The Social Times of Network Spaces: Sequence Analysis of Network Formation and Foreign Investment in Hungary, 1987-2001

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Abstract

To model, from its inception, inter-enterprise network formation and its interaction with foreign investment across an entire epoch of rapid and profound economic transformation, we gathered data on the complete ownership histories of 1,696 of the largest Hungarian enterprises from 1987 to 2001. We develop a combination of network and sequence analysis to identify distinctive pathways whereby firms use network resources to buffer uncertainty, hide or restructure assets, or gain knowledge and legitimacy. During the period, networked property grew, stabilized, and involved a growing proportion of foreign capital. Cohesive networks of recombinant property were robust, and in fact integrated foreign investment. Although multinationals, through their subsidiaries, dissolved ties in joint venture arrangements, we find evidence that they also built durable local networks. Our findings suggest that developing economies do not necessarily face a forced choice between networks of global reach and those of local embeddedness.
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“Social structures often are made to seem the antipodes to, or at least unrelated to details and nuances of, sequencing in timing. This is in part because of the influence of structuralism. Social times should instead be accounted as much part of structure as are network spaces” (Harrison White, 1992 p. 77).

INTRODUCTION

Business organizations today must cope with the challenges of a transforming global economy. Markets are volatile, technological change is rapid, and capital is mobile on an increasingly global scale. In settings of radical uncertainty, economic sociologists point to how firms cooperate in networks of strategic alliance (Kogut, Shan and Walker 1992; Kogut and Walker 2001; Powell and Smith-Doerr 1994; Powell, White and Koput 2001; Stuart 1998; Stuart 2000; Uzzi 1997). New research in political economy and the sociology of development similarly engages network conceptions of organization. Whether attentive to networks of “developmental associations” (Evans 1995), to “global commodity chains” (Gereffi and Fonda 1992), or to new conceptions of multinational corporations as transnational networks (Ghoshal and Bartlett 1990; Hedlund 1993), emphasis is turning from decision-making structures of boundedly-rational actors to the structure of ties in which organizations are embedded (Morgan, Kristensen and Whitley 2001). Sustainable growth is more likely, research suggests, where the subsidiaries of foreign companies are embedded in network ties within the host economy, as locals and foreigners alike recognize that business networks can be viewed as a strategic resource (Andersson, Bjorkman and Forsgren 2002; Bair and Gereffi 2003; Dicken, Forsgren and Malmberg 1994). From the earlier question of how a national economy is integrated into the global economy, a new agenda for the field of economic development asks whether and how foreign investment is integrated into the local networks of host economies.

This paper furthers that agenda by analyzing the evolution of a national network of interorganizational ownership ties in its relationship to foreign direct investment (FDI). Can high levels of foreign investment be compatible with inter-enterprise ownership networks in a developing economy? Our analysis is conducted in a setting strategically chosen for 1) extraordinarily high levels of foreign investment in a situation 2) where domestic firms were forming inter-organizational ownership networks in response to extraordinarily high levels of uncertainty in their business environment – conditions marking the postsocialist Hungarian economy between 1987-2001. Our case involves one
of the most rapid and far-reaching transformations of a national economy. During this period, the institutions of the Hungarian economy were fundamentally reorganized from planning to market coordination. The system of property was similarly transformed: As we shall see, our data reveal that state ownership of the large-firm sector declined from 98 percent to 15 percent and the share of the large firm sector that was foreign-owned rose from only 1 percent in 1987 to over 50 percent in 2001.

To analyze how FDI interacts with evolving network structures, we gathered data on the complete ownership histories of 1,696 of the largest Hungarian enterprises from 1987 to 2001 (see data section below for details). This time frame yields comprehensive coverage of a rapid and profound economic transformation, reaching back to the moment when firms could register as corporations and encompassing the institutionalization of private property, market coordination, and foreign investment. Our time frame thus includes the entire period in which firms were privatized and new regulatory frameworks were established (governing, for example, banking, bankruptcy, accounting, contracting, and corporate governance). We are thus able to model, from its inception, network formation across an entire epoch of economic transformation.

Our goal is to produce a sociological account of historical change. Network analysts are accustomed to thinking about network properties in spatial terms; to this, we add thinking about network properties in temporal terms. Once we consider structure as composed both of variable social times and social spaces, we become attuned to the possibility that the interweaving of the extrication from state socialism and the entrance of foreign investors will take multiple paths with varying temporalities.

To analyze these processes, we develop an innovative combination of analytic tools that enables us to reconcile the structural focus of social network analysis with the historical orientation of sequence analysis. In place of a focal point high above the field, we work at ground level, following the trails, literally hundreds of them, made by enterprises as they make, break, and reshape ties to other firms. For this purpose, we use sequence analysis, a new method in the social sciences, that makes it possible to recognize patterns across thousands of such tracings. The resulting pathways are not unidirectional nor are their coordinates plotted in advance. The economic field of postsocialism is given shape and repeatedly transformed by the interactions of the multiple strategies of firms attempting to survive in the midst of regime change and globalization.

Anticipating in brief our major findings: our analysis indicates, first, that high levels of FDI are compatible with the persistence of inter-enterprise ownership networks. Globalization and the reproduction of network embeddedness are not necessarily mutually opposing processes. Second, we find, that participation in ownership networks significantly reduces volatility in revenues. Network ties buffer uncertainty throughout the period; they are a resource both for navigating the uncertainties of postsocialism and for managing the new uncertainties of internationalization of the economy. We find, third, that network forms of “recombinant property” (Stark 1996) are robust throughout the period. Notably, one variant of recombinant property, characterized by cohesive network structures, is most likely to involve the participation of foreign investment. More
than a mere legacy of state socialism, these network forms are a viable organizational response to the challenges of an internationalized economy. Fourth, we find that the subsidiaries of foreign multinationals are not simply joining existing network structures but actively participate in network creation and growth. By 2001, only 30 percent of foreign capital is invested in subsidiaries that have never been part of ownership networks. In Hungary, foreign investment and network evolution are intertwined processes.

Part I presents the basic contours of our case – the Hungarian economy after the collapse of state socialism, the subsequent emergence of inter-enterprise networks, the demise of state ownership, and the rise of foreign investment. Subsequently, we frame our theoretical and methodological contribution as an attempt to model the structure of network practices through combined attention to topography and temporality. The methodological innovation at the core of this study is to combine the tools of sequence analysis and network analysis to yield a sequence analysis of changing network positions.

In Part II, after describing our data collection, we chart the changing proportions of the Hungarian economy that are foreign or domestic, and networked or isolated. Because network analysis has asserted more often than tested the proposition that networks reduce uncertainty, our analysis includes models to specifically test whether network participation induces stability of revenues. To identify the micro-processes of inter-organizational network formation that explain the macro-structural outcomes, we move in Part III to more fine-grained modeling that makes sequences the unit of analysis. We define the state space of local network topographies – the building blocks of sequences – and we describe the optimal matching operations for grouping firms on the basis of similarities in sequence patterns through that network space. We then present and discuss the typical pathways through the network space of local topographies. Recognizing that relational resources can be used for different organizing purposes, we interpret the temporal patterns of network properties to understand the interdependent practices of Hungarian managers and foreign investors. The transformation of a national economy is not a single process obeying a global logic but is formed out of the interweaving of multiple processes.

I. A SOCIOLOGICAL ACCOUNT OF HISTORICAL CHANGE

Emergence of inter-enterprise ownership networks

The postsocialist economies of Eastern Europe and the former Soviet Union offer a striking laboratory to study processes of network formation in a period of rapid and far-reaching economic change. In their extrication from state socialism, postsocialist firms confronted highly uncertain political, economic, and institutional environments. With the demise of the old COMECON alliance that regulated trade among the socialist economies, firms watched the collapse of their once secured trading partners. Literally within a month, and not at the margin but in overwhelming proportions, they had to seek new suppliers and new customers. They would do so in an institutional environment of extreme complexity. Newly elected democratic governments were dismantling the
socialist planning apparatus and launching ambitious programs of privatization. From one month to the next, government agencies promulgated regulations governing banking, bankruptcy, accounting, contracting, foreign direct investment, and corporate governance. For firms remaining in state ownership, for recently “privatized” firms, and for new start-up firms alike, the challenge was to navigate through a maze of new policies in which contradictory regulations and inconsistent enforcement produced ambiguity about which rules and which games were operating.

Writing in the mid-1990s, Stark (1996) drew on insights that inter-organizational ties might provide means to cope with highly uncertain environments. Based on data gathered through complementary research methods (ethnographic research in firms, the analysis of government agency documents, and the analysis of the ownership records of the 200 largest Hungarian enterprises and top 25 banks in 1994) Stark identified an ensemble of practices that he labeled recombinant property. Inter-enterprise ownership networks, Stark demonstrated, were a response to uncertainty, serving as a strategy to spread risk (see also Johnson 1997; McDermott 1997; McDermott 2000; Róna-Tas 1998; Spicer, McDermott and Kogut 2000; Böröcz 2001; Vedres 2000). Like mountain climbers assaulting a treacherous face, postsocialist firms used networks of cross-ownership as the safety ropes binding them together.

Two prevalent forms of inter-enterprise ownership networks were identified in Stark’s study. The first involved processes in which large state-owned or formerly state-owned enterprises spun off corporate satellites (some of which were still of considerable size and also spun off their own satellites), resulting in star-shaped networks with the very largest firms at the hubs. Along these vertical ties, firms shifted assets and liabilities to take advantage of shifting government policies. The second type of inter-enterprise ownership networks involved networks of greater density, resulting in de-centered, more cohesive structures. Unlike the simple star-periphery structures, along these more heterogeneous and cohesive networks, firms regrouped interdependent assets and restructured enterprises.

Stark stressed that recombinant property might increase chances of survival without increasing performance. Some firms were diversifying their portfolio of resources (blurring the boundaries of public and private) for the purpose of socializing liabilities while privatizing assets (Stark 1996: 1012-15). Similarly, business group networks were a means not only of risk-spreading but of risk-shedding in a context in which policies of credit-worthiness and debt forgiveness were highly politicized (Stark, 1996: 1009-12). Thus, networked assets could facilitate productive restructuring; but, as Stark demonstrated, they also offered avenues to exploit ambiguities in regulations and offload liabilities to the tax-payer in state-sponsored programs of bank bailouts and debt forgiveness.¹

¹ Writing at mid-decade, Stark noted, “Centralized management of liabilities will not continue indefinitely, but the organizational dynamics of enterprises formed under the new paternalistic conditions are likely to have strong path-dependent effects (Stark 1996: 1012).”
Stark’s observations of Hungarian enterprises were made while levels of foreign investment were modest, during the period of uncertainty when new regulatory frameworks had been introduced but were not yet institutionalized. Since then, extrication from state socialism has been decisive: the planned economy and the dominance of state ownership have been systematically dismantled. Similarly, the entrance of foreign investment has been massive: the Hungarian economy today is arguably one of the most globalized economies in the world. What, then, has happened to inter-organizational ownership networks over the time period studied?

**Foreign Investment meets Postsocialist Networks**

The existing literature on foreign investment and network forms in postsocialist settings suggests at least three possible scenarios. One possibility is that the shock of system change will produce early patterns of network formation that reach a tipping point to a self-reinforcing dynamic of almost unchecked network growth. Business groups would be strong, not simply because they are densely connected, but also because they link deeply into the political class. These domestic networks might then lock out foreign capital, perhaps even dispelling some initial foreign investors. In terms of the relative proportions of the economy that are networked or isolated, foreign or domestic, this would be a case where, at the extreme, almost everything is networked and domestically controlled. Even the modest levels of foreign investment would be bound to domestic business groups. This scenario of network crowding would correspond to the anti-developmental lines of the contemporary Russian economy analyzed so perceptively by Burawoy (Burawoy 1996; Burawoy and Krotov 1992) and others (Johnson 1997; Zon 1998).

A second possibility is that extraordinarily high levels of foreign investment will lead to the eradication of inter-enterprise ownership. This scenario corresponds closely to the view of Hanley, King, and Toth (2002) who, in challenging Stark’s approach, argue that inter-enterprise ownership networks were a transient and fleeting phenomenon, confined to the period immediately following the collapse of state socialism. The eradication of these inter-enterprise ownership ties, according to Hanley et al, has been carried out by “private parties” exercising “clear and unambiguous ownership rights” – in particular by foreign investors who, in their view, desire strong and unambiguous lines of control, undiluted by ownership network ties. Inter-enterprise ownership links that preceded foreign investment would be broken up when foreigners acquired firms through the privatization process. Moreover, given the powerful influence of foreign firm, (rich in resources – financial, managerial, and ideological), their predilection to shun network ties

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2 For the Hungarian case, where we know that foreign investment continued to grow, this first scenario is obviously counterfactual but, nonetheless, heuristically useful.

3 Hanley et al (2002) argue that inter-organizational networks are a mere holdover from the era of state socialism and that there are no reasons to think that new ties will be formed. By their logic, the overall number of network ties should decline as a strict function of the rate of broken ties because new ties are not likely to be formed.
would rapidly diffuse throughout the economy. The result of the direct actions of the foreign multinationals as well as of these indirect demonstration effects would be, at the extreme, an economy opposite to the first scenario – almost nothing would be networked.

A third scenario describes a segregated, dual economy as increasing levels of foreign investment leads to a radical separation between foreign and domestic firms. Foreign investment, in this view, results in “cathedrals in the desert” (Grabher 1994; Hardy 1998; Pavlinek and Smith 1998; Uhlir 1998). Like oil platforms in the open sea, these are platform operations importing semi-finished parts to be assembled locally for export. Whereas Hanley et al (2002) take a positive view of the spillover effects of FDI, in the dual economy model it is the very absence of spillover that is the root of the problem (Comisso 1998). FDI leaves the domestic economy untouched, thereby maintaining underdevelopment. A case where foreign investors do not make network ties and where the networks of domestic firms grow only among themselves (Zysman and Schwartz 1998) would correspond to a radically segregated, dual economy in which FDI is overwhelmingly isolated and domestic firms are predominantly networked.

With our data we can chart the proportions of the Hungarian economy that are 1) networked and foreign, 2) networked and domestic, 3) isolated and foreign, and 4) isolated and domestic. The findings, reported for the entire period in a subsequent section below, are at odds with each of the three scenarios: in 2001, large firm capital was distributed across the four cells in roughly equal proportions. Domestic networks have not crowded out FDI, and multinationals have not eradicated the networks; but Hungary is also not a radically segregated dual economy. This constellation of the macro-structure of ownership suggests that other processes are at play than those outlined in the scenarios above. The challenge, then, is to understand the processes whereby some foreign capital became integrated while other foreign capital was isolated, and how some network formations survived without foreign capital while other network formations developed with the participation of foreign investors. In short, what are the micro-processes that produced these macro-structural outcomes?

To address this question we must turn from macro-structural models using dichotomous terms such as whether foreign controlled and domestic controlled firms are “in” or “out” of the network to micro-processual models that examine the specific shapes of local network neighborhoods. That is, we investigate network structures of varying topographies and consider the possibility that the meaning of these topographies is not fixed but might vary according to temporal context.

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4 Whereas for Hanley et al (2002) the absence of network ties has positive effects as a model of good behavior that quickly dissolves differences across sectors, in the dual economy perspective the absence of ties perpetuates a segregated economy, malevolent because its radical separation allows no positive influence across sectors.
Property, with network and temporal properties

Studies of property transformation in the postsocialist setting typically focus on broad changes in the structure of property in terms of ownership categories such as state ownership, private ownership, foreign ownership, and the like. Whereas our macro-structural models adopt a similarly categorical approach, our micro-processual models examine the structure of property in terms of its network properties. Exploiting the polysemic character of the term “property,” we seek to understand the properties of property—i.e., the structural properties (characteristics) of interconnected properties (holdings).

We focus on network properties from the perspective of the individual firm, and we start from the notion that network ties are strategic resources for firms (Kogut and Walker 2001). But we do not assume that all firms have the same strategic orientations or that firms participate in network ties in the same way. Thus, in contrast to models that examine properties of the global network (e.g., the distribution of path distances or nodal degrees, see Barabási, Albert and Jeong 1999; Kogut and Walker 2001; Powell et al. 2002; Watts 1999), we are interested in variations in local network structures that reflect different practices of local network organizing. Therefore, in addition to our macro-structural modeling that identifies whether a given firm is embedded or not embedded, we will probe for qualitative differences in types of embeddedness. Different network properties reflect different networking practices. That is, the different shapes of local configurations—for example, their size and their cohesiveness—reflect different organizing logics. As we shall see, in postsocialist Hungary, network practices do vary: firms can use network ties, for example, to hide assets, to restructure assets, to gain access to knowledge, to increase legitimation, to secure supplies and markets, and so on.

But network properties vary not only across firms in network space but also across time. As firms make and break ties, they (and those around them in network space) reshape network properties. As they do, they produce distinctive sequences of network structures. Thus, in addition to topographic features, now conventional in social network analysis, we also examine temporal properties such as timing, pace of change, path dependencies, lock-ins, turning points, and so on. Just as we were attentive to variation in the specific shapes of the network properties in a given firm’s locale, here we are attentive to the variation in social times. Network times and network spaces, separately and in their combination, are structuring—they enable and constrain how network ties can be deployed as resources. Studying variation in the sequences of local structures, we argue, is a way to identify distinctive pathways of network evolution.

What are the relational path dependencies in which some firms “lock in” to a given network position? Some network positions might endure but they might also prohibit development. Are there pathways, for example, that buffer firms from uncertainty in the early postsocialist period but later pose barriers to including foreign investors? Which types of pathways include foreign investors in their early formation? Are there pathways of late entrance into inter-organizational networks that include foreign investors?
Do we find evidence of networks of recombinant property? Do they endure or do they dissolve? How was their dissolution or robustness related to the timing and the patterns of foreign investment? These questions directly address Hanley et al.’s (2001) challenge that recombinant networks were ephemeral and did not survive through 1997. Given that our dataset includes the formative years extending back six years prior to Stark’s mid-decade study, we are also able to answer questions about the temporality of the two variants of recombinant property networks. When do star-shaped spin offs, with their opportunities for asset-stripping and liability management, appear? Does cohesion evolve gradually out of star-shaped formations, or does it follow a separate pathway of evolution?

If we do find evidence that specific variants of recombinant property were robust, will foreign investors be shut out of these forms, will they be integrated into them, or will foreign investment vary according to these distinctive network properties? Will foreign investors be attracted to star-shaped networks because of their structural isomorphism to hierarchical supplier networks, or will they avoid these because of their historical origins as vehicles of managerial opportunism? Will foreign investors avoid entering cohesive and densely networked structures because they are cautious about the entanglements of such embeddedness, or will they prefer these structures because of their managerial entrepreneurialism?

Our modeling, it should be emphasized, does not assume that the action of network formation is all on the side of Hungarian actors, with foreign investors as merely reactive players, attracted to or repelled by different network properties. Instead, foreign investors are, potentially, actively participating as agents in network formation and restructuring. They are likely to use network resources in their attempts to gain footholds, increase presence, perhaps even achieve predominance in an emerging market. Thus, we expect that foreign investors will establish network ties to domestic enterprises within joint venture arrangements. Forming a joint venture means that a foreign investor establishes a strong network tie (in the form of shared ownership) with a local firm to obtain legitimacy in the eyes of domestic economic actors, national policy-makers, and local officials (Kogut 1988; Yiu and Makino 2002; Zaheer 1995). This strong network tie is potentially an avenue to obtain local knowledge, especially under conditions when the regulatory environment is untested, where domestic markets have culturally-specific features (e.g., involving tastes or practices in advertising, marketing, packaging, etc) (Kogut 1991), or where basic infrastructural logistics (e.g., utilities, transportation, etc.) have locally idiosyncratic features. We expect that foreign owners will form ownership ties with Hungarian firms in joint venture arrangements, especially in the earlier period of

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5 There are indications that the organizing principle of business networks might be compatible with the structure and practices of multinational firms. To cope with challenges of organizing across geographical and cultural distances, multinationals are increasingly structured as networks (Ghoshal and Bartlett 1990; Morgan, Kristensen and Whitley 2001), seeking flexibility through empowering subsidiaries and embedding in inter-organizational relations (Buckley and Casson 1998). Hedlund (1993), for example, suggests that multinational corporations are more heterarchical than hierarchical.
economic transformation – up to the middle of the nineties – as a buffer against uncertainties in policy preferences and changing institutions. Some of these ties will be long lasting; but many will be temporary, terminating as legitimacy is established, regulatory uncertainties are mitigated, locally-specific knowledge is acquired, and operations are running smoothly.

We further expect that foreign ownership will lead to the formation of star-shaped groups of suppliers. In contrast to firms whose existence pre-dated the collapse of the state-socialist economy, foreign firms are relatively more isolated and atomized actors in the economy; nonetheless, they take their positions in chains of inputs and outputs. Foreign owners might decide to secure some of their inputs by establishing ownership ties to Hungarian firms, thus starting to build business groups similar to those that are integral practices in their home countries (Podolny 1994). Such business groups might be longer lasting than joint ventures, ensuring the secure flow of inputs for foreign subsidiaries (Granovetter 1994). Moreover, joint venture arrangements can serve as seeds of group formation. But in analyzing a move from dyadic to other network shapes (and vice versa) we will be alert to the possibility that a given shift does not have the same meaning across the entire epoch of our study.

For an historical network analysis

To conduct a sociology of turbulent times, we propose an innovative synthesis of network analysis and sequence analysis. Building on recent efforts to bring dynamics into network analysis (Brudner and White 1997; Powell, White and Koput 2001; Snijders 1990; Snijders 2001; Stuart 1998; Watts 1999), we draw on sequence analysis, a recently developed research tool that makes it possible to study historical processes in an eventful way similar to historiography while retaining social scientific abstraction (see especially Abbott 1990; Abbott 1992; Abbott 1995). Instead of collapsing time to before-after dichotomies, sequence analysis reveals the variable structuring of time: the varying paces

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6 Inter-organizational networks are integral parts of business practices in the home countries of multinationals that invest in Eastern Europe. Numerous studies demonstrate the importance of such network ties in the US (Fliqstein and Brantley 1992; Galaskiewitz 1985; Glasberg and Schwartz 1983; Granovetter 1985; Granovetter 1994; Mizruchi and Galaskiewicz 1994), Japan (Gerlach 1992; Lincoln, Gerlach and Ahmadjian 1996; Lincoln, Gerlach and Takahashi 1992), Korea (Biggart and Guillen 1999), Canada (Buckley 1997), Germany and Britain (Windolf and Beyer 1996), and other parts of West Europe (Stokman, Ziegler and Scott 1985). (Erramilli 1996; Hennart and Larimo 1998) demonstrated that distinctive practices in the home country influence ownership arrangements in the host country.

7 For example, joint ventures might be formed either to gain legitimacy and/or to find domestic suppliers. These needs will have varying salience in different periods, and moreover, legitimacy might be acquired before foreign investors feel comfortable enough to engage domestic enterprises as trusted integrated suppliers. Early joint ventures based solely on the need for legitimacy are more likely to dissolve, while joint ventures formed later are more likely to transform into supplier groups.
of change, path dependencies, turning points, lock-ins, and contingencies – in ways that differ from simple calendar time. To study the unfolding of multiple, parallel processes, sequence analysis provides a methodology to follow, with much detail and rigor, events at the socially meaningful level of action. These events, changes within a state-space that is not assumed in advance but emerges from the analysis, are the building blocks of sequences. In taking up White’s challenge in our epigraph to make social times as much a part of structure as are network spaces, our contribution to a more historical network analysis does not simply include time as a variable but, instead, recognizes time as variable.

With its roots in the study of gene sequencing in biology, sequence analysis has been applied in sociology predominantly to the careers of persons (Abbott 1995; Abbott and Hrycak 1990; Blair-Loy 1999; Stovel, Savage and Bearman 1996; and see especially Giuffre 1999 for a combination of sequence and network analysis in a study of artists’ careers). Whereas sequence analysis has given us a perspective on careers as historical processes but has not been applied to business organizations, network analysis has been applied to business organizations but has not been done historically.

In combining the two approaches, we begin with the element that each shares – the notion that meaning is given by context (Abbott 1997). For the network analyst, no tie has meaning in itself. To interpret a tie, the analyst must understand its location in social space. In network analysis, structure – context – is topographic. For sequence analysts, as for historical sociologists more generally, no event has meaning in itself. The meaning of an action, an event, a social formation, or a relationship must be understood in its temporal context. In the theoretical approach that we are developing, structure is both topographic and historical. For us, the meaning of a tie must be identified at the intersection of topographic and temporal contexts.

In analyzing the evolution of inter-enterprise ownership ties in Hungary, we study topography at a socially meaningful level of action. Whereas much of the recent work on network dynamics has focused on topographic properties of the global network, in particular its properties of connectedness, we start from the perspective of the individual firm and analyze its position within a network neighborhood of local action. Ownership networks in Hungary, we reason, differ from networks such as electricity grids. In the latter networks of flow, where electricity, information or contagious disease can spread along any number of steps, the most important task is to understand the global configuration of the network, the redundancy of ties, and the overall structure of reachability. Hungarian ownership networks, however, have a shorter range (network parlance for the path distance beyond which there is no inter-relatedness). Path distances beyond two steps (the owners of owners) have little importance: whereas the owner of the owner can be important, the owner of the owner of the owner has little influence in the life of a postsocialist firm.

Accordingly, we focus on the shapes of local network configurations, building up from ties of the focal firm and of its near network neighbors. Starting from a set of elemental dimensions and applying a clustering algorithm (for details see the section on state space
below), we identify a finite set of distinctive local network properties. For a given firm, for any year in which it existed, we can then code its position within a local topography. Thus, in place of the topographic properties of the global network for each of the fifteen years in our study, our analysis is conducted on 18,073 micro topographies (i.e., one network position for each firm in every year that it existed).

These local topographies are the building blocks for the analysis of temporalities. At the basis of our project of historical topography is a reconstruction of the network histories of 1,696 firms. For each firm, we record its position within the state space of possible micro topographies for every year that it existed. The resulting sequence of positions is a network history of that firm. Some firms' histories, of course, are likely to resemble each other (not because they are tied to each other but because they have similar sequences of network positioning) while differing from others. Using an optimal matching algorithm modified from the analysis of gene sequencing, we identify the characteristic sequences – typical pathways – through the state space of local topographies.

A sequence approach to network histories leads to a reconceptualization of a network path: we do not focus on the geodesic path lengths that connect any two actors within a given synchronous cross section of the network, but instead we focus on the pathways that firms take over time across local network positions. It is by studying the historical topography of these pathways that we explore the multiple temporalities in the interwoven processes of extrication from socialism and the entrance of foreign investment.

II. THE EVOLVING SHAPE OF HUNGARY'S MIXED ECONOMY

Data collection

The comprehensiveness of our dataset is unprecedented in the literature on changing ownership structures in a transforming economy. The dataset we have assembled

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8 Similar research projects in the region on inter-enterprise networks cover fewer companies, in less depth, over less time. Toth (1998) used two samples of 300 companies (the largest companies based on revenue and export volume). His descriptive statistics recorded the presence of a Hungarian firm as an owner without constructing the network of ownership ties. Ferligoj et. al. (2001) have analyzed the networks of the largest Slovenian companies based on ownership and board interlock ties in 1997 and 2000. Their sample, however, was limited only to the top 150 firms. Both of these studies were cross sectional. Several studies outside the East European region examine panel data. Kogut and Walker (2001), for example, study ties among 550 of the largest firms in the Germany economy from 1994 to 1997 (i.e., during a period of restructuring not unrelated to the postsocialist experience but within a markedly different political economic setting). Keister (2001) examines 535 Chinese firms from 1988-1996. Her data involve 40 named and already identified business groups in which the location of a given firm in a given business group is fixed by lists from 1985.
includes the complete ownership histories of the largest enterprises in Hungary during the
period from 1987-2001. We define a large firm as being in the annual ranking of the top
500 firms (based on revenue) in any of the years from 1987 to 2001. Our inclusion rule
results in a population of 1,843 firms. For a small country like Hungary, this population
of firms accounts for more than a third of all employment, half of the GDP, and the
overwhelming proportion of export revenues (Figyelõ 2002).

Ownership data were transcribed by our research team directly from the 20 official courts
of registry where Hungarian firms are obliged to register their owners. For each firm we
collected the following: equity in thousand Hungarian forints, the names of the firm’s top
twenty-five owners and the percentage stake that each owner holds in the company. We
also have information on the date when the firm was founded and the date of filing for
bankruptcy, liquidation or cessation for any reason, i.e., the date when the file of the firm
was closed at the registry court. Out of the 1,843 firms, 147 ownership files were
unavailable or contained little or no information on ownership. Our final dataset contains
the full ownership histories of 1,696 enterprises. For any given firm in any given month
in our dataset we can precisely identify the owners and the percentage of the assets each
holds.

We define a tie as an ownership stake that one enterprise in our population holds in
another firm in the population. Our definition is restricted to direct ties (representing at
least a one percent ownership stake) among the largest Hungarian enterprises. It does not
include, for example, the numerous ownership stakes that these firms have in smaller
companies. Nor does it include a tie between two firms through a common owner, as in
the more inclusive definitions of affiliation networks (Kogut and Walker 2001;
Wasserman and Faust 1994). It follows that, in our population of firms, an ownership
stake by the state or a foreign owner does not constitute an inter-organizational tie. In
order to identify compositional features of the ownership structure, we have also coded
owners by type, using the names of owners to classify four categories: state, Hungarian
firm, Hungarian person, and foreign owner.

The changing proportions of the mixed economy

Our dataset makes it possible to chart the changing configuration of the macro-structure
of ownership across fifteen years of Hungary’s transforming and globalizing economy.
During this period, the ownership shares of the state and foreign investors have changed
radically.⁹ In 1987, about 97% of the total capital of the firms in our population was in
state ownership. By 2001, only 15% of large firm capital remained in state hands.
Conversely, only 1% of large firm capital was foreign owned in 1987, but this share

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⁹ The findings reported below are based on the following calculations: For each firm we record the
amount of capital in thousand Hungarian forints that is owned by various types of owners. To
calculate the share for a type of owner for a given year we sum its holdings in each of the
companies and divide that by the total amount of large firm capitalization in that year.
increased linearly\textsuperscript{10} to the end of the period we study, amounting to 50% of the total large firm capital in 2001\textsuperscript{11}. Domestic firms represent a third significant type of owner. In 1987, the ownership share of domestic firms was only 2%, but rose to 21% by 1991, and stayed at this level through 2001. Although individuals have ownership stakes in many of the large firms, their combined share in large firm capital is a mere 2.5% throughout the period.

How did the rapidity and magnitude of ownership change affect the evolution of network ties? In 1987, the first year of our historical study, we find a nascent but very small network with only 54 firms, representing about 10% of overall large firm capital. With the 1988 passage of the law that allowed state-owned firms to take a corporate form and with the beginning of political regime change, network growth gains momentum. By the end of 1989, more than 200 firms are participating in network structures, accounting for 31% of large firm capitalization. Within two years, 62% of the large firm capitalization is held in the more than 400 firms that have ownership network ties. The number of networked firms peaks in 1995, at 561 firms. Network ties decline after 1998; but by 2001, the number of firms with at least one direct ownership tie still stands at 454, representing 52% of capitalization.

Although the networked component of the economy becomes smaller, it does not – in contrast to the arguments of the transition school – dissolve. Moreover, there is evidence indicating that the strength of a given tie has increased. In the first years of our period an average network tie represented a 20% ownership stake in a company. By 2001, the average tie strength is 36%, suggesting the consolidation rather than the dissolution of the network.

To this point, we have examined how the networked component rises and then somewhat contracts in a period when overall foreign ownership increases. We have established that approximately 50% of the capital is foreign owned in 2001. We have also established that about 50% of the capital is in firms with at least one tie in the inter-organizational ownership network. We must now establish the extent to which these two segments are overlapping or segregated. Does Hungary have a dual economy in which the foreign component is isolated and the domestic component is networked?

\textsuperscript{10} As a test of linearity we have fitted regression lines to the trends of decreasing state ownership and increasing foreign ownership. The R-squared of a linear trend line is 0.97 for state ownership and 0.98 for foreign ownership. While transformations were radical in their consequences, they were also smooth in their timing. Contrary to Hanley et al (2002), these findings indicate that the dynamics of increasing globalization was not a function of government preferences and changes in privatization campaigns.

\textsuperscript{11} Europe has been, of course, the site of major changes in property structure other than those in the postsocialist cases. State ownership in Italy, for example, decreased from 23% to 3% -- but over the course of forty years, from 1960 to 2000 (Aganin and Volpin 2003).
To gain a picture of the evolving shape of Hungary’s mixed economy, we have computed the proportion of large firm capital with and without significant foreign ownership that is either networked or isolated from the network. A significant foreign owner, in our definition, is a clearly dominant owner or, at least, a coalition partner in ownership. Where there is an identifiably dominant owner, other entities with ownership interests would not be classified as significant owners. To assess the distribution of firms according to the concentration/dispersion of ownership, we used Ward hierarchical cluster analysis to find typical patterns of ownership based on the percentage shares held by a firm’s first largest owner, second largest, third, fourth, and fifth for every year in which it existed as a company. Because dispersed ownership is exceedingly rare in our population of the largest enterprises, a two cluster model is appropriate for representing ownership structure. A dominant ownership structure accounts for 45 percent of all firm years. In this first cluster, the dominant owner holds, on average, 98 percent of the shares, while the second owner holds less than 2 percent. Second owners in this cluster are not classified as significant owners. The second cluster represents a coalitional structure in which the first owner holds, on average, 51 percent of the shares, while the second holds 25 percent. Thus, either the first or the second owner of firms in this coalitional cluster is classified as significant owner.

For each year from 1987 to 2001 we can now calculate the proportion of large firm capital in four categories: 1) firms that are isolated from the network and domestically owned, 2) firms that are isolated from the network and have significant foreign ownership, 3) firms with a networked connection and are domestically owned, 4) firms with a networked connection and significant foreign ownership.

In a segregated dual economy, the overwhelming majority of firm capital would be in two categories: networked domestic (N-D) and isolated foreign (I-F). Our findings, represented in Figure 1, indicate that Hungary is not a segregated dual economy. In 2001, the distribution of capital among the four categories was the following: isolate domestic, 18 percent; isolate foreign, 29 percent; networked domestic, 26 percent; and networked foreign, 26 percent. Although the isolate foreign-owned firms form the biggest category, this component of the mixed economy contains only three percentage points more capital than the foreign owned networked group of firms.
Figure 1 presents the broad contours of the changing shape of Hungary's mixed economy across the period under study. The sum of the networked foreign and networked domestic represents the rapid growth and stabilization of the networked part of the economy described earlier. What is visible in Figure 1 is the steady growth, between 1991 and 2001, of the networked foreign component, eventually comprising half of the networked capital.

Figure 1 also illustrates that alternative scenarios were open possibilities from 1991. Selective extrapolation from early trends in different components could yield very different expected outcomes. For example, between 1989 and 1991, the networked domestic component increased from 27 percent to 57 percent. Selective extrapolation from this dramatic growth could suggest that networked domestic firms would crowd out other forms of property including foreign ownership, perhaps along the anti-developmental lines of the Russian economy (Burawoy and Krotov 1992; Johnson 1997). Similarly, focusing on the growth of the isolated foreign component, nearly doubling between 1989 (8 percent) to 1990 (15 percent of large firm capitalization), one could selectively extrapolate an economy dominated by foreigners and the extinction of domestic network forms of property (Hanley et al 2002). The high rate of growth of both the isolated foreign and networked domestic components could have encouraged predictions about an emerging segregated dual economy (Comisso 1998).
Network participation and revenue volatility

Our findings that the share of networked property grew and stabilized, that the strength of ties increased, and that foreign investment is compatible with inter-organizational ownership networks suggest that network ties can have an economic significance. One of these micro mechanisms, we argue, is the reallocation of capacities and resources that stabilizes the volume of orders and reduces the costs of reorganization during periods of restructuring. The supply patterns of networked firms will be less vulnerable to disruption, more able to shift orders to firms in their network with excess capacity, and better able to identify new organizational resources. Spreading risk might dampen potential for large and sudden upswings and growth, but it will also mitigate abrupt downturns. We expect that firms that were connected in the network will have longer episodes of stability and less volatility in their revenues than firms that were never networked. In this section, we test these propositions.

In a study of inter-organizational networks and corporate performance in Japan, Lincoln et al (1996), demonstrate that firms that are members of strong business groups show lower volatility of year-to-year profitability (see also (Miner, Amurgery and Stearns 1990). In the Hungarian economy, however, profitability is so rare through much of the period of our study that it cannot serve as a performance indicator to make distinctions among firms (Major 1999). As a more appropriate performance indicator we use annual rankings of firm revenues. To capture major upward or downward movements, we categorize rankings in five classes: a firm can be in 1) the top 50, 2) the top 100 but below the top 50, 3) in the top 200 but below the top 100, 4) in the top 500 but below the top 200, and 5. below the top 500. For a given firm, we measure stability as the longest stable period in years in the same ranked class divided by the total years the firm was alive. To measure volatility in revenues we construct two binary variables recording upward or downward mobility if a given firm ever moved up or down at least one class in revenue ranking.

We use analysis of variance to test the hypothesis that stability of revenues is induced more by networked ownership than by isolated ownership. We find that firms that were in an ownership network, with at least one inter-organizational tie for at least one year, have significantly greater stability in the revenue ranking than firms that were always isolates. Whereas for firms isolated throughout the period, the average ratio of the longest stable episode over the whole life of the firm is 0.22; for the networked firms this ratio is 0.29 (F=37.49, p=.000).

To estimate the probability that a networked firm, relative to an isolated firm, will drop or will climb at least one revenue rank class, we computed logistic regression models

12 Because bankruptcy procedures can take years and thereby induce seeming periods of stability (with flat lines of revenue while the firm is in the bankruptcy courts), our analysis is for those firms that have survived through the present day. We found no significant difference between isolated and networked firms in terms of frequency of bankruptcy (Chi-square=1.21, p=.270).
(presented in Table 1). In addition to the variable indicating that a firm has been part of the network, our models also include the length of the firm’s life in years that indicates exposure to revenue volatility. We find that the probability of both drops and climbs is significantly lower for networked firms.

<table>
<thead>
<tr>
<th></th>
<th>Drop in revenue rankings</th>
<th>Climb in revenue rankings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Chi-squared</td>
<td>42.033**</td>
<td>34.909**</td>
</tr>
<tr>
<td>Networked</td>
<td>-.293*</td>
<td>-.318*</td>
</tr>
<tr>
<td>Life in years</td>
<td>.106**</td>
<td>-.098**</td>
</tr>
<tr>
<td>Constant</td>
<td>-.355*</td>
<td>2.416**</td>
</tr>
</tbody>
</table>

*: p<.05, **: p<.01

Our models of revenue change indicate that network ties are means to buffer uncertainties, inducing longer periods of stability, making upward mobility less likely, but also decreasing the likelihood of drops in revenue ranking.

III. SOCIAL SEQUENCE ANALYSIS OF NETWORK EVOLUTION

Sequences of topographies

The state space. We now turn to more fine grained modeling that makes sequences the unit of analysis. We start from the observation that a given firm is not simply in or out of the network, but that the local properties of its network embeddedness can vary. Our first step is to define these local topographies. They comprise the network state space through which a firm can move across time. In defining the elements that make up the state space we do not start with pre-conceived categories. Instead, we begin by positing the dimensions along which a focal firm’s network topographies can vary. Our task here is to explicate these dimensions and then build up from the clusters of combinations across them to identify the typical local network topographies.

Our first dimension is the size of the focal firm’s network, operationalized here as the number of alters in the focal firm’s ego network. Our second dimension of local network properties is cohesion. An ego network of a given size can contain more or less ties between the alters of the focal firm. We operationalize the cohesion of a topography as the number of at most two step paths between alters. To analyze the topography in which a given firm is positioned, we also need to take into account the ego networks of its alters. Our third dimension is the average size of all alters’ ego networks, and the fourth is the average number of cohesive paths in all alters’ ego networks.
To identify typical topographies from the constellations of these four variables we use Ward hierarchical cluster analysis (Ward 1963). A case in this cluster analysis is the network topography (defined by our four dimensions) of any focal firm in any year. There were 18,073 network topographies in this analysis. Ward cluster analysis groups these topographies together if they have a similar pattern across the four dimensions. The following table (Table 2) shows the typical local network topographies that we derived from this cluster analysis.

Table 2: Typical local network topographies.

<table>
<thead>
<tr>
<th>Topography</th>
<th>N</th>
<th>Percentage of non-isolate</th>
<th>Means of ego network statistics</th>
<th>Graph a</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Isolate</td>
<td>12,378</td>
<td>-</td>
<td>Size: 0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cohesion: 0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' size: 0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' cohesion: 0.00</td>
<td></td>
</tr>
<tr>
<td>2. Dyad component</td>
<td>1,260</td>
<td>22.12%</td>
<td>Size: 1.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cohesion: 0.00</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' size: 1.00</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' cohesion: 0.00</td>
<td></td>
</tr>
<tr>
<td>3. Small star periphery</td>
<td>1,985</td>
<td>34.86%</td>
<td>Size: 1.22</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cohesion: 0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' size: 3.34</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' cohesion: 0.00</td>
<td></td>
</tr>
<tr>
<td>4. Large star periphery</td>
<td>280</td>
<td>4.92%</td>
<td>Size: 1.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cohesion: 0.00</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' size: 12.10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' cohesion: 0.00</td>
<td></td>
</tr>
<tr>
<td>5. Star center</td>
<td>543</td>
<td>9.53%</td>
<td>Size: 3.37</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cohesion: 0.00</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' size: 1.35</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' cohesion: 0.00</td>
<td></td>
</tr>
<tr>
<td>6. Cohesive group</td>
<td>899</td>
<td>15.79%</td>
<td>Size: 2.84</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cohesion: 0.46</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' size: 6.82</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' cohesion: 1.20</td>
<td></td>
</tr>
<tr>
<td>7. Strongly cohesive group</td>
<td>728</td>
<td>12.78%</td>
<td>Size: 2.71</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cohesion: 2.40</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' size: 9.91</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alters' cohesion: 8.55</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>18,073</td>
<td>100.00%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: a: White node indicates the focal firm in the ego network.
Optimal matching analysis of network positions. We analyze the transformation of the Hungarian large firm ownership network through the network careers of firms. We represent each firm’s network participation in the fifteen years that we study by the categories of the ego network of the firm for each year. This representation captures both the order and the temporality of firm network histories. Table 3 is an example of a firm network history.

Table 3: An example of a firm’s network career.

<table>
<thead>
<tr>
<th>Code</th>
<th>Year</th>
<th>Year</th>
<th>Year</th>
<th>Year</th>
<th>Year</th>
<th>Year</th>
<th>Year</th>
<th>Year</th>
<th>Year</th>
<th>Year</th>
<th>Year</th>
<th>Year</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>87</td>
<td>88</td>
<td>89</td>
<td>90</td>
<td>91</td>
<td>92</td>
<td>93</td>
<td>94</td>
<td>95</td>
<td>96</td>
<td>97</td>
<td>98</td>
<td>99</td>
</tr>
</tbody>
</table>

This firm starts as an isolate. After four years it becomes part of a star shaped neighborhood. In 1993 the network star becomes a large star of which the focal firm is on the periphery, and after two years its neighborhood is transformed into a cohesive group. In 1998 the firm becomes a small star periphery again. At the end of the period, from 2000, the star shrinks into a dyad.

We compile the network career of all the 1,696 firms we study in the same fashion as presented in this example, representing each network history by the sequence of the coded network positions for each year. Our dataset is thus 1,696 sequences that run across 15 years. Our next task is to measure the similarity of each of these sequences to one another in order to identify typical pathways. To accomplish that we use optimal matching.

Optimal matching of sequences is a method that historical sociology borrowed from natural sciences. The use of optimal matching in the natural sciences typically does not involve temporality; instead, the sequences are typically spatial. One major area in natural sciences for the use of optimal matching is DNA analysis. DNA molecules are considered to be very similar even when large chunks of the molecular sequence are in reverse order (Sankoff and Kruskal 1999). Unlike measures based on vector similarities, optimal matching has some advantages for historical application; but it has been justifiably criticized by Wu (2000) and others (Levine 2000) for its lack of sensitivity to the directionality of time. For example, a firm that is an isolate for eight years and then becomes a network member in 1995 for the next seven years represents a radically different career compared to a firm that is a network member for the first seven years and then becomes an isolate in 1995. Because the default optimal matching method would group these two cases as similar, we make adjustments to the parameters of the method to maximize temporal sensitivity. (See Appendix A. for details about the adjusted parameters used in our optimal matching analysis.)
After running optimal matching, we use hierarchical cluster analysis to identify clusters of sequences from the distance matrix that resulted from optimal matching. From among the commonly used clustering methods, we chose Ward’s method as the best fitting clustering solution. The resulting clusters contain sequences that have a low distance to one another, while they have a higher distance to sequences in other clusters.

Before introducing and interpreting the sequences of network positions, we note that we tested the hypothesis that network transformation in this case is a product of a merely random process. This hypothesis is a plausible one, especially given the pace of institutional transformation. Firms can resort to forming ad hoc ties (along friendship, collegial, or just purely random ties) when pressed to hedge against radical uncertainties. Similarly, it is plausible to assume that network ties are cut at random when a new owner appears. To evaluate the random network change hypothesis we ran simulations from which we conclude that the observed changes in network ties are not products of a random process. (See Appendix B. for details.)

Interpreting pathways and identifying processes

The pathways resulting from our sequence analysis reveal that both forms of recombinant property networks – the star-shaped spin-off structures and the cohesive groupings – have, for the most part, survived to the present day. Of the star-shaped spin-off structures, less than a fourth dissolved by 2001, while of the cohesive recombinants only a tiny fraction, about one-eighth have broken up by 2001.

Forms of recombinant property are robust structures that survived the entire epoch, but they are strikingly different in terms of the amount of foreign investment they attracted. Pathways in which spin-offs locked in to star-shaped structures enlisted hardly any foreign investment. While they represent about 11 percent of total capital, only about 4 percent of foreign networked capital participates in these pathways. Cohesively linked recombinants, by contrast, attracted a large amount of foreign capital, beginning already in the early nineties. By 2001 they represented 23 percent of large firm capital, and 48 percent of foreign networked capital.

Beyond the persistence of recombinant organizational forms, we find two other major processes of networking, both closely connected to the participation of foreign owners. These two processes involve firms that are considerably smaller than firms connected in

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13 We compare the fit of clustering derived from five algorithms: single link, average link, complete link, Ward (increase in sum of squares) hierarchical clustering, and CONCOR divisive clustering. The R-squared of a thirteen cluster grouping by these methods are: .014, .144, .349, .590, and .411 correspondingly. Thus we use Ward’s method as the one that best fits our data to identify groups of similar sequences. The clusters that we identify represent a meaningful reduction of the data: the T-test of comparing within cluster distances to between cluster distances is -231.300.
recombinant property forms. The first process starts with temporary foreign network involvement in joint ventures that then dissolves into isolated foreign subsidiaries. The firms in these temporary networks represent 11 percent of capital. The second process entails building networks that are durable; these are initiated by foreign subsidiaries organizing small network structures – typically dyads or small stars. These firms amount to 16 percent of large firm capital.

Table 4. presents the thirteen distinctive types of enterprise histories, or pathways, through the space of local network topographies. For each of the pathways, we present the typical sequence of network positions that best characterizes firm histories in that cluster. (See Appendix C. for details.)

Cell entries (1 through 7) correspond to the local network neighborhoods in the state space defined in Table 2. Enterprise histories are presented in six groups of pathways according to broad similarities in sequence patterns. The number of firms in each pathway is one way to measure their prevalence; but as a better indication of economic importance, we also list the share of each pathway in the total capitalization of the large firm population in 2001. Recalling the macro structure of Hungary’s mixed economy represented in Figure 1, Table 4 reports each pathway’s share in the four sectors of the mixed economy in 2001: networked-foreign, networked-domestic, isolate-foreign, and isolate-domestic.

<table>
<thead>
<tr>
<th>Pathways</th>
<th>n</th>
<th>Typical sequence of network positions a</th>
<th>Share in categories of capital in 2001 b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Networked</td>
</tr>
<tr>
<td></td>
<td>87</td>
<td>88</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spin-off star-shaped recombinants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>34</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>106</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Cohesive recombinants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>70</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>44</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Exits</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>97</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>63</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>65</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Durable small groups</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>70</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>101</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Late entries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>136</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>56</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Isolates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>854</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>1696</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: a: Cells indicate network positions from Table 2. Bold figures represent surges in foreign investment when new foreign capital amounted to at least 20% of the total capitalization of the pathway in the previous year. b: Proportions of capital are shown in the same categories as in Figure 1.
**Spin-off star-shaped recombinants.** The 140 firms in our first group of two pathways have distinctive histories of nearly continuous locations in star-shaped neighborhoods. The typical sequences are lengthy episodes either as star centers (5-5-5-5) or as small star peripheries (3-3-3-3). These pathways indicate the process by which state-owned firms spun off corporate satellites in the period of regime change and its immediate aftermath: by 1990, most of the firms in pathways 1 and 2 were stars or the peripheries of stars.

During the period of high institutional uncertainty in the early years of postsocialism, the firms in this first group of pathways follow courses consistent with playing the game of asset-liability management, spinning off satellites, spreading risk, and shedding risk by shifting assets and liabilities among them in attempts to take advantage of state-sponsored programs of debt forgiveness. Of course, not every firm (in the whole population) that starts its network career as a small star or in its periphery stays in that position. Some firms will break off (perhaps as dyads), be sold off (perhaps becoming isolates), or become involved in neighborhoods with more cohesion. If they did, their network histories will show different sequences, and they would not have been clustered in this group of pathways. The point is that the firms in these three pathways did not break off, were not sold off, and, for the most part, did not become involved in more cohesive ties. That is, in these two pathways we see clear evidence of path dependency: having established a pattern of network ties during the period of institutional uncertainty, these firms locked into patterns that endured throughout the epoch even after the organizational environment changed.

How did they fare? They survived. Did they thrive? By 2001, these 140 firms (i.e., about 8% of the enterprises in the large firm population) accounted for 10.9% of the total capitalization in that population. They are a modest but not a negligible component of the Hungarian economy. Are these dead end streets? Not at all. The Hungarian economy seems to have room even for path dependent roads, seen, for example, in our finding that the firms in the pathway of star centers (pathway 1) account for more than a quarter of the capitalization that is networked domestic. Did they attract foreign investment? Scarcely. The figures in Table 4 for these pathways show scant levels of foreign investment in 2001. In fact, our findings suggest that foreign investors shunned these firms. Created in the shadow of the state and likely facilitating some shady maneuverings, these ties buffered firms from uncertainty during the extrication from state socialism. But, locked into these path dependent ties, the firms in these pathways were locked out from participating with foreign investors.

**Cohesive recombinants.** Taken by itself, our first group of pathways might suggest evidence supporting the strong version of the dual economy thesis with domestic firms networked and foreign firms isolated. But that notion is quickly dispelled upon examining the network histories of firms in the second group of pathways. Here we find cohesive neighborhoods recombining with foreign investors.

The first part of the network history of the firms in pathway 3, like those in the first group, indicate the process of spin offs and state-owned conglomerates. As separate firms were formed out of the divisions and workshops of the state-owned enterprises, the size
of the ownership stars grew. But, unlike the pathways in the first group, ties were established among the spin-offs, yielding cohesion. These firms remain in cohesive neighborhoods until 1998 when some of the very largest firms are bought by foreign owners who reshape the ownership network of these large firms by consolidating the network of their spun-off subsidiaries.

The firms in pathway 4 are involved in cohesive neighborhoods from the moment of their founding. That is, at the outset of their appearance as a corporate form they are already participating in dense ownership networks. This cohesion, moreover, increases: between 1992 and 1997, the overwhelming majority of the firms are members of strongly cohesive neighborhoods. This strong cohesion, however, is not a barrier to foreign investors: by 2001, the firms in this pathway represent 4.9% of overall capitalization but constitute 12.2% of networked foreign capitalization.

The enterprises in these two pathways correspond to firms identified by Stark (1996) as parts of characteristically recombinant property networks. Based on comparable data collected from registry courts in 1994, complimented by ethnographic research in 1993-94, Stark’s research suggested that, for some of these firms, beyond maneuvering in the shadow of the state, these network ties were facilitating an active restructuring of assets. That is, recombinant property could involve creative recognition of resources and their recombination along network lines. From this research conducted during a period of extraordinarily rapid change, it remained an open question whether these network forms of property represented merely a snapshot of a fleeting process. Our findings, based on data gathered across fifteen years, indicate that this organizational form was not limited to the years of turbulent transformation, that it has been robust, and, moreover, that it has been open to a considerable amount of foreign investment. By 2001, almost one-quarter of the foreign-controlled capitalization in Hungary was in enterprises in these two pathways.

**Exits.** The third group of pathways represents networking, frequently involving foreign investment, ending in isolation. In these pathways, foreign owners are participating in partnerships with state-owned firms as well as enterprises whose owner is another Hungarian corporation. This group of pathways offers support for our expectation that foreign owners will use network ties to legitimize their presence, to obtain local knowledge, and to gain introduction into the social networks by having a local partner.

The three distinctive sequences represent three strategies of establishing a foothold in the economy at a time when foreign investors were not yet commonplace. In the case of pathway 5 where foreign companies found new ventures, they tend to co-operate as dyads, with relatively short episodes before exit. When foreign investors engage in joint venture strategies with firms that are embedded in denser network ties (in pathway 6), they tend to stay in these neighborhoods relatively longer before exiting. Pathway 7 represents cases where foreign companies buy into existing firms that are yet more cohesively embedded. What is distinctive about this pathway is not simply that exit is later but that it shows an abrupt move from cohesive neighborhoods to isolation. Recall that large enterprises had spun off firms in the early part of the decade. In 1997 and
1998, some of these firms and not only those with foreign ownership, dramatically reconfigured their holdings, shutting down or selling off firms to consolidate their positions.

A shared feature of how foreign investment punctuates these pathways is that there is a sizeable foreign capital inflow in the moment or soon before firms are isolated from the ownership network. However, there is a difference between the three pathways in foreign investments while firms are still connected into the network. In the pathway 5 there is a crescendo of foreign investment up to the moment where the firm moves to an isolate position, that is buying out the domestic partner and thus transforming the joint venture into a wholly owned subsidiary. This sequence represents best the script expected by the literature on foreign investment (Inkpen and Beamish 1997; Kogut 1988; Kogut 1991; Yiu and Makino 2002). The investment starts as a joint project of domestic and foreign actors, with the foreign actor using the opportunity of this arrangement to learn the rules of play and legitimize its presence. The other two pathways (6 and 7) in this family show a somewhat different pattern, generally indicating that the extent and length of network embeddedness is inversely correlated with the amount of early foreign investment.

**Durable small groups.** Our fourth group of pathways lies primarily in dyadic local neighborhoods. The firms in pathway 8 are involved in stable joint ventures with a tendency towards exclusivity after a period as small star peripheries. Firms here form joint ventures with another firm, typically holding a significant minority share in the partner. The histories of firms in pathway 9 are shorter, but they move in an opposite direction from dyads to small star peripheries. Notably, this move in network space corresponds to foreign participation. The distinctive timing of foreign investment in this family is that it begins at the origin of both the firms and the network structures within which they are embedded. The networking represented by this family seems to be initiated by foreign subsidiaries. These foreign-held companies are establishing ties with each other and are spinning off their own subsidiaries. That is, foreign investors in this case are not consolidating but are expanding the firms’ networks.

In contrast to the previous family, which suggested that small and sparse network structures are vulnerable to breakup, the durability of dyads in this family is remarkable. This pathway represents durable network positions of foreign subsidiaries, a path that represents an alternative to investing in existing evolving network groups initiated by postsocialist enterprises. The distinction between foreign-grown versus domestically evolving networks is not only an analytic comparison, but one that actors in the field note as well. Our interviews with corporate consultants indicate that there is often a manifest competition between foreign firms and domestic business groups to buy shares in a valuable supplier, thereby tying it to either a domestic or foreign driven group.

The newest firms in our population, representing the latest developments in network processes, are in pathway 9. These firms are foreign owned, and organized in small, but growing network groups (in the sequence of their network positions they move from being in a dyad to being a part of a star shape group). This pathway manifests a new wave of foreign-initiated network formation. Unlike the earlier, domestic network groups,
foreign subsidiaries start building networks from the most elementary form (a dyad), and add ties in a gradual way. While the economic context for the evolution of domestic networks in the late eighties and early nineties was radical institutional uncertainty, the context of the evolution of foreign initiated business groups is market risk taking. Small star shape groups in this context might ensure accountability towards the foreign headquarters and the ease of maneuvering by a clear hierarchy of ownership relations.

**Late entries.** Although the overall network tends to lose ties and cohesion after 1995, the firms in our fifth group of pathways go against this trend. Like the firms in pathways 1 and 3, the firms in pathways 10 and 11 have the longest histories, beginning as state-owned enterprises from the period before the regime change. But they also have the longest sequences as isolates. That is, these firms are not only relative late-comers to privatization, but they were also not involved in inter-organizational ownership ties with other firms while they were state-owned. In marked contrast to the transition framework that expects that severance of state ownership will be followed by severance of inter-organizational ties, in these pathways, after privatization, firms enter the network.

Pathways 10 and 11 are grouped because of broad similarities in their sequences. Together, these pathways illustrate that not all formerly state-owned firms used recombinant network strategies to mitigate the uncertainties during the period of extrication from state socialism. But separately, as we shall see, they show quite different processes at play, especially insofar as they involve foreign investment.

Unlike the firms in pathways 8 and 9, the firms in pathway 10 are not start-ups. These are privatized formerly state-owned companies that typically enter the network as dyads. Then with increasing foreign participation comes rearrangement and rebuilding of network ties. By 2001, firms in this pathway account for 21.6% of networked foreign capitalization. In this case, we find FDI not as foreign direct insulation but as foreign directed embedding.

Pathway 11 shows a peculiar sequence through the space of local network positions. After a long episode of state-owned isolation, they are privatized and simultaneously enter the network as peripheries of large stars. Then, after 1996, exactly when the period of institutional uncertainty is waning, they gain cohesion – which further increases to strong cohesion. Unlike pathways 3 and 4, however, where cohesion could co-exist with foreign participation, in this case, cohesive neighborhoods are not compatible with foreign investment. By 2001, the firms in pathway 11 constitute 7.0% of the total capitalization of the large firm sector but only 6.7% of the capitalization that is networked foreign. (By comparison, with 4.9 of total capitalization, pathway 4 contributes 12.2% of networked foreign capitalization; and with 18.2% of total capitalization, pathway 3 constitutes 36.1% of networked foreign capitalization.)

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14 In the early spells, the “1” notation typically connotes that the firm was state-owned. But state-owned firms need not be isolates. Moreover, a partially state-owned firm would not be in the network if its other owners are not in the large firm population.
In itself, being in a cohesive network – even being in a cohesive neighborhood at a critical time – does not ensure foreign investment. In 1997-1998, pathways 3, 4, 7, and 11 are all in cohesive or strongly cohesive neighborhoods. But pathway 11 is considerably less likely to involve foreign investors. Sequence matters. Creating cohesive networks from the outset has a different meaning than creating them after a long episode of clutching on to the state. For the former, dense networks promoted a process of restructuring, a creative cohesion; for the latter, dense ties fostered a defensive cohesion that, while not entirely excluding foreign investment, was not as open to it.

**Isolates.** The last pathway groups all the firms that have never been part of the ownership network. Firms in this pathway are smaller than average and are also characterized by a relatively late start. Although about half of the firms in our population are in this pathway, they represent only 30.7 percent of the population’s capital. The average size of a firm here is 44 percent of the size of firms that are or were part of the network.

As the bold font in Table 4 indicates, there was a surge of foreign investment in always-isolated firms in 1997. By contrast, for the population as a whole, foreign investment increased almost perfectly linearly across the time period. The linearity in the overall population masks pronounced punctuation at the level of pathways. Whereas firms in the isolate pathway received a surge of foreign investment in 1997 (following a major change in government policy), most other pathways have different timing in foreign investment. Cohesive recombinants have early, multiple surges of foreign investment; spin-off star structures have none at all; and the joint venture and durable small groups show yet different punctuations.

We found that the temporality of foreign investment varies by pathways. As an activity that establishes ownership ties foreign investment is not typically a function of changes in government policy but instead is closely linked to relational processes of organizing network resources at the firm level.

**CONCLUSION: THE HISTORICAL SOCIOLOGY OF TURBULENT TIMES**

By the term “mixed economy” political economists have typically referred to a mix of private and state ownership. Those categories remain meaningful; but it is worth reflecting on the extent to which they were part of the discourse of the Cold War and the global struggle between Capitalism and Communism. In that context, the very term “mixed economy” pointed to a real possibility that a given national economy might, in actual practice, combine features – of markets and planning, of private and public property – that were portrayed, on both sides of the ideological struggle, not only as antagonistic but as mutually exclusive.

In this paper, we also use the term “mixed economy.” But here we refer not to a mix of state and private property but to an economy that is a mix of foreign and domestic, of networked and isolated, firms. Yet whereas we have given the term new content, our intent, at another level, shares much with that of the earlier coinage, here signaling
limitations of either/or choices in the discourse about globalization. Our findings about Hungary’s contemporary mixed economy show that developing economies do not necessarily face a forced choice between networks of global reach and those of local embeddedness. High levels of foreign investment can co-exist with the reproduction of inter-organizational ownership networks in a developing economy. Moreover, foreign investment and network structures need not be radically segregated but can, in fact, be integrated.

How distinctive is Hungary? Do other postsocialist economies show a similar profile? Is the large firm sector in Russia predominantly networked and domestic? Across the region, from the Baltics to the Balkans, what are the national distributions across our four cells of networked-domestic, networked-foreign, isolated-domestic, and isolated-foreign? Our findings invite comparisons among a broader range of cases in various parts of the developing world. The new agenda for the sociology of economic development would call for investigations on the interaction of foreign investment and network evolution comparable to that presented for a fifteen-year period in Hungary (see Figure 1) in countries such as Argentina, Brazil, Vietnam, the Philippines and South Africa. In short, our methodology to chart the evolving shape of Hungary’s mixed economy provides a strong basis for further comparative research across a broad range of developing economies.

The terms of the language of mixed economy, useful for macro-structural overviews, we argued however, should give way to concepts that are more relational than categorical when attempting to understand the micro processes of economic transformation. Our approach to property transformation beyond a simple transition from state to private ownership but as restructurings of network properties is an example of this shift from categorical to relational concepts. Similarly, in place of thinking about a simple mix, i.e., a whole with identifiably distinctive parts, we think about mixtures in which the units themselves are combinatoric and generative.

Our findings about recombinant property are especially instructive in this light. The motivating question of this study has been less whether national ownership patterns can endure than whether they can be adaptive. Networks provide domestic and foreign actors with resources and opportunities to transform structures. As Powell et al (2003) demonstrate, interorganizational ties not only respond to institutional environments, they can also change them (see also Padgett 2001). Our study of pathways of property transformation found that the most cohesive type of recombinant property is most likely to involve the participation of foreign investors. This finding indicates that it would be mistaken to characterize networks of recombinant property as mere holdovers of state socialism, as reactionary or backward-looking agents that freeze action or resist change. If they were a legacy of the informal networks of state socialism, they were not, for that reason, condemned to merely replicate themselves. Network structures, like other social patternings, can be re-purposed. The cohesive pathways of recombinant property show such generative reformulation (Padgett 2001; Sabel and Zeitlin 1997), with an open potential, first as agents of asset restructuring and later, as this study demonstrates, with
potential open to foreign investors. Hungary’s transformation from state socialism to an emerging market economy with dynamic patterns of foreign investment did not occur despite its inter-organizational property networks but, in part, because of and through these networks.

Dramatic political and economic changes, such as those that took place in Eastern Europe in the final decade of the last century, lend themselves to easy appropriation by grand narratives (Tilly 1984) – the clash of socialism and capitalism, public versus private property, planning versus markets, domestic versus foreign capital. In these grand narratives, trajectories replace uncertainties; and the grand forces of History – e.g., the market, the state, rationalization, private property – replace the more diminutive actors who cope, strategize, and interact on the actual field of play.

In the East European case, these grand narratives have had two variants: the prospective and a new retrospective version. In the prospective variant, the analyst anticipates optimal outcomes (the science of the “not yet”) and evaluates actions and actors in terms of their approximation of these predetermined ends. Analytically, the problem with this method was not that the transitologists stared into their crystal balls, but that they held them up and looked at the then present through that distorting lens. In the retrospective variant, it is precisely because the analysts can see what has happened that gives them the authority to read back into the goals, strategies, and actions of real actors. Their actions are analyzed and judged through the distorting lens of what the analyst now “knows to have happened.” The problem in each case is that the most telling aspect of a turbulent historical period is suppressed – the fact that the actors in the situation were operating in a situation of genuine uncertainty.

Our challenge in this paper has been to examine historical data in such a way that analysis starts from and therefore restores that basic epistemological condition. The actions of the people who transformed the economies of East Central Europe become more, not less, understandable when we grasp that they did not know and could not have known what would happen. Moreover, given the uncertainty not only about the rules of the game but about which games were operative (on simultaneous play in multiple games, see Stark 1990; Padgett and Ansell 1993), there could be no strong consensus about what was happening contemporaneously. This would be constructed only after the fact in developmentalist narratives with their language of failures, successes, and false starts. Thus, in place of grand narratives we worked at ground level. To study transformations in the structure of property, we focused on the terrain in which it was and is taking place – at the level of the enterprises. More ambitious than narrating a history, we gathered the histories of 1,696 firms. Precisely because the social space could not be plotted in advance, with coordinates given and street signs already in place, we followed the actors, tracing the pathways that they made even as they reshaped the field of play. To study the actual processes of globalization we analyzed local topographies. In studying the specific case of Hungary we developed a method for historical sociology more generally: to do the sociology of a turbulent time, analyze the social times of network spaces.
Methodological Appendix A. The parameters used in optimal matching

Sequence analysis has recently been criticized by Lawrence Wu (2000) for using an algorithm that is insensitive to directional transitions (Wu 2000). Indeed, the prevalent optimal matching algorithm, adopted from natural sciences, does not have a concept of temporality built into it. In this appendix we briefly outline how we modified the optimal matching algorithm to maximize the method’s sensitivity to temporal ordering.

Two types of parameters can be adjusted to adapt optimal matching analysis to our purposes: the cost of inserting or deleting elements (the indel cost), and the cost of replacing elements (substitution costs) (Abbott and Hrycak 1990). Our aim is to adjust these two parameters so that their combination maximizes temporal sensitivity.

We start with the extant version of the algorithm (the so called longest common subsequence method) (Sankoff and Kruskal 1999), as the baseline version we seek to improve. Sociologists have proposed adjustments to the cost parameters of the optimal matching algorithm (Abbott 1995; Abbott and Hrycak 1990; Blair-Loy 1999; Stovel 2001; Stovel, Savage and Bearman 1996), but they have not systematically tested whether and how these adjustments improve temporal sensitivity. We test these previously proposed adjustments and specify our final cost schedule to maximize this sensitivity.

We measure temporal similarity between two sequences by a matching coefficient that counts the matches when two sequences, \( a \) and \( b \), were in the same state in the same year, divided by the length of the shorter sequence. This metric is one if the two sequences are the same, or the shorter sequence is completely contained within the longer, and it is zero if there is no match at all between the two sequences. We use a second measure to capture reverse temporality. This second measure is a matching coefficient between sequence \( a \) and the reverse of sequence \( b \). The coefficient is calculated the same way. In this case, a coefficient of one means that sequence \( b \) is the exact reverse of sequence \( a \). Our goal is to find cost parameters for optimal matching that reward similarity in temporal ordering and punish similarity in reverse temporal ordering.

We ran optimal matching analyses with various cost parameters, recording the resulting dyadic distance matrices for each. We created a dataset with dyads as cases (altogether there were 359,128 dyads between the 848 sequences), with optimal matching distances as one set of variables and the matching and reverse matching coefficients as another. We then used linear regression models with optimal matching distance as the dependent variable and the matching and reverse matching coefficients as independent variables. Table 5 reports the regression coefficients for four models, with four different dependent variables: optimal matching distances with the longest common subsequence approach (Model 1), with the same constant substitution costs and twice as expensive indel cost (Model 2), with a structured substitution cost matrix based on transition frequencies (Model 3), and our final model with a slightly higher indel cost (Model 4).
Table 5: Linear regression models of optimal matching distances and matches and reverse matches between sequences.

<table>
<thead>
<tr>
<th></th>
<th>Model 1: Longest Common Subsequences</th>
<th>Model 2: Expensive indel</th>
<th>Model 3: Structured substitutions</th>
<th>Model 4: Final model</th>
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<td>359 128</td>
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Notes. a: all coefficients are significant at the p<0.0001 level.

Our linear regression analysis indicates that the baseline version of the optimal matching algorithm (the longest common subsequence approach) is indeed insensitive towards temporal ordering. The coefficients of both matching and reverse matching are negative, indicating that the algorithm records a smaller distance between sequences that are similar regardless of directionality. As the second model indicates, making the cost of insertions and deletions higher effectively increases the sensitivity of the method for temporal ordering. In Model 2 the coefficient for matches is negative (sequences that go through the same states with the same timing are closer), while the coefficient of reverse matching becomes positive, indicating that optimal matching with increased indel cost now penalizes reverse temporal similarity between sequences. Restating this finding in terms of the example raised by Wu (2000), we can say that in Model 2 the sequence of employment to unemployment is now seen as different from the sequence of unemployment to employment. The third model employs a structured substitution cost matrix derived from transition probabilities (see details below). This model is even less likely to group sequences with reverse temporality as similar (it has a higher positive coefficient of reverse matching than in the previous model).

Our final model (Model 4) fine-tunes both the substitution cost matrix and the indel cost. We defined substitution costs in the following way: The cost of substituting two non-isolate positions is proportional to the relative frequency of the transitions from one position to the other in the whole sequence dataset. The substitution costs are defined by first calculating transition probabilities:

\[
p(x,y) = \frac{\sum_{t=1}^{T-1} N_{t,t+1}(x,y)}{\sum_{t=1}^{T-1} N_t(x)},
\]
where $x$ and $y$ are network positions. Then from transition probabilities the costs are calculated by the following formula:

$$\omega(a_i, b_j) = 2 - p(a_i, b_j) - p(b_j, a_i) \text{ if } a_i \neq b_j,$$

where $a$ and $b$ are two sequences. Substitution costs range between zero and two. A cost of zero only occurs if one network position always follows the other and vice versa. Although this is not likely, substitution costs will be low for network positions that very frequently follow one another. The assumption behind this is that if it is relatively easy to step from one network position to another, these network positions should make a relatively small difference between sequences. That is if the only difference between two sequences is that one of them is in state $a$ at time $t$, while the other is in state $b$ at the same time $t$, then the distance between these two sequences is a function of the similarity between states $a$ and $b$, that is in turn read from the transition frequencies (displayed in Table 6).

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Table 6: The frequency of transitions between network positions.

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Table 7: Substitution costs.

There are two states that are not substituted with a cost proportional to transition probabilities: the isolate state and the non-existence state. We assign a high (maximal, that is 2) cost to substituting an isolate state. Because we are interested in ways of participating in the network, the moment of entering or exiting the network is especially
important. We have made the substitution of an isolate state expensive (a cost of 2), because the distinction between being part of the network and being out of it is important for us. If the only difference between two sequences is that one is isolated in year t, and the other is part of the network, this should make a bigger difference between them than any form of network participation. We assign a low cost (1) for the substitution of the non-existence state. In doing so we make the algorithm less sensitive to differences in the length of the life of a firm and more sensitive to its network career. See the final substitution cost matrix in Table 7.

To specify the optimal indel cost we run regression models with our substitution cost matrix, varying the indel cost between 1 and 2.5. We found that the maximal coefficient for reverse matching (that is, with the most aversion to grouping sequences with reverse temporality together) occurs when the indel cost equals 2.01. As displayed in table 5, the coefficient for reverse matching for an optimal matching model with indel cost 2.01 is 5.658. The coefficients for 2.00 and 2.02 are 5.499 and 5.506. The 2.01 indel cost equals the maximal substitution cost plus the difference between the maximal and the second largest substitution cost, suggested by Andrew Abbot and Alexandra Hrycak (1990).
Methodological Appendix B. Simulation test of the random change hypothesis

To test the hypothesis that the network change we record is merely a result of a random walk process, we run network simulations. For each pair of years we observed the number of broken ties and new ties. We can simulate the change of the network from one year to the next by randomly breaking the same number of ties observed to be broken in the given year, and randomly assigning the same number of new ties observed to be created. If the frequency of the various local network positions is not significantly different in our observed data and in the simulations, we cannot reject that network change from the first year to the next was a result of a random process.

For each pair of consecutive years from 1987 to 2001 we ran 1000 random simulations of network change to compare simulated and observed frequencies of dyad, star periphery, star center, and cohesive group local network positions. Throughout the period there are more cohesive positions and less star centers than we would expect by random change. In the early years (1989-90) and at the very end of our period there are more dyads and star peripheries than would be expected if the changes were random. As an illustration, for the cohesive positions we display for each year the box-plots of the frequencies in the simulation together with the observed frequencies on Figure 2. For every year, except 1989 and for 2000 network change from one year to the next produces more cohesion than we would expect in a random walk process.

![Figure 2: Cohesive neighborhoods in observed and simulated data. Asterisks indicate frequencies in observed data, box-and-whiskers plot indicates simulation results. Box indicates inter-quartile range, whiskers indicate range between the 5th and 95th percentile.](image-url)
Methodological Appendix C. Constructing ideal-typical sequences

We construct ideal-typical sequences to represent each pathway of clustered sequences. Our task is to identify the characteristic states of a pathway’s ideal-typical sequence, as well as the typical timing of transitions between these states. To do so, we analyze the distribution of transitions, by constructing a scree-plot that represents the transitions in a decreasing order of their frequencies. See Figure 3 for an example of such a scree plot, constructed for the 4th pathway.

Figure 3: Scree-plot of transition frequencies in pathway 4. The vertical axis shows the frequencies of transitions, the horizontal axis lists transitions in a descending order of frequency. For example “7-6” indicates the transition from state 7 (strong cohesion) to state 6 (cohesion).

From this scree-plot we selected highly frequent transitions as characteristic features of the pathway. For example, for pathway 4 we identified the transitions “7-6” (strong cohesion to cohesion), and “6-7” (cohesion to strong cohesion). To identify the timing in which these characteristic transitions occurred, we produced plots of the transition frequencies by year, smoothing with a three year moving average. Figure 4 presents this chart for the 4th pathway. In the case of the 4th pathway, we thus chose 1992 as the transition from cohesion to strong cohesion (6 to 7), and 1997 as the year for the transition back from strong cohesion to cohesion (7 to 6).
Figure 4: Frequencies of characteristic transitions by time, smoothed by a three-year moving average.
References


