CLUSTERS AND BRIDGES IN NETWORKS OF ENTREPRENEURS

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I. Introduction

The predominant sociological approach to formation of economic networks focuses on past interaction: people get to know and trust each other, especially in social settings ("embeddedness"), and are then able to share information and do business together. Economists instead argue that actors strategically choose to invest in certain relationships based on forward-looking incentives. Oversimplifying, in economics you choose your network but in sociology your network chooses you.

Our chapter takes a step towards merging these two approaches. We do not attempt to do so at the most general level. Instead we focus on a specific class of actors (entrepreneurs) and thereby hope to show how merging the economic and sociological approaches can yield new predictions and policy recommendations in a concrete empirical setting.

Our model of network formation is guided by the desire to match two common features of economic networks identified by sociologists. The first feature is what we call a "cluster and bridge" network structure, in which groups of densely tied agents (clusters) are connected by sparse ties (bridges), as opposed to either completely isolated groups or a uniform density of ties among all agents.[1] A cluster and bridge network structure arises in many economic settings from a combination of exogenous and endogenous forces that produce densely tied groups within a larger whole: divisions within a large firm, industries within an economy, metropolitan areas within a country. A second common feature of economic networks is higher rewards to agents whose ties span clusters than to agents whose ties are confined within a given cluster. Evidence

[1]The much more abstract network formation model of Jackson and Rogers (2005) is similarly motivated. Their "islands" play the same role as our "parent firms" below.

has accumulated in diverse settings that agents with bridge ties perform better than agents with cluster ties (see Burt 2000 for a survey): firms that bridge clusters in interfirm networks show higher profits, managers that bridge clusters in intrafirm networks receive higher pay and more rapid promotions.[2] This may be due to opportunities for arbitrage ("brokerage") across clusters of differences in information or resources, or could reflect selection of the most able agents into bridging positions. In our model economy a combination of gains from trade and selection will be at work.

We will be specifically concerned with clusters that form among entrepreneurs that spin off from a common "parent firm." Having already worked together, such entrepreneurs know each other's capabilities and needs and are thus at least weakly tied at "birth."[3] It is thus relatively easy for them to form partnerships with each other or do business with each other as independent firms.

It is widely recognized that spinoffs or "entrepreneurial spawning" are a major source of entrepreneurship. Bhide (2000, p. 94) reports that 71 percent of the firms in the Inc 500 (a list of young, fast-growing firms) were founded by entrepreneurs who "replicated or modified an idea encountered through previous employment." This process has been especially well studied in the high-tech, venture capital context, where the classic example is the spinoffs from Fairchild

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[2]Insofar as exporting connotes a bridge tie, additional supporting evidence is provided by consistent findings that exporting firms are larger and have higher productivity than non-exporting firms. Fafchamps et al. (2003) list the relevant references, and also report that Moroccan exporting firms were typically exporters at start-up or very soon thereafter. This is consistent with our model below, in which firms are born through the formation of either bridge ties or cluster ties.

[3]For a definition of "weak ties" along these lines see Rauch (2001, p. 1179).

Semiconductor in Silicon Valley (Braun and Macdonald 1982). Gompers et al. (2003, p. 3) explain the fertility of this process as follows: "Working in such firms exposes would-be entrepreneurs to a network of suppliers of labor, goods, and capital, as well as a network of customers. Because starting a new venture requires suppliers and customers to make relationship-specific investments before it is guaranteed that the venture will get off the ground, networks can be particularly useful in alleviating this chicken-and-egg problem." They report that the share of U.S. venture-capital backed entrepreneurs in the period 1986-99 who previously worked for publicly traded firms is around 45 percent.

There is no need to appeal to a high-tech, venture-capital backed environment to explain entrepreneurial spawning, however. It is also generated by a more mundane process of "client-based entrepreneurship" (Rauch and Watson 2003), in which employees try to wrest the value of client relationships from their employers by setting up their own firms and taking their clients with them. This can occur in any industry in which client relationships are important, including manufacturing, business services, and personal services. According to the 1992 Economic Census of the United States (1997, p. 86), 45.1 percent of nonminority male business owners "previously worked for a business whose goods/services were similar to those provided by the [current] business."

In our model economy, workers leaving their firms to become entrepreneurs may take the relatively easy avenue of forming partnerships with their former colleagues, or might at greater cost seek partnerships with unknown workers leaving other firms to become entrepreneurs. Those that succeed in the latter endeavor form bridges, whereas those that do not form clusters. Specifically, we assume that a cluster partnership serves as the fallback option when deciding

whether to accept a potential bridge partnership. Selection then ensures that accepted bridge partnerships will be of higher quality and thus perform better on average than cluster partnerships, and the extent to which this is true will increase with the average of the quality of potential bridge partnerships relative to cluster partnerships, representing the potential for gains from trade.

Entrepreneurs tend to form their firms in the communities in which they live. A cluster consisting of entrepreneurs who spun off from a common parent firm will therefore tend to be geographically localized. This tendency allows us to link our model of entrepreneurial network formation to the literature on "border effects" in interregional and international trade. This literature began with a paper by McCallum (1995) that found that Canadian provinces traded more than 20 times as much with other Canadian provinces as with U.S. states of comparable economic size and distance away. Border effects were subsequently found for jurisdictional borders that impose no apparent cost on trade. In particular, Wolf (2000) found much higher trade within U.S. states than across U.S. states than could be explained by relative economic size and distance. Our model economy will display community border effects because cluster partnerships are formed only within communities whereas bridge partnerships are formed both within and across communities.

We will investigate two types of policies that affect network formation. One type of policy targets effort expended to form bridge partnerships and is analogous to programs that subsidize the search for international trading partners (see Rauch 1996 and Rauch and Watson 2004). The other type of policy is enforcement of employment contracts that restrict the ability of workers to form firms that compete with their former employers and thus discourage

formation of cluster partnerships (see Rauch and Watson 2003).

We present our model economy in the next section of this chapter. In section III we analyze this model economy and in section IV we extend it so we can address additional issues. Section V summarizes what we have accomplished in light of the goals set forth in this introduction.

II. A model economy and its underlying network structure

In this section we will describe a hypothetical or model economy. As mentioned above, part of the purpose of this exercise is to show how a simple, empirically observed mechanism of firm formation can generate a cluster and bridge network structure. However, the fact that our model economy is logically consistent enables us to do more. First, we can observe how changes in features of the economic environment affect key outcome variables and use these results to make some new, testable empirical predictions. Second, we can ask how government actions affect the total income generated by the model economy and therefore draw implications for policy.

The model economy and its analysis can be presented in mathematical language, but we will keep this entirely in the background, with some loss of precision but considerable gain in intuitive understanding. Unlike in the chapters by Burt and by Kranton and Minehart, we will not keep track of individual network links. Instead we will focus on two aggregate features of the model economy: its wage level and its distribution of firm sizes. These in turn will be determined by the level of effort expended to form bridge partnerships, which yields the aggregate division of partnerships into bridge and cluster types. Bridge and cluster partnerships

are the underlying network structure of the model economy. We will also be concerned with the "bridge premium" and the border effect, which summarize important features of this structure.

In our model economy there exist two generations of agents in every period, young and old. The young agents are workers and the old agents are entrepreneurs. In each successive period, the old agents die, the young agents become the new entrepreneurs, and a new generation of young workers is born.

Workers are employed by firms. In turn, each firm is made up of two entrepreneurs who have formed a partnership. The quality of the partnership or the size of the firm depends on how well the partners are matched. Partners who are better matched will hire more workers and produce more output.

Every firm produces the same type of output and thus we assume that no firm has the ability to influence the market price. Similarly, firms take the wage rate of labor as given. It follows that the only choice variable for each firm is how much labor to hire, and it chooses this amount to maximize profits. The higher is the wage rate, the less labor each firm hires. In the aggregate, the wage rate adjusts so that the total amount of labor demanded by all firms equals the total amount of labor supplied by workers.

We assume that the amount of labor supplied is simply fixed by the number of young workers born in each period. The number of firms (partnerships) equals half the number of entrepreneurs, which in turn is fixed by the number of workers born each preceding period. The key determinant of the wage rate in any period will therefore be the quality of firm partnerships, because this determines how many workers firms want to hire for any given wage. We now discuss how the distribution of this quality across firms is obtained.

At the end of a given period, when young agents employed as workers in existing firms are about to become old, they engage in a matching process culminating in the formation of the firms that they will manage in the next period. An agent can match with someone in the same existing firm (a cluster match) or with someone who is currently working in a different firm (a bridge match).

The matching process runs as follows. First, each young agent expends effort at some personal cost to search for a match with someone in a different firm. We allow for the possibility that his effort is subsidized by the government, and the rate of this subsidy will be one of the key policy variables in our analysis. In an international context, this subsidy could be interpreted as support for participation in international trade missions or trade shows, or as favorable tax treatment for foreign direct investment. The probability that an agent will find a match in another firm increases with both his own effort and the effort being made by his potential partners. When two potential partners from different firms actually find each other, the quality of their match is random and is drawn from a fixed distribution of qualities for bridge matches. Knowing this quality level, the agent and his potential partner then decide whether to form a firm.

If an agent fails to form a partnership with someone from another firm (either because he does not obtain a bridge match or because he does not consummate such a match), then this agent freely obtains a cluster match with someone from his current firm (who also failed to form a bridge partnership). The quality of the cluster match is always the same. This lack of randomness reflects the idea that within a firm agents already know each other and know whom to approach and what they are getting. After all matches are consummated, firms hire labor and

engage in production.

The part of firm output that is not paid out as wages accrues to the firm partners as profits. How do the partners share the profits of the firm? Note that when they form a bridge partnership their outside options are to find partners within their own firms, and when they form cluster partnerships their outside options are zero. In either case, the two partners are in symmetrical positions so it is natural to assume that each receives half of the profits.[4] Total profits scale up in proportion to firm size, that is, in proportion to match quality. It follows that potential partners who draw a match quality from the bridge distribution will form a bridge firm if and only if this quality is at least as great as the cluster match quality.

We can understand how our model economy works with the aid of Figure 1, which shows how the amount of effort each agent will spend in his search for a bridge partnership is determined. Reading from top to bottom, the distribution of firm match qualities or sizes is determined by the search effort of each agent: the greater the search effort, the more bridge matches are formed and the higher is average firm quality. The wage rate depends on the distribution of firm sizes because this is what determines the aggregate demand for labor in the economy. To complete the circle, note that the incentive of each agent to search is the prospect of finding a better match than he could in his own firm, given the existence of potentially complementary information, resources, and skills across firms. This incentive in turn depends on the wage rate: the lower is the wage rate, the greater is the extent to which better match

[4]This is the outcome if we apply the Nash bargaining solution with equal bargaining weights.

quality translates into higher profits.[5]

An equilibrium for our model economy consists of a wage rate that equates aggregate demand for labor to supply, a distribution of firm sizes that generates that aggregate demand at the equilibrium wage rate, and a search effort that generates this distribution of firm sizes and equates the incentive for search to its cost. To see that an equilibrium exists, and to see why there is only one equilibrium, consider what happens if each agent were, hypothetically, to choose a very low level of search effort. In this case very few bridge matches will be formed and average firm quality will be low. Demand for labor will then be low and so will the wage rate. This low wage rate, however, yields a high return to search effort, implying that the original choice of low search effort was not an equilibrium level. As search effort is increased, the distribution of firm qualities improves and the wage rate increases, reducing the return to search effort, so eventually the incentive for search and its cost are brought to equality.

The underlying network structure of our model economy is shown in Figure 2. Agents within a shaded circle are all weakly tied to each other by virtue of having previously worked together in the same "parent firm." Some of these agents have formed partnerships (new firms) with their former colleagues; these strong ties are denoted by dotted lines and labeled as "cluster ties." The rest of these agents have formed partnerships with entrepreneurs from different parent firms; these strong ties are denoted by dashed lines and labeled as "bridge ties." Some bridge ties are formed within the agents' own community and some are formed between communities, where communities are denoted by large circles.

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[5]Each agent searches with a fixed expectation of the search intensity of his potential partners. In our model economy, all agents are in a symmetrical position and they exert the same level of search effort in equilibrium.

Figure 2 reflects our assumption that entrepreneurs who spin off from a given parent firm remain in their original community. In the representative cluster shown in detail, two-thirds of the agents have formed partnerships with their former colleagues and one-third have formed bridge ties. Since bridge ties are the result of random matching, they are formed in proportion to the sizes of the communities: community α contains half of all entrepreneurs and thus receives half of all bridge ties, community β contains one-third of all entrepreneurs and receives one-third of all bridge ties, and community γ receives the remaining one-sixth of all bridge ties.

Two empirically observable features of this underlying network structure have received considerable attention in the literature. The first could be called a bridge premium: the excess of the return to an agent with a bridge tie over the return to an agent with a cluster tie. The second is the border effect: the excess of observed trade within a community above what would be predicted if intra-community trade were determined in the same way as inter-community trade. These two features of the underlying network structure of our model economy will be analyzed in the next section.

III. Analysis of the model economy

A. Subsidies, distributions of match qualities, bridge premia, and border effects

Absent any government subsidy to effort for building bridge partnerships, we can see that the equilibrium search effort supplied in our model economy will be less than the level that would maximize aggregate output (net of effort). The reason is that agents do not take account of the fact that their own search effort makes the efforts of others more productive. It follows

that a small subsidy to search effort to build bridge partnerships must increase aggregate output,[6] and that there exists a positive optimal subsidy that maximizes aggregate output. Most governments provide subsidies to formation of international bridge partnerships by sponsoring international trade missions and trade shows (Rauch 1996). Our analysis suggests that these subsidies raise world output, provided that international bridge partnerships are not systematically less productive than domestic bridge partnerships.

We can also analyze the impacts of changes in the distribution of qualities for bridge matches. An improvement in the bridge distribution of match quality (technically, a first-order stochastic dominant shift) implies an increase in the "gains from trade." Therefore agents will increase their effort made to search for bridge partners, which will improve the size distribution of firms (also in the sense of first-order stochastic dominance), and thus increase the equilibrium wage. Note that increased variability of bridge match quality (technically, a second-order stochastic dominant shift) can have the same effect as an increase in average bridge match quality: intuitively, increased variability intensifies the selection effect for bridge partnership formation. In contrast, improved match quality in cluster partnerships leads to less effort to form bridge partnerships. This has an ambiguous effect on the distribution of firm sizes, because the size of firms formed through cluster partnerships increases but fewer larger firms are formed through bridge partnerships. Since improved cluster match quality has an ambiguous effect on the distribution of firm sizes, it also has an ambiguous effect on the level of wages.

As we noted, the cutoff match quality for a bridge partnership is the match quality of a

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[6]We implicitly assume that a method of taxation is available to finance this subsidy that does not itself create "distortions" in the economy that more than offset the benefit of the subsidy.

cluster partnership. Thus, it must be that a firm formed from a bridge partnership generates a profit that is higher than that achieved by a firm formed from a cluster partnership. We define the bridge premium as the ratio of the observed average return to agents in bridge partnerships to the observed average return to agents in cluster partnerships. It follows that the bridge premium is a function only of the (constant) cluster match quality and the distribution of bridge match qualities.

The community border effect for measured trade arises in our model because trade across communities is generated by random matching of agents forming bridge partnerships, whereas trade within a community is generated by the sum of cluster partnerships and random matching of agents forming bridge partnerships. Hence there is "excess trade" within a community beyond what would be predicted by random matching. The border effect measures this excess trade relative to predicted trade and thus varies directly with the value of cluster partnerships relative to bridge partnerships.[7] This will be a function of the cluster match quality and the distribution of bridge match qualities, like the bridge premium, and of the search effort, through its effect on the probability of finding a potential bridge partner.[8]

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[7]Real-world data used to estimate border effects measure trade in physical commodities, simply because this is observed relatively easily. To use our model economy to make predictions about real-world border effects, it must be that the process of partnership formation we are studying generates observed trade in physical commodities. Elsewhere (Rauch and Watson 2003) we have argued that spinoff entrepreneurship, even more than entrepreneurship in general, is more common in business services than in manufacturing. Nevertheless, it is plausible that a business service firm such as a consultancy that has partners in two communities will tend to generate shipments between those communities, by linking across the two communities clients involved in goods production or distribution or by finding sales opportunities for such clients across the two communities.

[8]In our model economy the probability of forming a bridge partnership within a community increases with its size but the probability of forming a cluster partnership is invariant to

We can now see how the bridge premium and border effect vary as the characteristics of our model economy change. First, an increase in the rate of subsidy leaves the bridge premium unchanged and reduces the border effect. The increased subsidy induces greater search effort, which raises the probability of finding a potential bridge partner. This does not change the quality of realized bridge partnerships relative to cluster partnerships, but it increases the proportion of agents who form partnerships across communities and therefore reduces the border effect. Second, an improvement in the bridge distribution of match quality (technically, a first-order stochastic dominant shift) will increase the bridge premium and decrease the border effect. Again, greater variability in bridge match quality (technically, a second-order stochastic dominant shift) can have the same effects. The first effect follows from the definition of the bridge premium, whereas the second effect follows because the induced increase in effort to form bridge partnerships combines with their greater productivity to reduce the share of trade accounted for by cluster partnerships and therefore the border effect. Finally, improved match quality in cluster partnerships tends to decrease the bridge premium and certainly increases the border effect. The requirement for the first effect is that average bridge match quality increase less than proportionately with an increase in the quality of the fallback cluster match, and the second effect follows from the fact that with greater incentive to form cluster partnerships, the share of trade taking place within a community will increase and therefore so will measured

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community size. Border effects therefore vary inversely with community size. If we were to "estimate" the border effect using the "data" generated by our model economy, we would have to adjust for the share of agents in each community in the total population of agents. This procedure is in agreement with Anderson and van Wincoop (2003), who show that estimating border effects by applying the standard equation based on random matching to trade data will yield values that vary inversely with community size.

border effects.

B. Analysis of Non-compete Covenants and Similar Restrictive Employment Contracts

One of the goals of this chapter is to gain insight into policies that can affect network formation. So far, the only policy we have analyzed is a subsidy to effort to form bridge partnerships. The closest corresponding real-world policy is government sponsorship of international trade missions and trade shows. In some countries similar activities are sponsored at the regional level, but it is doubtful whether effort to form intra-community bridge partnerships could even be observed by government, let alone subsidized. However, it might be possible to achieve a similar effect by discouraging formation of cluster partnerships. In this section we will analyze the impact of one such policy, enforcement of covenants not to compete and similar restrictive employment contracts.

Entrepreneurs who spin off from a parent firm may capitalize on technological knowledge or client relationships developed while working for their former employer, or may simply go into direct competition with their former employer. All of these outcomes are more likely when an agent forms his new firm in partnership with a former colleague from the same parent firm than when he forms his new firm with a partner from a different parent firm, since the former colleagues are more likely to stay in an identical line of business or one very closely related to that of their common former employer.[9] Restrictive employment covenants such as non-compete agreements, non-solicitation agreements, or restrictions on use of intellectual

[9]Indeed, one could argue that more bridge partnerships are likely to be associated not only with smaller "border effects" but also with more trade across industries ("inter-industry trade") relative to within industries ("intra-industry trade").

property developed within the firm will therefore tend to discourage cluster partnerships relative to bridge partnerships.[10]

We can incorporate restrictive employment covenants into our model economy in the following simple way. We assume that all workers have to sign restrictive employment contracts when hired, and that these contracts are enforced with probability p. A worker who leaves at the end of a period to form a cluster partnership causes a reduction (tax) T in the profits of his former employer (so the employer loses $2T$ for each cluster partnership formed by his former employees). If the former employer sues successfully to block formation of the new firm, each worker in the partnership must buy out his contract by paying his former employer T. In contrast, a worker who leaves at the end of a period to form a bridge partnership leaves the profits of his former employer unchanged.

Under these assumptions, on average a worker-turned-entrepreneur loses pT from a cluster partnership relative to the situation in which he did not have to sign a restrictive employment contract. This will affect both his decision whether to accept a bridge partnership rather than a cluster partnership and his decision regarding effort to find a bridge partnership. Specifically, an entrepreneur is willing to accept a lower quality bridge partnership now that a cluster partnership is a worse alternative, and will expend more effort to find a potential bridge partner for the same reason. The impact of restrictive employment covenants on the distribution

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[10]Strictly speaking, in our model economy the spinoff firms do not begin to operate until the parent firms have ceased to exist: only one generation of firms operates in any given period. It would seem that this precludes competition between the spinoff firms and the parent firms. One way to allow them to compete would be to suppose that parent firms serve clients that survive into the next period. If the new cluster firms are formed by "stealing" the clients of the parent firms, agents can prevent their current employer from realizing the profit from a client despite the fact that they do not serve the client until the next period.

of firm sizes (qualities) is therefore ambiguous. Since the distribution of firm sizes determines the demand for labor, the effect of restrictive employment covenants on the wage rate is also ambiguous.[11]

The enforcement probability p is the government's policy instrument.[12] Starting from a subsidy to search of zero, the impact on aggregate output (net of effort) of increasing p from zero is clearly positive, since it both causes agents to internalize the cost T when deciding whether to accept a bridge partnership and induces them to increase search effort in the same way as would a positive subsidy. However, it may be that if we were to enrich our model economy we would find that the cost T to the worker's former employer is not a cost to society as a whole – for example, it could be offset by a benefit to a client that the worker took from his employer. In this case, the positive effect on aggregate output of increasing p from zero through its impact on effort is offset by a negative effect through its impact on the cutoff match quality for bridge partnerships. A necessary (but not sufficient)[13] condition for aggregate output to increase is that the distribution of firm sizes improves (again, in the sense of first-order stochastic dominance),

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[11]Actually, unless $p = 1$, the demand for labor is also influenced by the risk to the employer that he will lose T if a worker he hires leaves to form a cluster partnership. We can avoid complicating the model in this way if we assume (unrealistically) that the average loss to the employer is deducted from each worker's pay when he is hired. In effect, this is a "lump-sum tax" on labor.

[12]The government loses this policy instrument if employers and workers do not choose to negotiate restrictive employment contracts. Rauch and Watson (2003) present evidence that they do, and show why they will want to negotiate such contracts in the case in which the workers-turned-entrepreneurs take clients away from their former employers: a non-compete or non-solicitation covenant increases the bargaining power of the employer and worker vis-a-vis the client when the separation of the worker from his employer is negotiated.

[13]This condition is not sufficient because more effort has been expended, which could cause output net of effort to decline.

which will be reflected in an increase in the wage rate.

The predicted effects of variation in the enforcement probability p on the bridge premium and border effect are more straightforward to analyze than is the impact on aggregate output. Since the cutoff match quality for bridge partnerships falls as p increases, the bridge premium (gross of pT) unambiguously decreases. The border effect decreases unambiguously for the same reason: more bridge partnerships and fewer cluster partnerships are formed. In principle these predictions could be tested using data for U.S. states, which differ widely in their policies regarding enforcement of non-compete and non-solicitation covenants. In particular, the data needed to estimate border effects for U.S. states have already been collected (see Wolf 2000).

IV. Extensions

A. Phased formation of partnerships

In addition to border effects, an interesting feature of inter-community trade revealed by the data is the predictive power of past trade for current trade, even in the presence of explanatory variables (specifically, community-pair fixed effects) that capture the influence of all contemporary determinants of trade (e.g., Moenius 2004). It has been argued that this predictive power is at the root of the continued influence of past colonial relationships on current international trade (Eichengreen and Irwin 1998). Some have hypothesized that this influence of past trade on current trade reflects network effects, where networks formed in the past continue to have an impact on trade in the present (Anderson and Smith 2003). This is not a feature of our model economy since we assume that networks dissolve at the end of every period and are recreated from scratch in the next period. However, if we modify our model economy to allow

for the possibility that some entrepreneurs form their partnerships before others, we may find that it is useful for analyzing this phenomenon.

Let us divide all agents into groups 1 and 2. There are two rounds of entrepreneurial matching. Group 1 agents match first. Since the outcomes of their matches are unaffected by the actions of group 2 agents, their matching process is identical to what we already described in section II. Group 2 agents match second. As in section II, firms hire labor and engage in production after all matches have been consummated. We relax our assumption that all agents within a parent firm are weakly tied to each other, and suppose that some group 2 agents are lucky enough to be weakly tied to group 1 agents who formed bridge partnerships and some are not. We will call these group 2 agents "well connected" and "poorly connected" and label their shares in group 2 population a and $1 - a$, respectively. The well connected share of group 2 agents a will increase with the ratio of group 1 to group 2 agents and with the share of group 1 agents that form bridge partnerships. We assume that a well connected group 2 agent has a higher probability of meeting a potential bridge match for a given level of effort. For example, a well connected group 2 agent may learn from a group 1 colleague which trade show to attend to meet potential matches from the parent firm (cluster) from which the colleague's match was drawn. This and other plausible motivations for our assumption suggest that a well connected group 2 agent will seek to meet agents from particular parent firms, specifically those from which came the partners of their group 1 former colleagues. However, this behavior will have no consequences for the pattern of trade at the community level, which at this point will not display dependence of current trade on past trade.

Clearly there will be more bridge matches and a higher value of trade per agent for group

2 than for group 1, provided $a > 0$. The border effect will be lower for group 2 than for group 1, but otherwise the pattern of trade will be unaffected. For any given parent firm, well connected group 2 agents will on average realize higher incomes than will poorly connected group 2 agents. A survey would therefore show that, among agents who pursued their entrepreneurial ventures later, those whose intrafirm networks were "better" in the sense that the members of the network had been luckier in forming bridge partnerships will have been more successful on average, all else equal. (This is a clear example of the kind of situation discussed in the chapters by Stuart and by Reagans, Zuckerman, and McEvily, in which features of an agent's network that are beyond his control -- exogenous -- influence his measurable economic outcomes.) Finally, we should note that the argument for a subsidy to search effort will be strengthened, because not only is there an external effect of the average effort of any group on the productivity of each individual's effort but there is also an external effect through *a* of the effort of group 1 agents on the productivity of effort of group 2 agents.

The reason that the pattern of intra-community trade in our extended model shows no dependence of current trade on past trade is that the determinants of this pattern do not change between the first and second phases of partnership formation, so if these determinants are used to predict current trade then past trade will have no additional explanatory power.[14] In the remainder of this subsection we will therefore study the following simple scenario. Divide all communities into non-overlapping groups separated from each other by trade barriers or internally unified by preferential trading agreements. Inter-community trade therefore takes

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[14]If these determinants (i.e., community sizes), are omitted, past trade predicts current trade perfectly since there is no reason for agents, be they well connected or poorly connected, to behave differently in round two than in round one.

place only within each of these community groups. Between round 1 and round 2, all barriers to trade between communities are removed or all preferential trading agreements between communities are eliminated. Poorly connected agents now match randomly among all communities, but well connected agents follow the pattern of trade established in round 1, effectively behaving as though the trade barriers or preferential trading agreements still exist.

Figure 3 illustrates our scenario using four equally sized communities with equal population shares for groups 1 and 2 and $a = 1/2$ (recall that a is determined by the equilibrium of our extended model economy). During the first round of matching all inter-community partnerships are formed between entrepreneurs from communities α and β or between entrepreneurs from communities γ and δ. Between the first and second rounds of matching, the trade barrier between the two groups of communities is removed (e.g., a bridge is built across a river that divides them) or preferential trading agreements within each group of communities are eliminated (e.g., colonial relationships are terminated). Poorly connected agents now match randomly among the four communities, so there are six inter-community trading relationships instead of two. Since there are half as many poorly connected agents matching in round two as total agents matching in round one, the value of trade between any two communities generated by poorly connected agents is one-sixth of the round one value ($1/6 = (1/2)(2/6)$). To this must be added the trade generated by well connected agents between communities α and β and between communities γ and δ. This will be somewhat more than half of the round one value because well connected agents have a higher probability of finding bridge matches.[15]

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[15]We can see from this example that the smaller is the size of any group of communities that were preferentially linked in the past relative to the total size of all communities, the greater will be the ratio of "excess" trade between any two formerly linked communities to trade predicted

In addition to helping to interpret the effect of past trade on current trade, our extended model economy allows us to predict that denser intrafirm networks will generate a larger impact of past trade on current trade by raising the proportion of agents who are well connected. If surveys can establish a regularity such as inverse variation of intrafirm network density with firm size (which seems plausible but hardly obvious), then countries whose exports are dominated by small- to medium-sized firms (Italy and Taiwan, for instance) can be predicted to show greater impacts of past exports on current exports than countries whose exports are dominated by large firms (Korea, United States).

B. Post-matching production

Here we will sketch another extension that takes us farther afield from the basic model economy of section II. We will suppose that, after all the new firms hire labor and generate output, they engage in an additional round of production before dissolving as their workers become the next generation of entrepreneurs. This additional round of production allows for exchange across firms and therefore exploitation of additional interfirm complementarities. As the result of formation of bridge partnerships, it should now be possible for a firm from a given cluster (parent firm) to interact with a firm from any other cluster through a series of weak ties. Nevertheless, survey evidence indicates that information transmission decays rapidly after one or two links (see, e.g., Friedkin 1983), and it is in accord with common experience to limit referral-

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by the standard determinants. This point has been missed by, for example, the literature estimating the impact of past colonial relationships on current bilateral trade. Correct estimation requires an adjustment along the lines of the adjustment for border effect estimation discussed in footnote 7.

based exchange to those no more than two links away ("our friend recommended me to you"). If we make this assumption, it follows that all firms belonging to clusters between which at least one bridge partnership exists can interact, if all agents within a parent firm are weakly tied to each other. It also follows that if no bridge partnership exists between two clusters, firms formed from cluster partnerships cannot interact across the two clusters.[16]

If we maintain this two-link limitation on interfirm exchange, the complementarities exploitable by a given cluster firm are limited by the number of clusters to which its cluster is connected through bridge partnerships. In principle, we could test for the existence of such "cluster connectivity effects": firms formed from cluster partnerships whose clusters have more connections to other clusters should be involved in more productive exchanges and hence have higher sales and profits, all else equal. These effects should be present even after controlling for cluster size.

As in the previous subsection, externalities are generated by bridge partnerships. Specifically, complementarities in production across clusters are realized by firms formed through cluster partnerships through the links established by bridge partnerships. These are analogous to the benefits generated for well connected group 2 entrepreneurs by group 1 entrepreneurs who form bridge partnerships. Again, there is an argument for subsidizing the formation of bridge partnerships.

Finally, we should note the possibility that the benefits from connectivity may appear at a global level rather than, or in addition to, the cluster level. This could occur if

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[16]The situation for firms formed from bridge partnerships is less clear. It could be argued that these firms can interact with any firms not only from their own two clusters but from any cluster connected by a bridge partnership to either of their own two clusters.

complementarities in production could be realized through more than two links. In this case, it is tempting to think in terms of the classic "small world" phenomenon (Watts and Strogatz 1998), where formation of a sufficient number of bridge partnerships could drastically reduce the smallest number of links needed to connect any two firms. For this phenomenon to be of economic importance in our model, it would need to be the case that the efficiency with which production complementarities can be realized diminishes with the number of links used, yet does not become too small for more than two links.

V. Conclusions

We set out to meld the economic and sociological approaches to network formation in a specific real world context. In our model economy the impact of past interaction emphasized by sociologists was captured by weak ties among colleagues of the same parent firm, and the forward-looking decisions to form links emphasized by economists were captured by effort to find potential business partners from other parent firms and decisions to form these partnerships only if they are superior to partnerships with known colleagues. The result of this process is that partnerships within any parent firm are much more dense than across any pair of parent firms, since an entrepreneur has an equal chance of meeting up with a potential partner from any other parent firm of given size but his fall-back option is always the colleagues from his own parent. A graph of the network links for our model economy therefore has a cluster and bridge structure, as we saw in Figure 2, with a cluster existing among the colleagues from each parent firm.

The sociological literature finds that agents whose links span clusters are more successful than agents whose links remain within clusters, but it is usually unclear whether this is true

because of selection (better agents form bridges) or because bridges make agents more productive. In our model economy it is true for both reasons: potential bridge partnerships may be no more productive than cluster partnerships on average but they are more variable, allowing entrepreneurs to select the more productive bridge partnerships because they are more profitable than cluster partnerships. Nevertheless, in this basic story there is no exogenous effect of network structure on agent success in that only links that entrepreneurs chose to form have any impact on their profits. Put differently, all agents are in a symmetrical position with regard to network links prior to their search for business partners, so one cannot predict their success based on differences in network structure.

This limitation is surmounted when we extend the model economy to allow for two rounds of partnership formation. In this extended model economy, agents who search for partners in the second round will do better if linked to entrepreneurs who found bridge partnerships in the first round. Being linked to these fortunate entrepreneurs is itself a matter of chance, and thus constitutes an exogenous impact of network structure on agent success. Only then does network structure have a causal force in our model economy similar to the kind found, for example, in the chapter by Reagans, Zuckerman, and McEvily.

Our model economy also generates predictions regarding the observed pattern of inter- and intra-community exchange. In particular, given the assumption that cluster partnerships form within a community (because both partners live in the same community by virtue of working for the same parent firm) whereas bridge partnerships may form within or across communities, intra-community exchange is predicted to be greater than would be generated by random matching of partners. This prediction is consistent with "border effects" that are found

in observed trade, where the amount of trade drops off sharply when comparing trade within to trade across communities, controlling for determinants of trade such as community sizes and distance between trading partners.

When extended to two rounds of partnership formation, the model economy predicts that agents who search for partners in the second round, and who are linked to entrepreneurs who found bridge partnerships in the first round, will imitate the patterns of bridge partnership formation established in the first round. This behavior will create a tendency for patterns of inter-community exchange to persist over time, even if other determinants of inter-community exchange change, and is therefore consistent with the observed impact of past trade on current trade.

The major policy implication of our model economy is that formation of bridge partnerships relative to cluster partnerships should be encouraged, for two reasons. First, when agents search for bridge partnerships they do not take account of the fact that their own search makes the search of others more productive (because others are looking for them), and therefore do not devote enough effort to finding potential bridge partners. Second, agents choose their effort based on the profit they expect from bridge partnerships relative to cluster partnerships, but their decision ignores the additional output for workers (wages) that is generated by the bridge partnerships that are actually selected.

This analysis helps us to evaluate a real-world policy regarding entrepreneurship: restrictive employment covenants that prohibit employees from competing with their former employers after they have left a parent firm. Such a policy tends to discourage cluster partnerships since firms that result from such partnerships are more likely to be in the parent's

line of business and market area. Enforcement of restrictive employment covenants should therefore increase inter-community exchange and reduce observed border effects in trade. It is possible, however, that it over-corrects the problem of insufficient effort to find bridge partners, because agents will now accept bridge partnerships whose quality is too low relative to cluster partnerships.

An important area for improvement of our analysis is network decay, which takes place in a very artificial way in our model economy: the entire network vanishes as the old generation of entrepreneurs dies and a new generation of workers turned entrepreneurs takes its place. As a result of this assumption, networks in our model economy cannot evolve over time. Capturing richer network dynamics such as those described in the chapters by Burt and by Munshi and Rosenzweig could be a fruitful next step.

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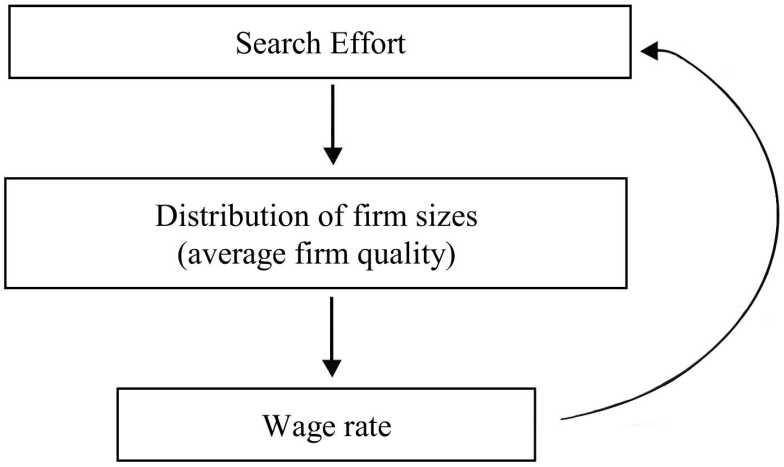

Figure 1: Determination of search effort, distribution of firm sizes, and wage rate in the model economy

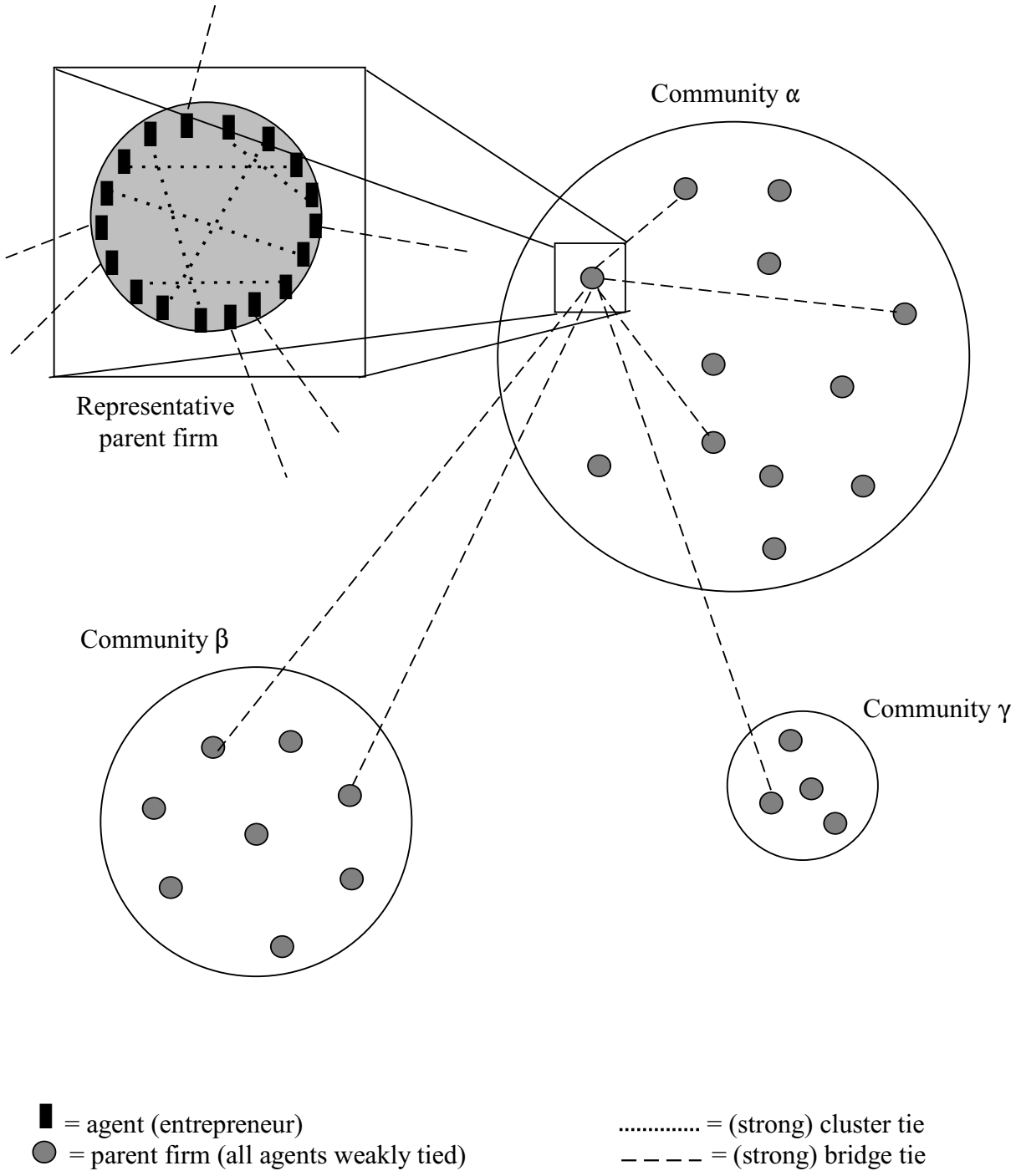

Figure 2: Underlying Network Structure

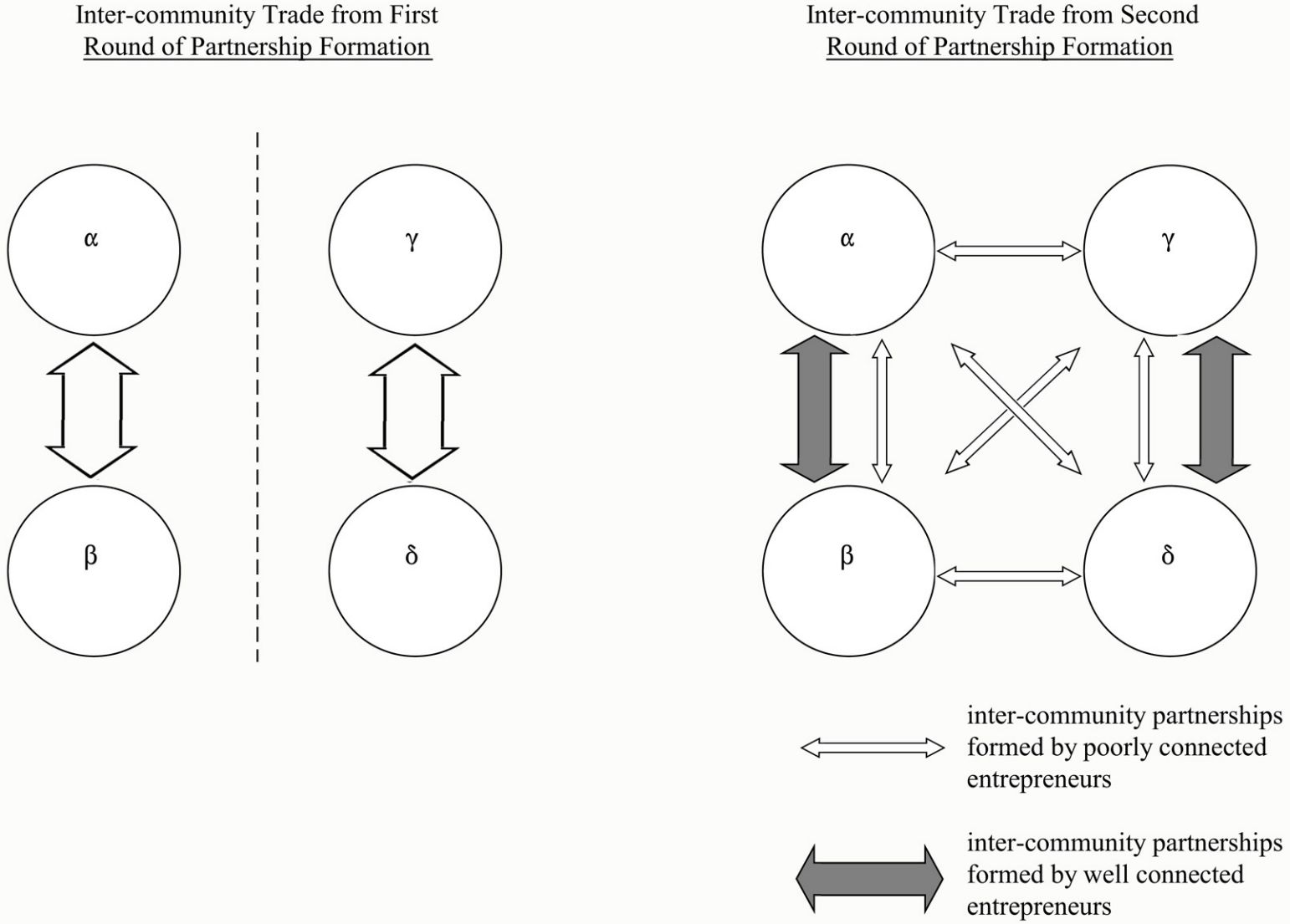

Figure 3: Trade Barrier Eliminated Between First and Second Round of Partnership Formation