implication is that the value of social network capital will vary across households. For households with sufficient privately-held assets, $A_{kt} \geq \underline{A(S_{kt})}$, adoption of H is optimal regardless of their stock of social network capital, but S_{it} nonetheless reduces the fixed costs they incur, thereby increasing the productivity of their asset stock. Their investment incentives are thus driven by the relative costs of investment in 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 prospective benefit from increased future social network capital eventually 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

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

$$U_i = u(C_{i0}) + \rho u(C_{i1}) \tag{9}$$

where ρ is the discount factor. We further assume there are no financial markets, thus autarkic saving is the only investment strategy. A subsistence consumption constraint applies such that

$$u(C_{it}) = -\infty \quad \text{for any } C_{ir} \leq 0 \text{ and } r \leq t. \tag{10}$$

This puts a minimal limit on the intertemporal consumption tradeoff available to the household by permanently penalizing non-positive consumption in any period.[13]

[13] This condition is redundant for some classes of utility function. We, however, include it here to generalize the context of the model. It will also be useful for part 5 as we will consider the special case of linear utility.

In period 0, a 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) column vector reflecting the combination of social relationships it establishes during period 0 – and the column vector of costs the household has to incur to establish or maintain these relationships (K_i).[14]

Note that the household incurs costs in period 0 for establishing network X_{i0}, but 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, as described in section 4. In period 1, the household again chooses the optimal production technology and consumes all the resulting income.[15]

A key distinction between A and S 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 unilateral decision, we thus define X^d_{i0} as a household i's desired network, representing the social network it would choose unilaterally, were that feasible. Note that this is not an equilibrium network.

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[14] Both K_i and X_{i0} are described in more detail in section 4.
[15] Zero investment in the terminal period is obviously an artifact of our simplifying assumption of a known, finite lifetime with no subsequent generations.

For every possible desired network, X_{i0}^{d}, a household can derive its corresponding optimal investment, $I_{i0}^{*}\left(X_{i0}^{d}\right)$. Specifically, the indirect utility that household i with endowments $\left(A_{i0}, S_{i0}\right)$ derives from a possible desired network X_{i0}^{d} is

$$V_{i}^{*}\left(X_{i0}^{d}\right) \quad = \quad \underset{\left\{C_{i0}\left(X_{i0}^{d}\right), I_{i0}\left(X_{i0}^{d}\right), C_{i1}\left(X_{i0}^{d}\right)\right\}}{Max} \quad u\left(C_{i0}\right)+\rho u\left(C_{i1}\right) \tag{11}$$

subject to:

$$C_{i0} \leq Y\left(A_{i0}, S_{i0}\right)-I_{i0}-X_{i0}^{d} K_{i}$$

$$A_{i1}=\left(1-\delta_{A}\right) A_{i0}+I_{i0}$$

$$S_{i1}=\left(1-\delta_{S}\right) S_{i0}+X_{i0}^{d} B_{i}$$

$$C_{i1} \leq Y\left(A_{i1}, S_{i1}\right)$$

$$S_{i1}, A_{i1} \geq 0$$

$$C_{i0}, C_{i1}>0.$$

The production function follows (7) and the subsistence constraint is incorporated into the final non-negativity constraint. Unilaterally, each rational household in this economy can perform intertemporal cost-benefit calculus for any of their possible networks. This structure provides a framework for the household's network formation strategy and creates a natural link between real capital and social network capital investment decisions. We now detail the specifications for the endogenous network formation and the suitable equilibrium concept in order to resolve this dynamic optimization problem.

4. Optimal social network structure

Because the formation of links is a strategic decision affecting households' optimal consumption and investment decisions, we model network formation as a non-cooperative game in which link formation is based on a binary process of mutual consent between individuals who costlessly observe the current wealth distribution. Due to the multiplicity of Nash equilibria, many of which make little sense from a social network perspective, we reduce the range of feasible equilibria through imposing two restrictions. The first follows from the fact, well-established in sociology, 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 apply the notion of pairwise stability to characterize social networks consistent with a stable Nash equilibrium in this economy. The ensuing subsections develop these points and the noncooperative network formation game in detail.

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

A broad literature suggests there exist boundaries to prospective social interactions. Santos and Barrett (2005, 2006), among others, find that not everyone knows everyone else, even in small, ethnically homogeneous rural settings in which households pursue the same livelihood, and that knowing someone is effectively a precondition to establishing an active link. Consistent with this, many models of network formation emphasize local interactions within prescribed neighborhoods (Ellison 1993, Ellison and Fudenberg 1993, Fagiolo 2001).

In our setting, each household is characterized by its universally observable (A_0, S_0) endowment. Thus each household can identify its social distance from every other household in (A, S) space. As in Akerlof (1997) or Mogues and Carter (2005), we use the geometric distance between households' endowments to reflect social distance,

$$d(i, j) = \sqrt{(A_{i0} - A_{j0})^2 + \alpha(S_{i0} - S_{j0})^2} \quad ; \alpha \geq 0, \tag{12}$$

for any pair of households, *i* and *j*, where α establishes the relative weight of pre-existing social network capital in determining social distance. Conceptually, social distance measures relative proximity between two households, which reflects the degree of discomfort in their social interaction. Potentially, it can thus serve as a proxy for the cost of establishing and maintaining a social relationship.

Formally, a household *i* incurs total costs of $X'_{i0}K_i$ to establish its network of links X_{i0}, where K_i is a column vector of costs they have to incur to establish each active link. Specifically, we assume that the economic cost to household *i* to establish a link with household *j* is

$$K_i(j) = \theta_1(d(i, j)) \cdot \left(\frac{A_{j0}}{A_{i0}}\right) \text{ with } \theta_1, \theta_1' > 0 \text{ for } d(i, j) \leq \bar{d}, \ \theta_1' = \infty \text{ otherwise.} \tag{13}$$

The idea is that it is easier to establish a link with people who are socially proximate, and intuitively the poorer partner may incur more costs. We assume no economies of scale or scope in building networks.

The constant $\bar{d}$ reflects a social distance threshold beyond which social interaction is not feasible. In our context, we assume that $\bar{d}$ is economy-specific but universal to each household in the economy.[16] It implicitly reflects physical and social barriers on the probability that individuals meet and interact. A low $\bar{d}$ 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 $\bar{d}$, 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' (at least partially nonrivalrous) asset endowments into augmentation to its social network capital next period. Specifically, the gross benefit to household *i* from a link with household *j* follows

$$B_i(j) = \theta_2 A_{j0} - \theta_3 \left| A_{i0} - A_{j0} \right| \text{ with } 0 < \theta_2, \theta_3 < 1. \tag{14}$$

Implicitly, $0 < \theta_2 < 1$ emphasizes the nature of access to link partners' (at least partially nonrivalrous) capital.[17] This generalization is highly stylized but very intuitive. 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 affecting (at some degree) the owner's (or other borrowers') use, but perhaps with degraded performance for the borrowing (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.

As with the costs of links, we assume that social network capital benefits are link-specific and independent of all others links the household establishes. The social network

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[16] This assumption is reasonable give households' identical preferences. The sensible extension of this context is to allow $\bar{d}$ to vary with other socioeconomic characteristics (e.g., initial endowments, groups).
[17] Note that in this simple model, benefits are only generated from direct links. There are no benefits from being connected to other households indirectly through one's direct links.

capital gained from a link is not 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 term in (14). The asymmetric specification fits the empirical pattern that great wealth disparities reduce the likelihood of link formation between households.[18]

Two fundamental points distinguish our network formation model from others. First, costs and benefits of links are realized intertemporally.[19] A household's preference over possible networks, therefore, relies on its 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 will benefit from social network capital. Therefore, many households' valuation of a given link is conditional on their success in establishing other links as well. To take into account these spillover possibilities, households' network strategies involve choosing among possible networks of links, instead of just myopically considering each link separately.

Let the indirect utility $V_i^*(X_i)$ represent the net intertemporal benefit to household *i* from a network X_i. To apply the established network decision framework in the proper noncooperative game setting, we now need to introduce the network structures and terminology.[20]

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[18] Of course, our cost-benefit specifications are highly stylized and thus somewhat arbitrary. Reasonable deviation from these specifics nonetheless retains the main ideas and results reported in section 5-7.

[19] In existing network formation models, relationship payoffs occur within the period (Jackson and Wolinsky 1996, Johnson and Gilles 2000, Calvo-Armensol and Jackson 2001, Goyal and Joshi 2002).

[20] We apply the widely accepted network notation, established by Jackson and Wolinsky (1996) and Jackson (2004).

4.2 Social network structure

Social links can be established within the feasible interaction space determined by $\bar{d}$.[21] We use the notation ij to 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:

$$X_i = \left(x(ij) / \, j \in N, j \neq i, d(i,j) \leq \bar{d} \right) \quad \text{where} \quad x(ij) \in \{0,1\}. \tag{15}$$

The binary index $x(ij)$ is defined by joint agreement to establish a link, $x(ij)=1$, or failure to jointly establish such a link, $x(ij)=0$.

By way of illustration, consider an economy with $N=\{1,2,3,4,5\}$ and the endowment distribution $\phi(A_0, S_0)$ illustrated in figure 3. For $\bar{d}=9$, for example, household 3's network can be generally represented by $X_3 = \begin{pmatrix} x(31) \\ x(32) \\ x(34) \end{pmatrix}$ with $x(3k) \in \{0,1\}$ for all $k=1,2,4$. Clearly interaction between 3 and 5 is not feasible because $d(3,5) > \bar{d} = 9$. Hypothetically, $X_3 = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$ represents household 3's network that consists of only a link with household 1. $X_3 = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$ arises when 3 establishes links with everyone with whom interaction is feasible, while $X_3 = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$ presents the case where household 3 has no links. Defining household *i*'s set of all feasible networks as Ω_i, in this example,

$$\Omega_3 = \left\{ \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}, \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}, \begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}, \begin{pmatrix} 0 \\ 1 \\ 1 \end{pmatrix}, \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} \right\}.$$

[21] In the language of the networks literature, $\bar{d}$ distinguishes between local and global interactions.

More generally, for an economy described of $N = \{1,2,...,n\}$ households, the set of all feasible links is represented by $g^N = \{ij/i, j \in N, i \neq j, d(i,j) \leq \overline{d}\}$.[22] The economy's network *g* represents any set of links $g \subset g^N$. The set $G = \{g/g \subset g^N\}$ denotes the set of the economy's all feasible networks. In any economy's network $g \in G$, household *i*'s network represents the combination of links in g involving household *i*. That is $X_i(g) = X_i$ with $x(ij) = 1$ for all $ij \in g$. The corresponding net intertemporal benefit to household *i* in an economy's network g is thus $V_i^*(X_i(g))$.

4.3 Noncooperative game of network formation

Endogenous social network formation results from costly, mutually consensual links formed between pairs of households. It is natural to treat this process as a noncooperative game. We therefore use a generalization of Myerson (1991)'s simple model of network formation under binary consent in a cooperative game setting.[23]

Generally, for a finite set of players represented by households $N = \{1,2,...,n\}$, a noncooperative game (A, Π) can be described as follows.

For every household $i \in N$, A_i denotes an action set:

$$A_i = \{(l_i(j)/ j \neq i, ij \in g^N)/l_i(j) \in \{0,1\}\}, \tag{16}$$

where an action $a_i = (l_i(j)/ j \neq i, ij \in g^N)$ reflects household *i*'s unilateral decision over all the feasible links. $l_i(j)$ indexes household *i*'s action with respect to a link ij and so $l_i(j) = 1$ if *i* seeks a link with *j*. Therefore, a link ij is established if $l_i(j) = l_j(i) = 1$. The set of economy-wide actions is thus described by $A = \prod_{i \in N} A_i$. The resulting network from any action $a \in A$ is thus given by

$$g(a) = \{ij \in g^N / l_i(j) = l_j(i) = 1\}. \tag{17}$$

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[22] Notice that g^N is not a set of all subset of N of size 2 as we only consider local interaction based on $\overline{d}$.

[23] Generalizations of Myerson (1991) are widely used, by Calvo-Armengol and Ilkilic (2004), Bloch and Jackson (2006) and Gilles, Chakrabarti and Sarangi (2006), among others.

For every household $i \in N$, $\Pi_i : A \rightarrow \Re$ denotes household i's payoff function assigning to every action $a \in A$, a net payoff $\Pi_i(a)$, deduced from participation in a network $g(a)$. Specifically, $\Pi_i(a) = V_i^*(X_i(g(a)))$. And the composite payoff function is represented by $\Pi = (\Pi_1,...,\Pi_n): A \rightarrow \Re^N$.

For every action $a_i = (l_i(j)/ j \neq i, ij \in g^N) \in A$ and $i \in N$, we denote actions selected by the households other than i as $a_{-i} \in A_{-i}$ where $A_{-i} = \prod_{i \neq j} A_j$. A network $g(a^*) \subset g^N$ is supported by a Nash equilibrium with an action $a^* \in A$ in our game (A, Π) if for every household $i \in N$, $\Pi_i(a^*) \geq \Pi_i(a_i^{**}, a_{-i}^*)$ for every action $a_i^{**} \in A_i$.

Because mutual consent is required to form a link but each individual partner can unilaterally delete a link in order to increase its payoff, this game will have many Nash equilibria. As but one obvious example, the empty network is supported as a Nash equilibrium in this game. This is especially unnatural in our context where links result in some net positive intertemporal payoff. We therefore need to refine the equilibrium concept in order to deal with this essential characteristic of mutually consensual link formation.[24] We choose to apply the pairwise stability concept.

4.4 Pairwise stability

The concept of pairwise stability[25] is due to Jackson and Wolinsky (1996). In our setting a network is pairwise stable if (i) no household would be better off if it severed one of its links, and (ii) no pair of households would both benefit (with at least one seeing a strict benefit) from adding a link that is not in the network.

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[24] It is well-recognized in the networks literature that the mutual consent requirement for link formation poses a hurdle to the use of any off-the-shelf game theoretic technique. Jackson (2005) thus suggests that either some sort of coalitional equilibrium concept or an extensive form game with a protocol for proposing and accepting links in some sequence is required. The game is necessarily ad hoc, and fine details of the protocol (e.g., the ordering of who proposes links when, whether or not the game has a finite horizon, players' patience, etc.) generally matter.

[25] This stability concept is criticized as insufficient for a network to be stable over time (Jackson 2005). Because it only considers deviations on a single link at a time, it might be possible that some group of players could be made better off by some complicated reorganizing of their links. Of course, one can use other refinements, such as the notion of strong stability (Dutta and Mutuswami 1997), which allows for deviation of larger coalitions. It may, however, not be necessary in this simple model, since we study only one round of network formation and do not aim to study the network structure per se.

Formally, a network $g' \in G^N$ is pairwise stable with respect to payoff structure Π if

(i) for all $ij \in g'$, $\Pi_i(g') \geq \Pi_i(g'-ij)$ and $\Pi_j(g') \geq \Pi_j(g'-ij)$ and

(ii) for all $ij \notin g'$, if $\Pi_i(g'+ij) > \Pi_i(g')$ then $\Pi_j(g'+ij) < \Pi_j(g')$ (18)

where $g'+ij$ represents the network that results from adding the link ij to the network g and similarly, $g'-ij$ denotes the network obtained by removing the link ij from network g.

The pairwise stable network g^* that arises from our noncooperative game will thus depict every household *i*'s optimal network $X_i^*(g^*)$ in this economy.[26] In the next section, we analyze household's equilibria and patterns of economic mobility for any pairwise stable network that may arise in this economy. And in section 6, more interestingly, we develop a specific protocol for the proposed noncooperative game that allows us to simulate a unique pairwise stable network for any economy. We then use such simulations to demonstrate our main results and the public policy implications.

5. Households' equilibria and patterns of economic mobility

Due to the mutual consent requirement for link formation, household *i*'s optimal network, resulting from the economy's pairwise stable network structure, constrains the optima for each household in the economy. The equilibrium of this model is, therefore, characterized by every household's accumulation decisions $\{X_{i0}^*, I_{i0}^*\}_{i=1,\dots,n}$, which determine current and future technology choice, consumption levels, and thus each household's level of well-being.

The preceding model specifications and equilibrium concepts prepare us now to study how social network capital influences households' economic mobility through their optimal network formation and capital accumulation decisions. We proceed by assigning specific functional forms to the general mappings outlined in section 3.

Specifically, in an economy of $N = \{i = 1,2,\dots,n\}$ households, we consider the case where each household *i*, initially endowed with (A_{i0}, S_{i0}), faces the unilateral

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

intertemporal utility maximization problem (11). We consider the extreme case where utility is linear in consumption, thereby maximizing a household's willingness to bear short-term reduction in current consumption in order to take advantage of a high rate of return on investment in owned assets or social network capital:

$$U_i(C_{i0}, C_{i1}) = aC_{i0} + \rho a C_{i1} \text{ , with } a > 0 \text{ and } 0 < \rho < 1. \qquad (19)$$

The household faces the non-convex production technology set satisfying conditions (1)-(6) in each period $t = 0,1$:

$$Y(A_{it}, S_{it}) = Max\,[\; k_1(A_{it})^{\alpha_1}, k_2(A_{it} - Fk_3^{-S_{it}})^{\alpha_2}\,] \quad \text{where} \qquad (20)$$

$$0 < \alpha_1, \alpha_2 < 1, \alpha_2 > \alpha_1,\; k_1, k_2 > 0,\; k_3 > 1 \text{ and } F > 0.$$

It is well-known that in this setting, with a non-convex technology set and constrained autarkic savings, there may exist multiple equilibria, one of which is the poverty trap associated with the choice of the low-return technology. We begin, in the next sub-section, by analyzing the benchmark case without social networks, in which the household's optimal welfare depends solely on its autarkic savings and accumulation capacity. We then expand the analysis to consider the case in which the households can form a social network and explore its effects on economic mobility, especially among those who might otherwise be trapped in poverty.

5.1 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. The non-convex production set in (20) 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.[27] For simplicity's sake, assume those who choose the low return technology (the first argument on the right-hand side of (20)) generate income that leaves them poor while those who choose the high-return technology (the second argument on the right-hand side of (20)) earn income that renders them non-poor. Thus threshold $\underline{A}$ represents a static asset poverty line, which distinguishes *current* poor from non-poor. In

[27] $\underline{A}$ satisfies a condition analogous to that in (8).

any period *t*, the poor in our context are, therefore, those households with $A_t < \underline{A}$, i.e. those currently undertaking low-return production.

Household *i*'s first-order conditions for an interior optimum thus potentially yield two equilibria: the low-level equilibrium (poverty trap) $U_{iL}^{*}\left(S_{i0}=0, X_{i0}=\underline{0}\right)$ and the high-level equilibrium $U_{iH}^{*}\left(S_{i0}=0, X_{i0}=\underline{0}\right)$ such that

$$U_{iL}^{*}\left(S_{i0}=0, X_{i0}=\underline{0}\right)=aC_{i0L}^{*}+\rho aC_{i1L}^{*}= \tag{21}$$

$$a\left(Y\left(A_{i0}\right)+\left(1-\delta_A\right)A_{i0}-\left(\rho\alpha_1k_1\right)^{\frac{1}{1-\alpha_1}}\right)+\rho a\left(k_1\left(\rho\alpha_1k_1\right)^{\frac{\alpha_1}{1-\alpha_1}}\right) \qquad \text{and}$$

$$U_{iH}^{*}\left(S_{i0}=0, X_{i0}=\underline{0}\right)=aC_{i0H}^{*}+\rho aC_{i1H}^{*}=$$

$$a\left(Y\left(A_{i0}\right)+\left(1-\delta_A\right)A_{i0}-\left(\rho\alpha_2k_2\right)^{\frac{1}{1-\alpha_2}}-F\right)+\rho a\left(k_2\left(\rho\alpha_2k_2\right)^{\frac{\alpha_2}{1-\alpha_2}}\right).$$

We ensure the existence of these two equilibria by making two rather innocuous assumptions, which constrain our parameterization. First, for any household *i*, a high-level equilibrium of well-being is always preferred to a lower one:

$$U_{iH}^{*}\left(S_{i0}=0, X_{i0}=\underline{0}\right)>U_{iL}^{*}\left(S_{i0}=0, X_{i0}=\underline{0}\right) \quad \Leftrightarrow \tag{22}$$

$$\left[\rho\left(k_2\left(\rho\alpha_2k_2\right)^{\frac{\alpha_2}{1-\alpha_2}}\right)-\left(\rho\alpha_2k_2\right)^{\frac{1}{1-\alpha_2}}-F\right]-\left[\rho\left(k_1\left(\rho\alpha_1k_1\right)^{\frac{\alpha_1}{1-\alpha_1}}\right)-\left(\rho\alpha_1k_1\right)^{\frac{1}{1-\alpha_1}}\right]>0.$$

Not every household, however, can achieve U_{iH}^{*}. This depends on a household's feasible autarkic savings. Formally, household *i* reaches a high-level equilibrium if and only if $C_{i0H}^{*}\left(S_{i0}=0, X_{i0}=\underline{0}\right)\geq 0$, i.e., if they can afford the autarkic savings corresponding to the high-level equilibrium. For others who cannot afford this costly savings, we then make the second assumption that accumulation toward U_{iL}^{*} is at least feasible, thus

$$C_{i0L}^{*}\left(S_{i0}=0, X_{i0}=\underline{0}\right)>0 \quad \Leftrightarrow \quad Y\left(A_{i0}\right)+\left(1-\delta_A\right)A_{i0}-\left(\rho\alpha_1k_1\right)^{\frac{1}{1-\alpha_1}}>0. \tag{23}$$

Now consider the benchmark setting where it is possible for some initially poor household to escape poverty. Formally, the initially poor households graduate to the high-level equilibrium, and thereby escape poverty, through autarkic savings if and only if

$$C_{i0H}^{*}\left(S_{i0}=0, X_{i0}=\underline{0}\right)>0 \quad \Leftrightarrow \quad k_1\left(A_{i0}\right)^{\alpha_1}+\left(1-\delta_A\right)A_{i0}-\left(\rho\alpha_2k_2\right)^{\frac{1}{1-\alpha_2}}-F>0. \tag{24}$$

Typical for any poverty trap model, (24) suggests the existence of a dynamic asset threshold A_0^* at which optimal household savings (i.e., asset accumulation) bifurcates. Those initially poor households with $\underline{A} > A_{i0} \geq A_0^*$[28] will save and escape poverty in the future (albeit not in the initial period), while other poor with $A_{i0} < A_0^*$ are trapped in long-term poverty. This dynamic asset threshold is analogous to the *dynamic asset poverty line* proposed by Carter and Barrett (2006). In the absence of social network capital, a household's initial endowment of productive assets, A_{i0}, determines its long-term equilibrium well-being. Note also that by this construction initially non-poor households (whose $A_{i0} \geq \underline{A} > A_0^*$) are always able to achieve the high-return equilibrium.[29]

5.2 The possibilities presented by social networks and their limitations

Let us now reintroduce the possibility of social network capital that reduces the fixed cost associated with using the high-return production technique. This generalizes the static asset poverty line $\underline{A(S_t)}$ such that any household with $A_{i0} \geq \underline{A(S_{i0})}$ optimally undertakes high-return production in period 0, while those with $A_{i0} < \underline{A(S_{i0})}$ optimally choose the low-return technique in the first period. $\underline{A(S_{i0})}$ thus solves

$$k_1[\underline{A(S_{i0})}]^{\alpha_1} = k_2[\underline{A(S_{i0})} - Fk_3^{-S_{i0}}]^{\alpha_2} \tag{25}$$

with $\underline{A'(S_{i0})} < 0$, so that greater social network capital lowers the static asset poverty line, as previously discussed in section 3.1. 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

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[28] 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 $\underline{A} < A_{i0}$, $k_1(A_{i0})^{\alpha_1} < k_2(A_{i0} - F)^{\alpha_2}$, and so the household can initially adopt high-return production technology. Thus, $Y(A_0) = k_2(A_{i0} - F)^{\alpha_2}$. But as $A_{i0} < A_0^*$, $C_{i0H}^*(S_{i0} = 0, X_{i0} = \underline{0}) < 0$ implies $k_2(A_{i0} - F)^{\alpha_2} + (1 - \delta_A)A_{i0} - (\rho\alpha_2 k_2)^{\frac{1}{1-\alpha_2}} - F < 0$. This, however, contradicts (24).

[29] This condition rules out the possibility of downward mobility of the initially non-poor, which is reasonable given there is no uncertainty in the model.

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.

The existence of multiple equilibria is confirmed by our previous assumptions in (22) and (23). For any optimal social network X_{i0} that household *i* establishes, the two possible equilibria are

$$U_{iL}^*\left(X_{i0}\right)=aC_{i0L}^*+\rho aC_{i1L}^*= \tag{26}$$

$$a\left(Y\left(A_{i0},S_{i0}\right)+\left(1-\delta_A\right)A_{i0}-X_{i0}'K_i-\left(\rho\alpha_1 k_1\right)^{\frac{1}{1-\alpha_1}}\right)+\rho a\left(k_1\left(\rho\alpha_1 k_1\right)^{\frac{\alpha_1}{1-\alpha_1}}\right) \quad \text{and}$$

$$U_{iH}^*\left(X_{i0}\right)=aC_{i0H}^*+\rho aC_{i1H}^*=$$

$$a\left(Y\left(A_{i0},S_{i0}\right)+\left(1-\delta_A\right)A_{i0}-X_{i0}'K_i-\left(\rho\alpha_2 k_2\right)^{\frac{1}{1-\alpha_2}}-Fk_3^{-\left[\left(1-\delta_s\right)S_{i0}+X_{i0}'B_i\right]}\right)+\rho a\left(k_2\left(\rho\alpha_2 k_2\right)^{\frac{\alpha_2}{1-\alpha_2}}\right).$$

Analogous to the benchmark case, any household *i* with an optimal social network X_{i0} can achieve the high-level equilibrium $U_{iH}^*\left(X_{i0}\right)$ if and only if $C_{i0H}^*\left(X_{i0}\right)\geq 0$.

Perhaps more interestingly, and less obviously, household *i*'s ability to establish a network X_{i0} may affect the dynamic asset poverty line. Consider an initially poor household (whose $A_{i0}<\underline{A(S_{i0})}$). It can gradually accumulate resources toward the high-level equilibrium, and thus escape future (but not current) poverty, if it establishes a productive network X_{i0} such that[30]

$$C_{i0H}^*\left(X_{i0}\right)>0 \Leftrightarrow k_1\left(A_{i0}\right)^{\alpha_1}+\left(1-\delta_A\right)A_{i0}-\left(\rho\alpha_2 k_2\right)^{\frac{1}{1-\alpha_2}}-Fk_3^{-\left[\left(1-\delta_s\right)S_0+X_{i0}'B_i\right]}-X_{i0}'K_i>0 . \tag{27}$$

Therefore, according to (27), there exist three distinct avenues by which the initially poor can reach the high-level equilibrium. First, a poor household can undertake autarkic savings, just as in the previous section without social network capital. Note that unlike in the preceding case, a greater endowment of social network capital (S_{i0}) reduces the savings required to reach $\underline{A(S_{i0})}$ and thus to reach the high-level equilibrium in the future. Those well-endowed with social network capital are thus better positioned to escape

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[30] If there exists a network $X_{i0}\neq\underline{0}$ such that $C_{i0H}^*\left(X_{i0}\right)>0$, then $U_{iH}^*\left(X_{i0}\right)>U_{iL}^*\left(X_{i0}=\underline{0}\right)$ if $C_{i0H}^*\left(X_{i0}\right)>C_{i0H}^*\left(X_{i0}=\underline{0}\right)$ by (22) and (23). 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 $C_{i0H}^*\left(X_{i0}=\underline{0}\right)>C_{i0H}^*\left(X_{i0}\right)>0$, then it is optimal for the household to graduate from poverty through autarkic savings.

poverty through an autarkic savings strategy. Second, the initially poor household can establish new social links that generate enough future social network capital to drive down $\underline{A(S_{i1})}$ to the point that the high-return technology becomes optimal in the next period, without necessarily having to accumulate capital itself. Third, the household can invest in both social links to lower the asset threshold and private capital to augment its initial endowment and let it attain this lowered threshold level.

These latter two avenues indicate that the dynamic asset poverty threshold depends not only on 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. 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 long-term well-being. Unlike standard poverty traps models in which one's initial conditions determine one's growth prospects, in a setting where social interactions can condition investment behavior, the initial conditions of the entire economy now matter.

Intuitively, (27) suggests that there exists a dynamic asset threshold condition on a given endowed network structure, $A_0^*(S_{i0} / X_{i0} = \underline{0})$, such that for initially poor households with $A_0^*(S_{i0} / X_{i0} = \underline{0}) \le A_{i0} < \underline{A(S_{i0})}$,

$$C_{i0H}^*(X_{i0} = \underline{0}) > 0 \quad \Leftrightarrow \quad k_1(A_{i0})^{\alpha_1} + (1-\delta_A)A_{i0} - (\rho\alpha_2 k_2)^{\frac{1}{1-\alpha_2}} - Fk_3^{-[(1-\delta_s)S_{i0}]} > 0 . \quad (28)$$

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

$$C_{i0H}^*(X_0) > C_{i0H}^*(X_{i0} = \underline{0}) \quad \Leftrightarrow \quad \frac{X'_{i0}K_i}{Fk_3^{-[(1-\delta_S)S_{i0}]}} + k_3^{-X'_{i0}B_i} < 1 . \quad (29)$$

For other initially poor households with $A_{i0} < A_0^*(S_{i0} / X_{i0} = \underline{0}) < \underline{A(S_{i0})}$, they cannot reach the high-level equilibrium without establishing new social links so as to accumulate additional social network capital and thereby make future adoption of the high-return technology optimal.

Any household that fails to meet condition (28) – 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 – will never consider establishing a social network with others. 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. This follows from

$$U_{iL}^*(X_{i0} = \underline{0}) > U_{iL}^*(\widehat{X}_{i0}),\ \forall \widehat{X}_{i0} \neq \underline{0}. \tag{30}$$

This captures the notion that for many poor people, social networks do not provide a viable escape route from long-term poverty, as Mogues and Carter (2005) and Adato et al. (2006) argue with reference to post-apartheid South Africa.

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 $A_0^* \le A_{i0} < \underline{A(S_{i0})}$ 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 – in advancing economic mobility. For such households, social network capital reduces the savings required to graduate to the high-level equilibrium and thereby increases lifetime utility. In such cases, social network capital is a substitute for traditional capital accumulation in facilitating productivity and welfare growth.

For the initially poor households (whose $A_{i0} < \underline{A(S_{i0})}$) 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. There are 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 that, even with social network capital depreciation, δ_S, their extant social network capital suffices to enable traditional capital accumulation enough to reach the high-level equilibrium in period 1. 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.

5.3 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 society 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 (whose $A_{i0} < \underline{A(S_{i0})}$) upon realization of their optimal network X_{i0}^*. In the next section we explore, via simulation, the process by which these patterns originate. Here we simply characterize these distinct subpopulations, building directly on the previous sub-section.

(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. Their optimality condition can be characterized as

$$X_{i0}^* = \underline{0} \text{ and } U_i^* = U_{iH}^*(X_{i0}^* = \underline{0}). \tag{31}$$

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., $U_{iH}^{*}\left(\vec{X}_{i0}\right) < U_{iH}^{*}\left(X_{i0} = \underline{0}\right)$, $\forall \vec{X}_{i0} \in \Omega_{i0}$. Other households may be regrettably autarkic in their climb out of poverty, having failed to establish any preferred network, $\hat{X}_{i0} \in \Omega_{i0}$ such that $U_{iH}^{*}\left(\hat{X}_{i0}\right) > U_{iH}^{*}\left(X_{i0} = \underline{0}\right)$. 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.

(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

$$X_{i0}^{*} \neq \underline{0} \text{ and } U_{i}^{*} = U_{iH}^{*}\left(X_{i0}^{*}\right). \tag{32}$$

This subpopulation's experience of a socially-mediated climb out of poverty is the phenomenon that 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 $A_{i0} \geq A_{0}^{*}\left(S_{i0} / X_{i0} = \underline{0}\right)$ 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 $A_{i0} < A_{0}^{*}\left(S_{i0} / X_{i0} = \underline{0}\right)$. 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. This subpopulation is fortunate in that the underlying attribute distribution in the economy generated sufficient social proximity that others were willing to link with these poor households.

(3) *Households involuntarily excluded from social networks and trapped in poverty*

Others are not so fortunate. The next subpopulation of the initially poor could escape from poverty if they were able to establish one or more of their preferred social networks. However, they are rebuffed by those they approach for possible links and in the absence of their desired social network capital, 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. A bit more formally, although there exists at least one network $\widetilde{X}_{i0} \in \Omega_{i0}$ such that $C^*_{i0H}\left(\widetilde{X}_{i0}\right) > 0$, 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

$$X^*_{i0} = \underline{0} \ , \ U^*_i = U^*_{iL}\left(X^*_{i0} = \underline{0}\right) \ \text{and} \ \exists \widetilde{X}_{i0} \in \Omega_{i0} \ \text{such that} \ C^*_{i0H}\left(\widetilde{X}_{i0}\right) > 0 \,. \tag{34}$$

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) *Households who choose social isolation and remain trapped in poverty*

The final subpopulation comprises those with especially meager endowments, $A_{i0} < A^*_0\left(S_{i0} / X_{i0} = \underline{0}\right)$, 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

$$X^*_{i0} = \underline{0} \ , \ U^*_i = U^*_{iL}\left(X^*_{i0} = \underline{0}\right) \ \text{and} \ C^*_{i0H}\left(\overleftarrow{X}_{i0}\right) < 0 \ \text{ for all } \ \overleftarrow{X}_{i0} \in \Omega_{i0} \,. \tag{33}$$

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 distinct mobility and immobility patterns are a product of the underlying distribution of endowments in society and the limits to social interaction. The next section uses simulation methods to illustrate these patterns and further examine the underlying socioeconomic structures of social network formation that affect economic mobility.

6. Simulation of endogenous network formation and economic mobility

As the final step towards simulating patterns of endogenous social network formation and associated economic mobility, we now develop a specific protocol for generating a unique pairwise stable network in a given economy. We then apply this protocol to simulate households' resulting long-run equilibria for several randomly generated economies.

6.1 Network formation protocol

To sort out a unique pairwise stable network, we extend the proposed normal form noncooperative game by specifying an algorithm for proposing and accepting links that yields a sequential matching process.[31] More specifically, every household *i* can develop a set of ranked networks, Ω_i^{Ranked}, by ranking all the feasible networks in Ω_i based on the corresponding indirect utilities. In our matching protocol, households attempt to establish their utility maximizing network and therefore interact with others using Ω_i^{Ranked} as their best response function as follows.

Initially, households consider their top-ranked network. They simultaneously propose to each of the other households with which they wish to link. The link between two households is established if and only if (i) both agents propose to each other, and (ii) 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 network, this link is binding. Such partners continue to play the game, with their utility maximization now constrained by the link commitment. All households that do not optimize their networks in a proposal stage move on to the next stage, when they again make simultaneous proposals to each of those

[31] 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, however, from Gale and Shapley's (1962) original approach, which considers a two-sided one-to-one matching game in which members of two sides are referred to as Xs and Ys. It also differs from marriage models and roommates problem in which individuals can match with only one partner.

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.

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., the one with lowest A_0) has to forego its top-ranked network and instead use its second-best network while the rest still play with their top-ranked networks. If still no one can optimize the network, the second poorest household then sacrifices its first-best network and must play make link proposals to its second-best network while all richer households still play their first-best strategy, and so on. The process of sequential matching continues until everyone optimizes their networks following the protocol outlined above. For any preferences, the process eventually stops because there exists a finite set of households in this economy. This ensures the existence of a unique pairwise stable matching (a sub-game perfect equilibrium) in this finite extensive form game with perfect information. Figure 4 offers a numerical example of this game and its pairwise stable matching for the example economy from Figure 3.

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 directly from the fact that households' preferences with respect to 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 economywide. This creates a stark contrast vis-à-vis the optimality conditions that would result from unilateral decisions regarding social network structure. Third, the game's unique pairwise stable network tends to favor those households able and/or preferring to link with a small number of others in the first place.[32]

6.2 Simulation results

The analysis assumes 17 households,[33] each endowed with randomly generated (A_0, S_0), cumulatively representing the economy's endowment distribution, $\phi(A_0, S_0)$. Appendix 1 reports the exact parameterization of this model. Our goal is to illustrate the emergence of the distinct patterns of economic mobility and immobility among the initially poor we identified earlier. One core point we emphasize is that mobility and immobility patterns vary with the socioeconomic structure of the economy (represented here by the joint distribution of endowed capital and social network capital). Two otherwise identical households, dropped into quite different economies, can follow quite different patterns. Economic mobility is thus, at least in part, socially constructed.

Figures 5-10 each depict a randomly generated economy. Households are represented by their 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 household that enjoys the high-level equilibrium 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 (or immobility) of the initially poor.

[32] This is illustrated in the simulation statistics in appendix 2.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 (bottom graphic in appendix 2) and non-monotonically in feasible network size (top graphic in appendix 2). This merely reflects that the more matches one wishes to make, the more likely that at least one prospective partner rebuffs one's link offer. More complex networks are harder to establish.

[33] 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.

Figure 5 provides a simple illustration of the distinct patterns that emerge from this model.[34] The initially poor who escape from poverty without forming new social networks are represented by the household with initial endowment (3,7). 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 (6,5)). 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 with the lowest A_0 endowments).

Figure 6 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_o^* represents the dynamic asset poverty line in the absence of social network capital, as in Carter and Barrett (2006). 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 substitute for savings and traditional capital accumulation. But households in region A are all independently economically mobile.

Those households beneath the dynamic asset threshold A_0^* all require social network 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.

[34] This particular set of random endowments, which we label "Economy 1", will be used again in Figures 12 and 13 to demonstrate particular points. The label is meant to facilitate visual comparison across these figures.

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. Figure 6's mapping of endowment space thus underscores the multiple roles social network capital can play in conditioning household economic growth paths, 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 7-10 illustrate clearly the impact of the initial socioeconomic 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 Figure 6 – and displays four panels that differ solely by the initial distribution of households in the economy. The southeastern panel in each figure shows the case of a highly polarized economy, so that we can underscore the impact of socio-economic polarization on the economic mobility of the poor, a point raised insightfully by Mogues and Carter (2005).

Figures 7 and 8 depict the initially poor who are autarkically mobile, in the former case irrespective of social network capital, in the case of Figure 8, thanks to their initial endowment of social network capital. Neither household *a* in Figure 7 nor household *b* in Figure 8 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 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 9 illustrates perhaps the most interesting case. Here we see how the underlying structure of the economy conditions economic mobility for some of the initially poor, those (such as household *c*) in what Figure 6 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 Figure 9, 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[35] 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 equilibrium. The subpopulation depicted in Figure 9 is thus the group for whom social networks and the underlying structure of society fundamentally shape economic mobility (or immobility).

Finally, as shown in Figure 10, 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.

[35] We label this particular initial endowment "Economy 2" for further use in Figure 13.

Those who begin too poor simply can't leverage their meager endowments no matter how skillfully they interconnect themselves with others. This is underscored more sharply in Figure 11 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.

7. 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. (1995) and Cox et al. (2004), 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 are formed endogenously, then transfers could change the configuration of networks. 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. Figure 12 visualizes our base case without transfers, overlaying four specific households – *e*, *f*, *g* and *h* – with region C identified in figure 6. The upper two rows of Figure 13 then illustrate the possible crowding-in effects for four distinct cases of transfers to the households depicted in Figure 12 – using exactly the same initial endowments, i.e., economy 1. The bottom row of

Figure 13 presents two different cases of transfers to every poor household in a polarized economy (economy 2, previously depicted without transfers in the southeastern quadrant of Figure 9).

The upper left example in Figure 13 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, as shown in Figure 12. But with the benefit of a modest transfer,[36] 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 depicted in Figure 12 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 Figure 13 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, in Figure 12. 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 Figure 13 shows a similar effect, in this case through a one unit transfer to household *f*, which was socially excluded in the no-transfer setting (Figure 12), but now links to three other households, one of which was already able to climb out of poverty through autarkic savings, another of which was, like *f*, socially excluded but can leverage its new social link to accumulate enough social network capital to climb out of poverty by period 1, and the third of which 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 Figure 13 illustrates how even relatively large transfers – 1.5 units of *A* to household *h* – can fail to generate

[36] 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.

poverty reduction gains when they are poorly targeted. Although the transfer brings household *h* right 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. Even in a highly polarized economy, such as that previously depicted in the lower right quadrant of Figure 9, transfers to multiple poor households can stimulate the emergency 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 Figure 13, 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 Figure 13, which shows the result of transfers to all poor households of just one unit of *A* instead of two units, as in the previous example. 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.

8. Conclusions

Social network capital can be an important facilitator of upward 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 households, 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 (Carter and Barrett 2006) 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 instead. And 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 social exclusionary mechanisms are economy-specific, depending fundamentally on the underlying distribution of endowments that determine the net benefits to agents of social links.

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Figure 1: Locally increasing return production technology

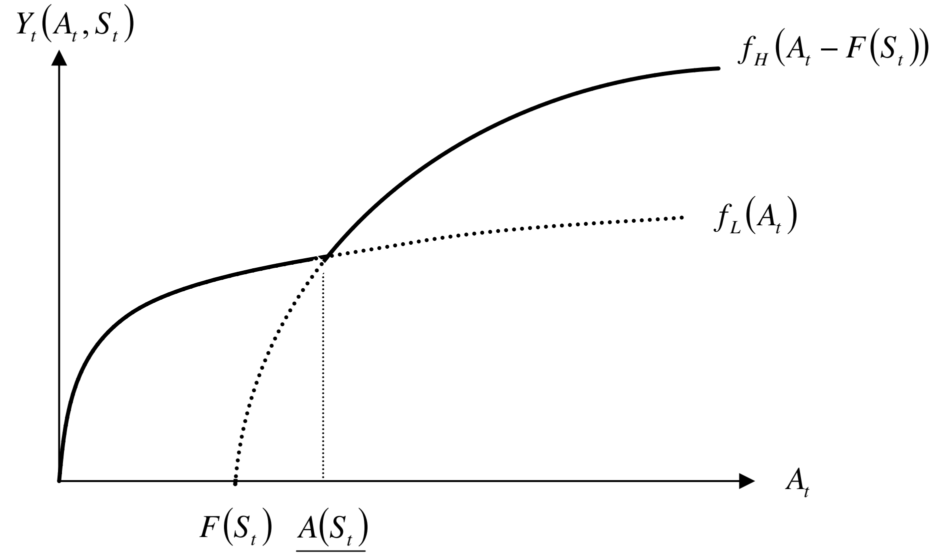


Figure 2: Locally increasing return production technology when acquiring more social networking capital ($S_t' > S_t$)

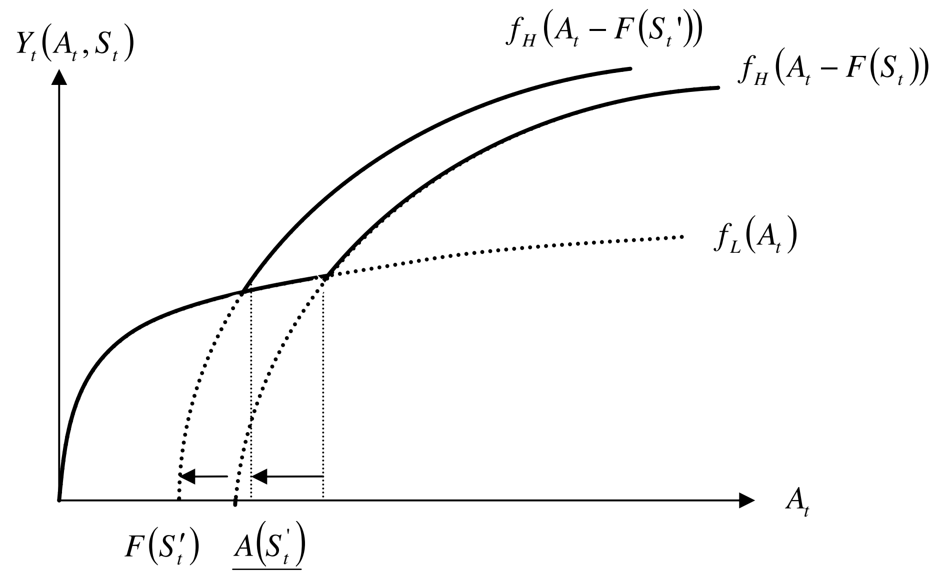


Figure 3: Example economy with $N = \{1,2,3,4,5\}$ and initial distribution $\phi(A_0, S_0)$

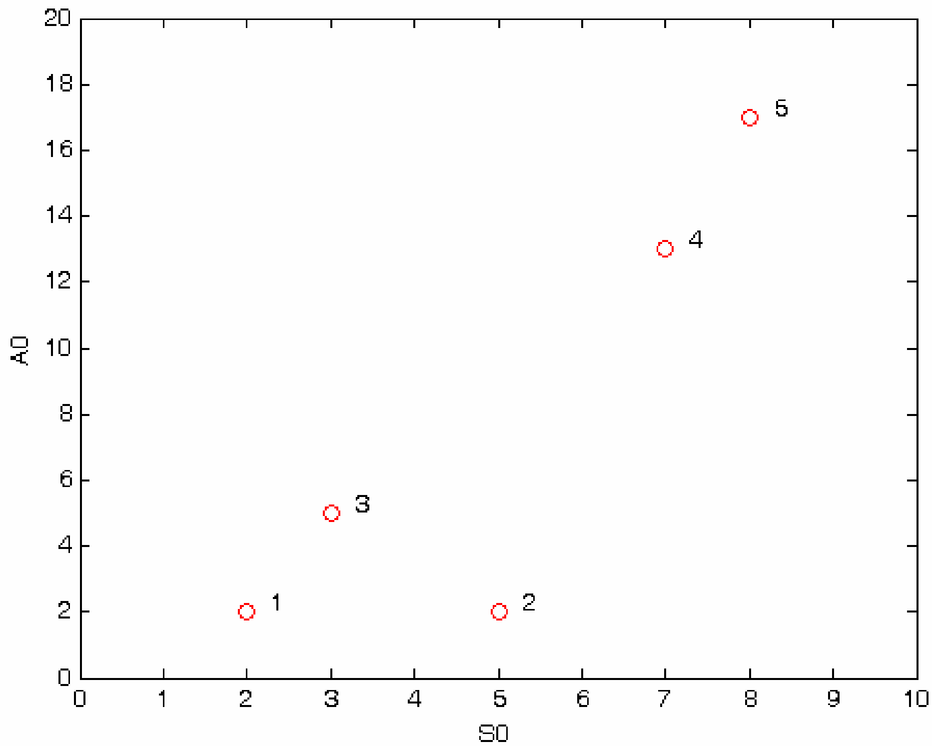
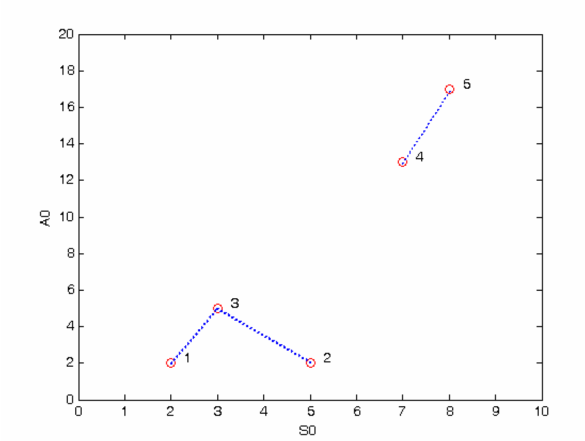


Figure 4: Example of endogenous network formation



$$\Omega_1^{Ranked} = \left\{ \begin{pmatrix} x(12) \\ x(13) \end{pmatrix} \right\} = \left\{ \begin{pmatrix} 1 \\ 1 \end{pmatrix}, \begin{pmatrix} 0 \\ 1 \end{pmatrix}, \begin{pmatrix} 1 \\ 0 \end{pmatrix}, \begin{pmatrix} 0 \\ 0 \end{pmatrix} \right\}$$

$$\Omega_2^{Ranked} = \begin{Bmatrix} x(21) \\ x(23) \end{Bmatrix} = \left\{ \begin{pmatrix} 0 \\ 1 \end{pmatrix}, \begin{pmatrix} 1 \\ 1 \end{pmatrix}, \begin{pmatrix} 1 \\ 0 \end{pmatrix}, \begin{pmatrix} 0 \\ 0 \end{pmatrix} \right\}$$

$$\Omega_3^{Ranked} = \begin{Bmatrix} x(31) \\ x(32) \\ x(34) \end{Bmatrix} = \left\{ \begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}, \begin{pmatrix} 0 \\ 1 \\ 1 \end{pmatrix}, \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}, \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}, \begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}, \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \right\}$$

$$\Omega_4^{Ranked} = \begin{Bmatrix} x(43) \\ x(45) \end{Bmatrix} = \left\{ \begin{pmatrix} 0 \\ 1 \end{pmatrix}, \begin{pmatrix} 1 \\ 1 \end{pmatrix}, \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 \\ 0 \end{pmatrix} \right\}$$

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

The progress of interaction procedure is shown below, "$\rightarrow$" stands for "propose to"

	Round 1	**Round 2**	**Round 3**
HH 1:	$\rightarrow 2$ No	$\rightarrow 2$ No	
	$\rightarrow 3$ Match	$\rightarrow 3$ Match	$\xrightarrow{established} X_1^* = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$
HH 2:	$\rightarrow 3$ No	$\rightarrow 3$ Match $X_2^* = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$	
HH 3:	$\rightarrow 1$ Match	$\rightarrow 1$ Match	
	$\rightarrow 4$ No	$\rightarrow 2$ Match $X_3^* = \begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix}$	
HH 4:	$\rightarrow 5$ Match $X_4^* = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$		
HH 5:	$\rightarrow 4$ Match $X_5^* = 1$		

Figure 5: Basic simulation illustration

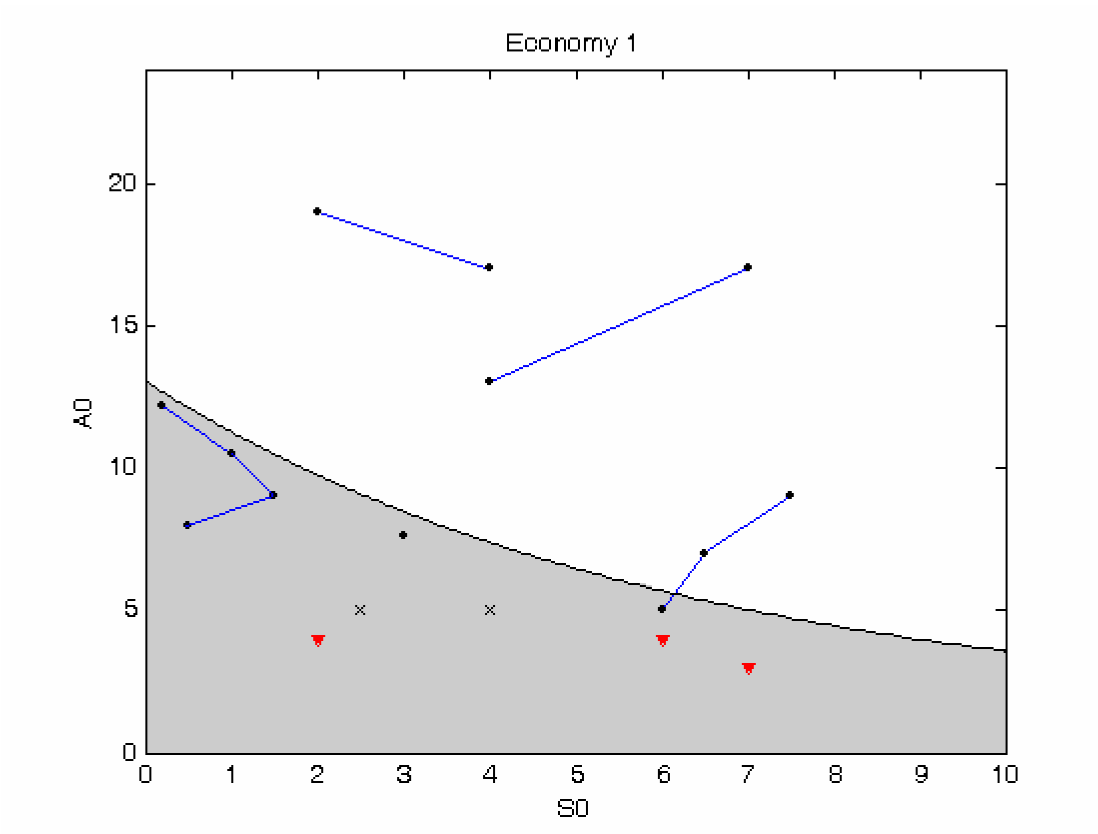


Figure 6: The space of social mobility and immobility in one simulated economy

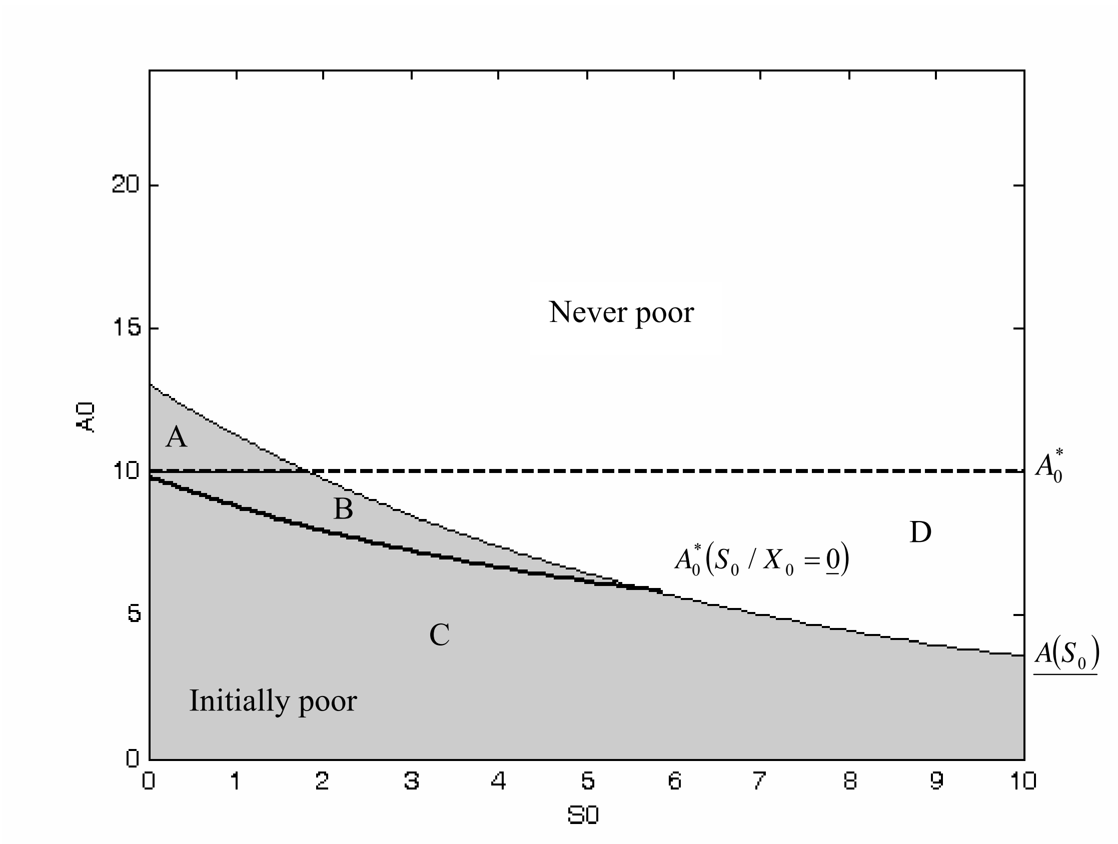


Figure 7: Different patterns for an autarkically mobile household

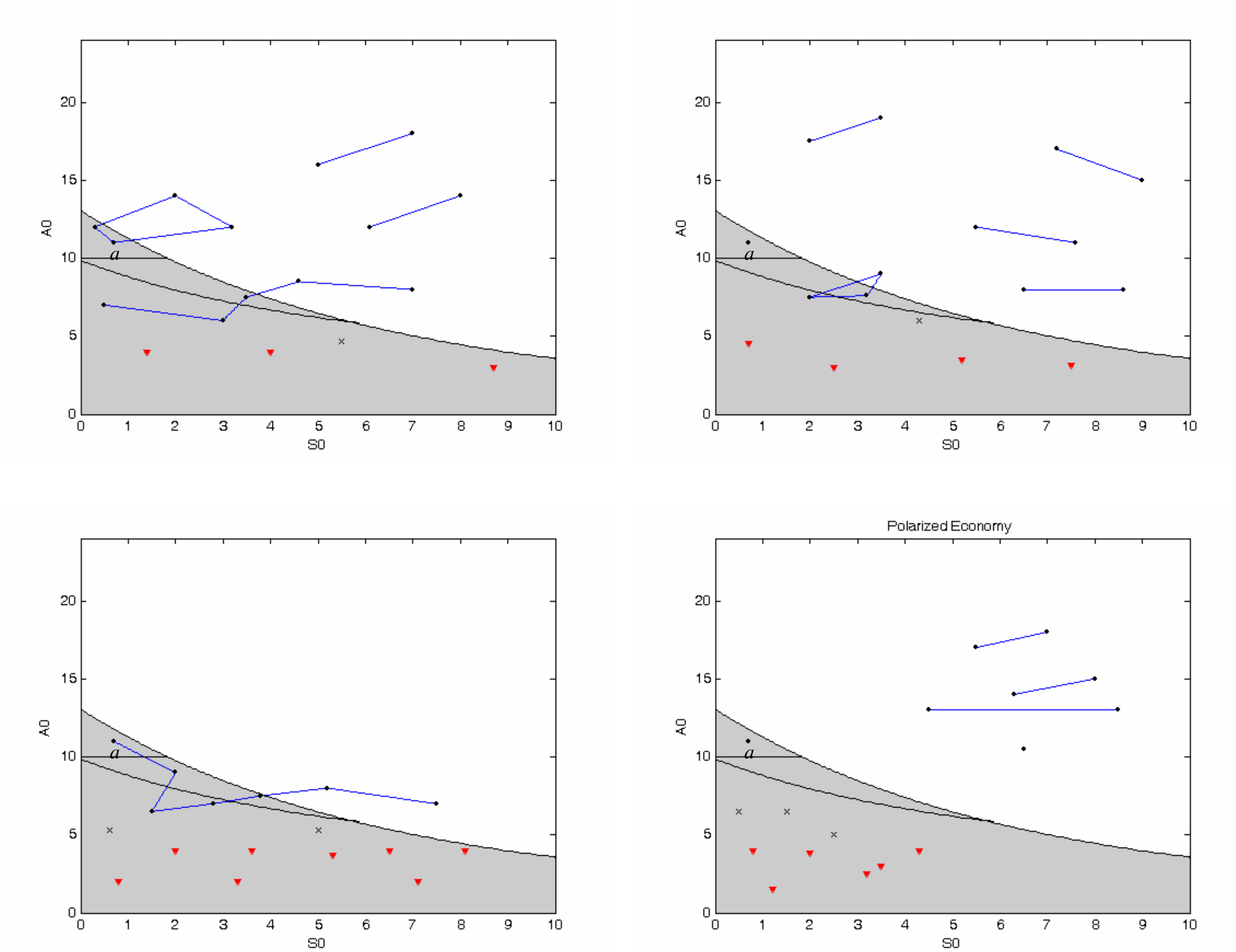


Figure 8: Different patterns for a household autarkically mobile given its S_0

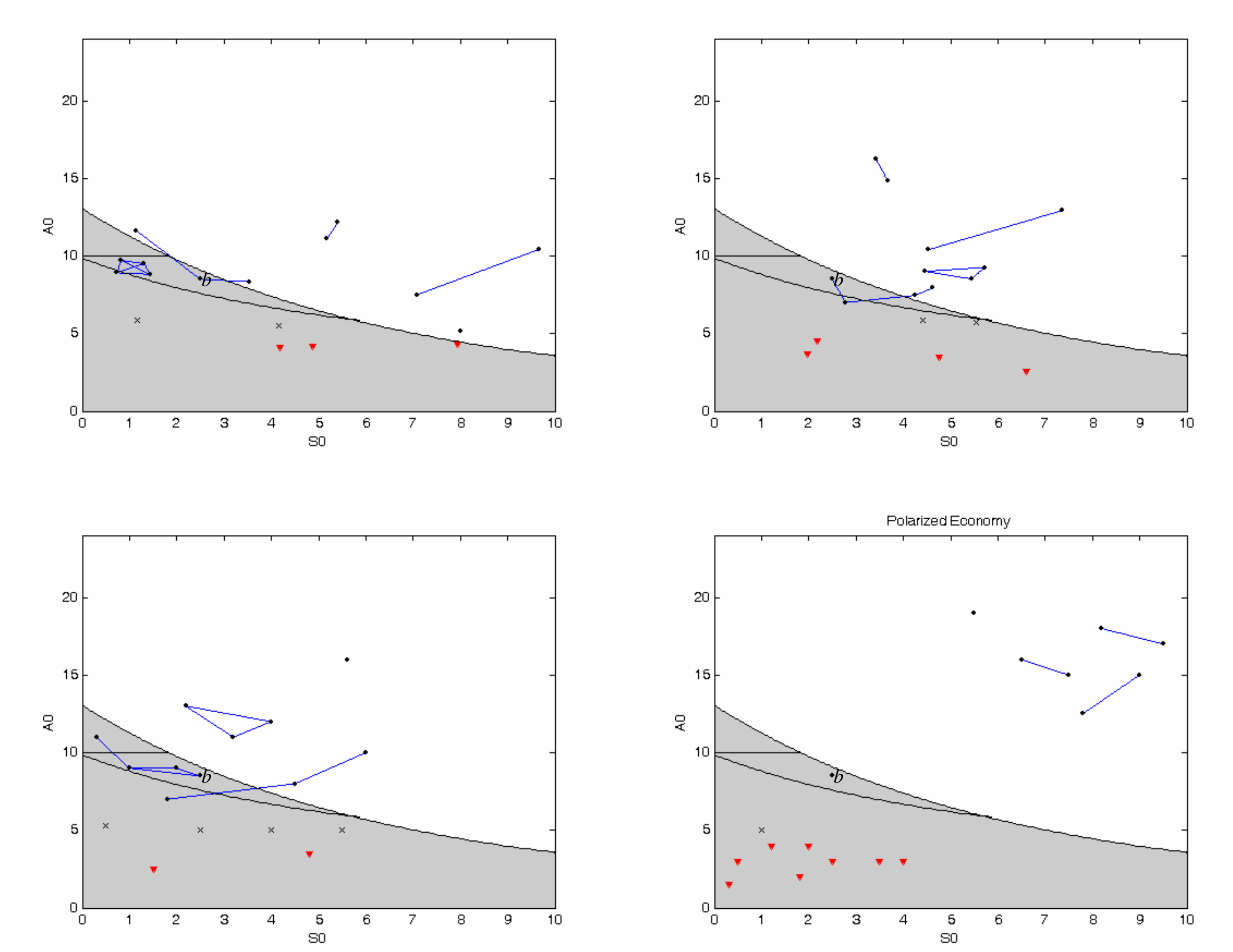


Figure 9: Different patterns for a household whose mobility depends on social links

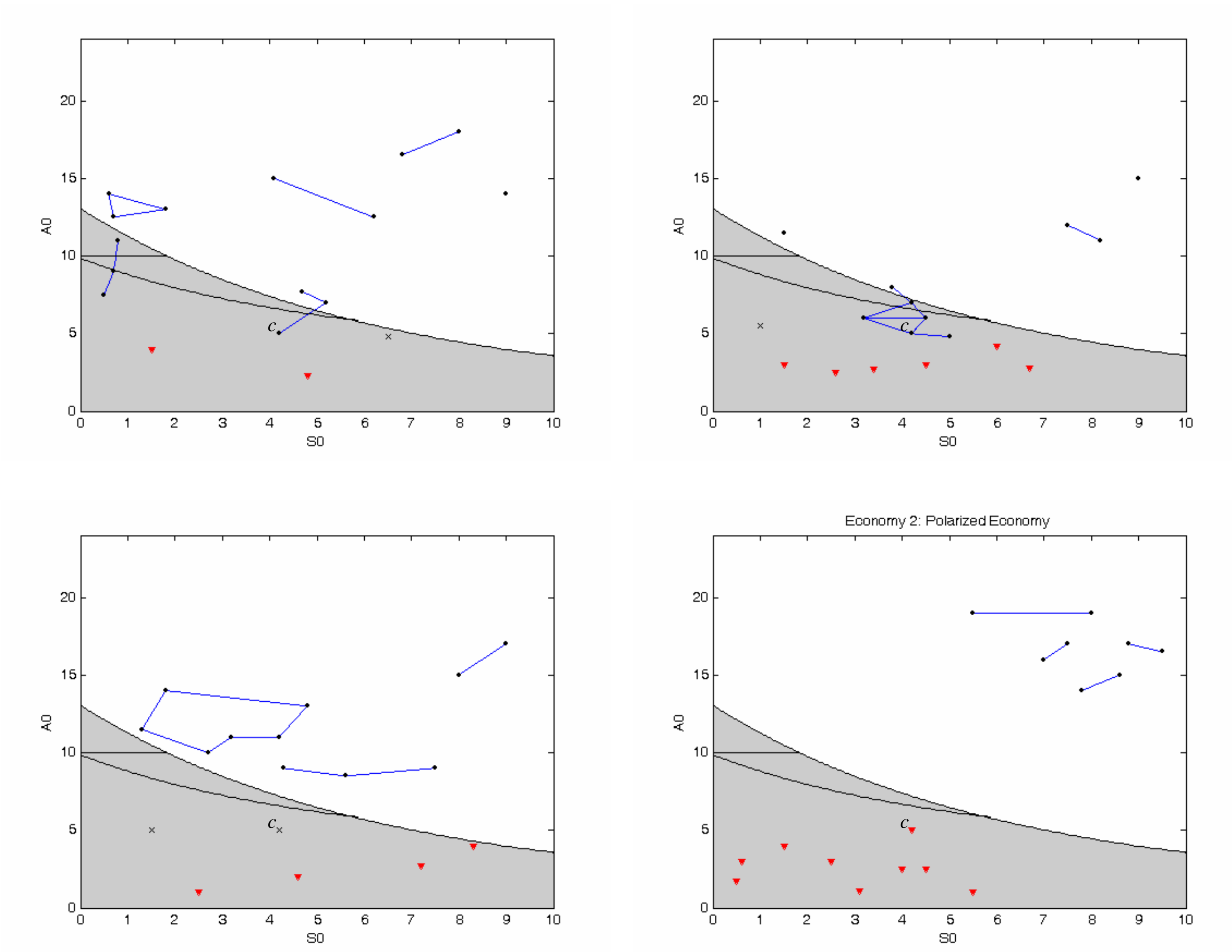


Figure 10: Different patterns for a destitute, economically immobile household

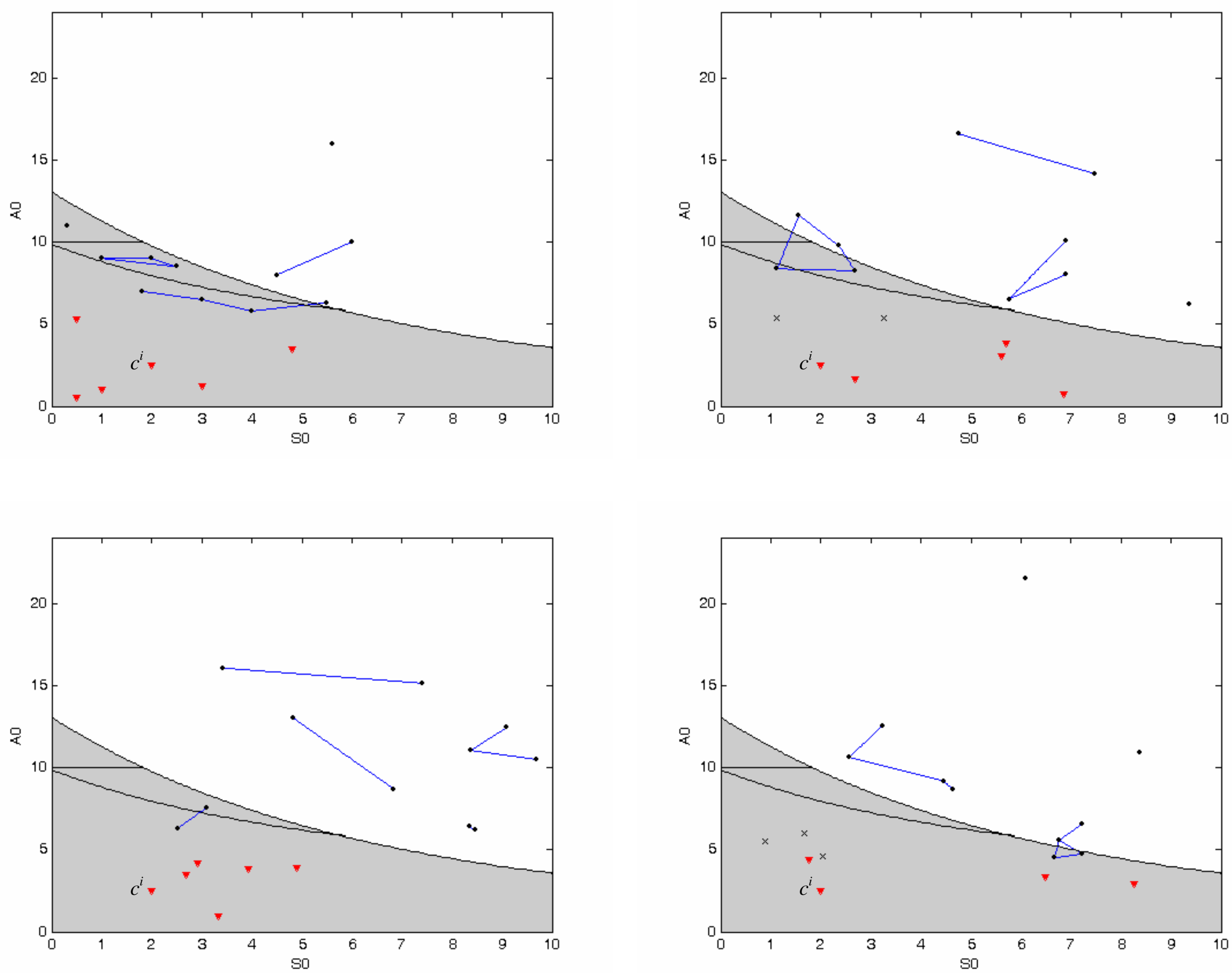


Figure 11: Equilibrium social networks and long-run equilibria for 100 economies

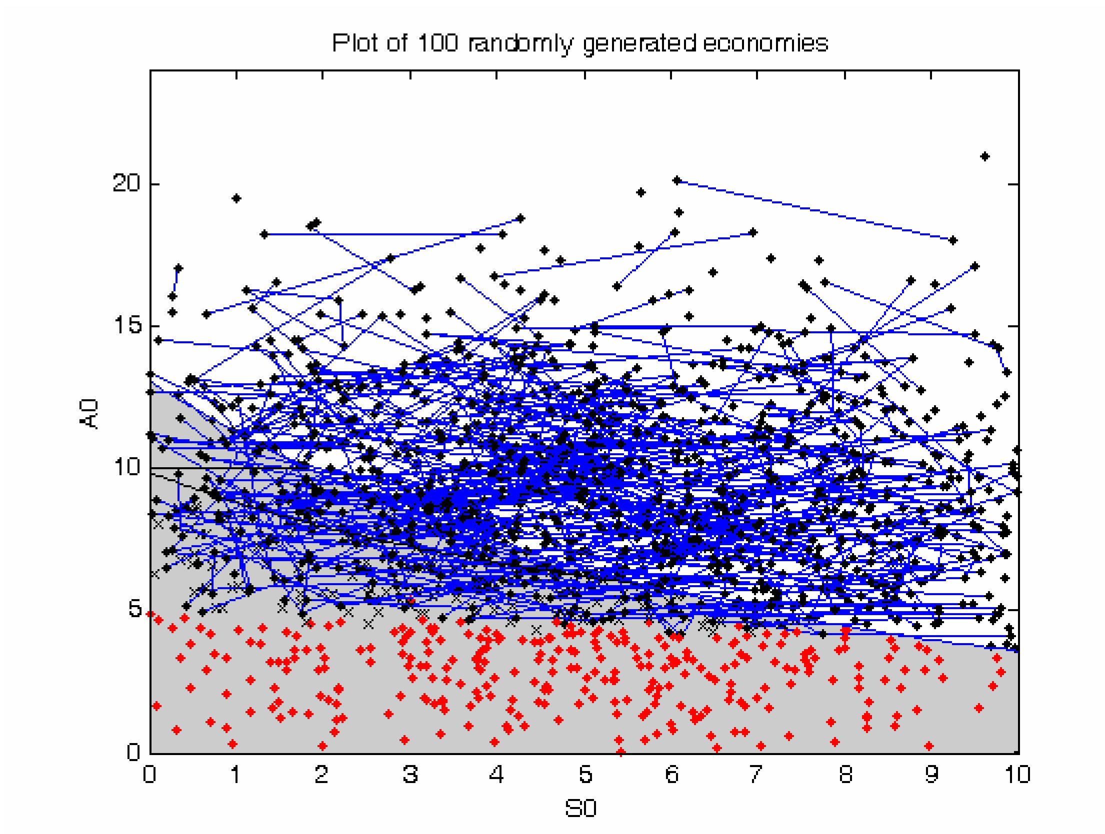


Figure 12: Households and regions combined in a simulated economy

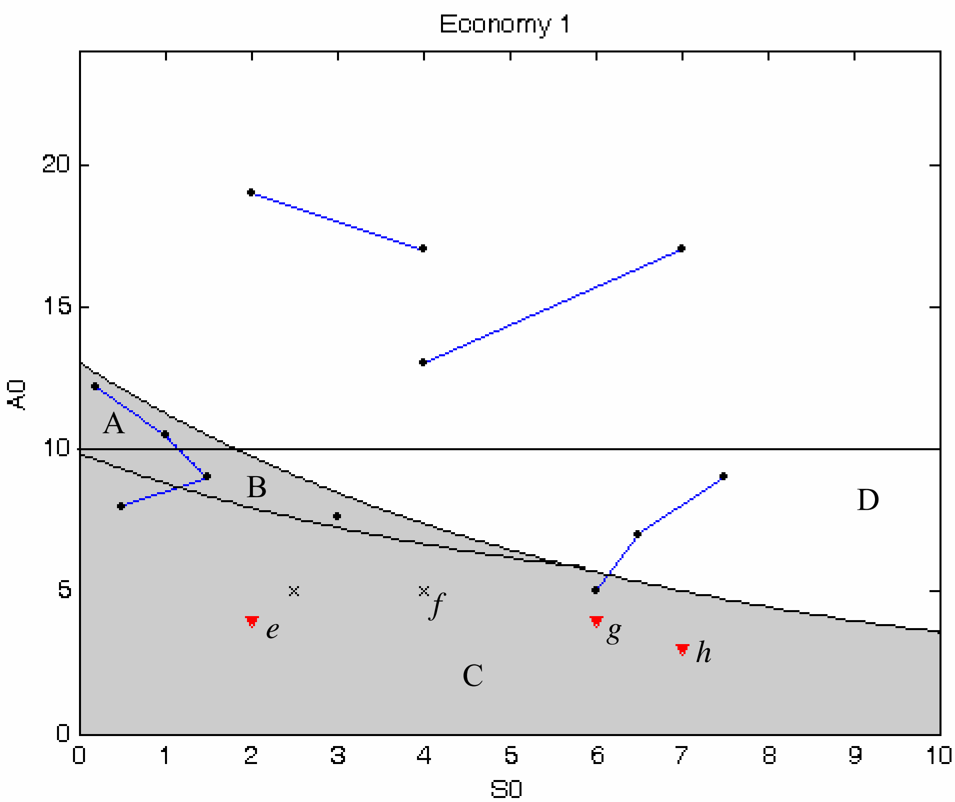
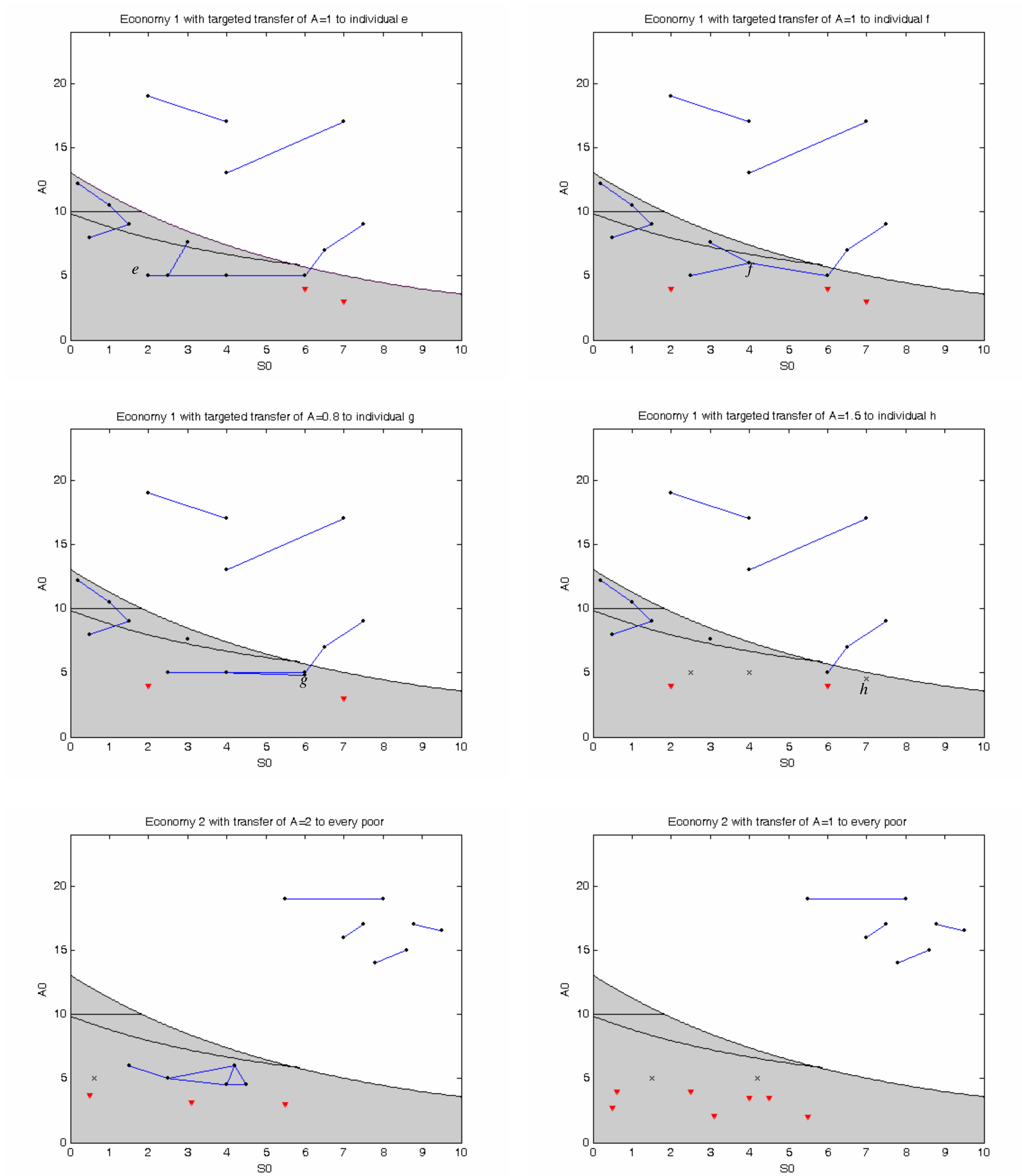


Figure 13: Targeted transfers and "crowding in" effects



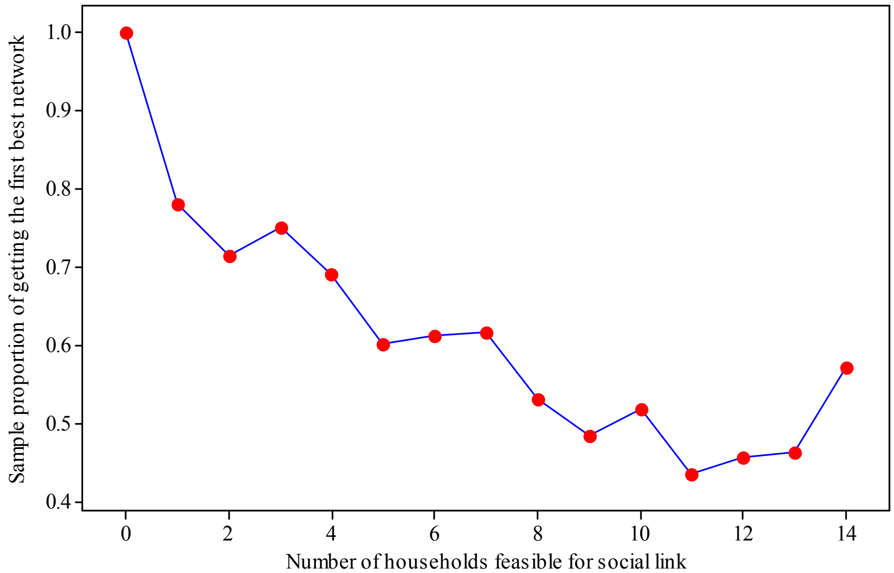
Appendix 1: Parameterization of the simulation

1. Utility: $a = 1, \rho = 0.95$
2. Production function: $k_1 = 9, k_2 = 8.5, k_3 = 1.2, \alpha_1 = 0.25, \alpha_2 = 0.5, F = 9$
3. Cost/benefit of link: $\overline{d} = 5$, $\theta_1(x) = 0.125x, \theta_2 = 0.4, \theta_3 = 0.33$
4. Asset accumulation: $\delta_S = \delta_A = 0.05$
5. For each randomly generated economy with $\phi(A_0, S_0)$, N=17 with randomly generated initial endowments (A_0, S_0):

   $A_0 \in [0,20]$, $S_0 \in [0,10]$

Appendix 2: Network simulation statistics

Sample proportion of those getting their first best network
vs. number of households feasible for social link
(100 economies of 17 households)



Sample proportion of those getting their first best network
vs. number of households in the first best network
(100 economies of 17 households)