The Problem of Emergence

by

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Chapter 1

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Organizational Novelty

Darwin's question about the origin of species is worth posing and exploring as much in the social sciences as it was in biology. Human organizations, like living organisms, have evolved throughout history, with new organizational forms emerging and transforming in various settings: new types of banks and banking in the history of capitalism; new types of research organizations and research in the history of science; new types of political organizations and nations in the history of state formation. All of these examples are discussed in this book. The histories of economies and polities are littered with new organizational forms that never existed before. In biological language, this emergence of new organizational forms is the puzzle of speciation.

We economists, political scientists, and sociologists have many theories about how to choose alternatives, once these swim into our field of vision. But our theories have little to say about the invention of new alternatives in the first place. New ideas, new practices, new organizational forms, new people must enter from off the stage of our imaginary before our analyses can begin. Darwin asked the fundamental question, but our concepts are like those of Darwin before Mendel and Watson and Crick. We understand selection and equilibrium, but we do not understand the emergence of what we choose or of who we are. Our analytical shears are sharp, but the life forces pushing things up to be trimmed elude us.

Novelty almost by definition is hard to understand. Something is not genuinely new if it already exists in our current practice or imagination. The terms *innovation* and *invention*, as we use them in this book, mean the construction of something neither present nor anticipated by anyone in the population. We do not mean that planned incremental improvement on what already exists is not possible—quite the opposite. This type of learning occurs far more often than does the production of genuine novelty. The conundrum for both researchers and participants is that logical cognition, no matter how useful for refinement and improvement, is unlikely to be a fundamental process for generating novelty, because logic can only use axioms that are already there.

The literature on "organizational innovation" is voluminous, but that literature largely focuses on learning,[1] search,[2] and diffusion,[3] and often uses patents as indicators.[4] The term *innovation* in organization theory refers to products and ideas, never to the emergence of organizational actors per se.[5] Social science studies processes of innovation, so defined, but mainly by abstracting from the content of innovation itself.[6] Lest this limitation be mistaken for criticism, it is important to remember that Darwin himself never truly answered his own question about the origin of species. He "only" analyzed the natural selection of populations of organisms within species, once species existed. Some parts of social science with an evolutionary sympathy

[1] See, for example, March (1991), Zander and Kogut (1995), Szulanski (1996), Argote (1999).
[2] See, for example, Levinthal and March (1981), Hansen (1999), Rivkin and Siggelkow (2003).
[3] See, for example, Strang and Meyer (1993), Guillén (1994), Davis and Greve (1997), Simmons, Dobbin and Garrett (2006).
[4] See for example, Mansfield (1986), Griliches (1990), Jaffe, Trajtenberg and Henderson (1993), Owen-Smith and Powell (2004), Fleming and Sorenson (2004).
[5] Numerous scholars have lamented that the origins of institutions have been largely opaque to social scientists. Kreps (1990: 530) has remarked that whereas the economics literature emphasizes the effects of institutions, it "leaves open the question, where did institutions come from?" In an assessment of the sociological literature, Barley and Tolbert (1997) underscored the neglect of how institutional arrangements are created. More recently, in a comprehensive review of organizations research, Greenwood et al. (2008: 26) conclude that "institutional studies have not been overly concerned with how institutions arise."
[6] Fortunately there are some valuable exceptions: Hughes (1983), Bijker, Hughes and Pinch (1987), Latour (1988), Hutchins (1995), Galison (1997), Sewell (2005).

have absorbed Darwin,[7] but natural (or artificial) selection alone does not solve his puzzle of speciation.

Besides this introductory chapter and a coda, this book contains fourteen historical case studies of the emergence of organizations and markets, plus three modeling chapters that apply concepts from biochemistry to social evolution. The case studies are divided into three clusters: four case studies on the European co-evolution of early capitalism and state formation, four case studies on Communist economic reform and transition, and six chapters about technologically advanced capitalism and science. These case studies, discussed below, were selected because all of them contain instances of the historical emergence of organizational novelty. Some chapters also discuss failed emergence, as a control group. Not all of the chapters involve speciation in the radical sense of new to human history, but nearly half of them do. All involve speciation in the sense of organizational novelty in the context of the population under study.

The three modeling chapters in part 1 extract the foundational concept of autocatalysis from the existing chemistry literature on the origins of life and then apply this concept, through agent-based computer models, first to the self-organization of economic production and second to the evolution of primitive language and communication. These simple, biochemically inspired models are in no way rich enough to capture the phenomena or the array of emergence mechanisms observed in the historical case studies.[8] But they do provide an analytical framework for specifying with some precision the social science problem of emergence. In this volume, inductive histories and deductive models are viewed as complementary (not competitive) research strategies, both being dedicated to the discovery of social processes of organizational genesis and emergence.

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[7] For example, Simon (1969), Nelson and Winter (1982), Hannan and Freeman (1989).
[8] Colyvas and Maroulis in chapter 16, however, explicitly develop autocatalyic models for their biotechnology case.

Organizational genesis does not mean virgin birth. All new organizational forms, no matter how radically new, are combinations and permutations of what was there before. Transformations are what make them novel. Evolution, therefore, is not teleological progress toward some ahistorical (and often egocentric) ideal. It is a thick and tangled bush of branchings, recombinations, transformations, and sequential path-dependent trajectories, just as Darwin said it was. Invention "in the wild" cannot be understood through abstracting away from concrete social context, because inventions are permutations of that context.

Historical path dependency does not imply that there are no transformational principles at the base of endless open-ended generation. Scientific prediction in open-ended, creative systems such as life is not the specification of a fixed-point equilibrium. It is the description of processual mechanisms of genesis and selection in sufficient detail to be capable, in the rich interactive context of the study system, of specifying a limited number of possible histories. This is the biology, not the physics, view of science.

A barrier, however, inhibits social science investigation into processes of organizational emergence or speciation. Most social science proceeds according to the logic of methodological individualism. That is, the analyst takes as given some constitutive features of the hypothesized individual or actor (typically preferences, beliefs, and resources), and then derives aggregate or behavioral conclusions from them. "Actors" are objects imbued with boundaries, purposes and choices, whose teleological behavior is explained thereby. Useful as this approach is for many purposes, it creates in our understanding a black hole of genesis. To assume axiomatically that real people are *actors* makes them logically impenetrable to the theories built upon them. No theory can derive its own axioms. The problem is not that the social science concept of actor is not useful. The problem is that the atomic conception of actor precludes investigation into the

construction and emergence of the real people and organizations that we refer to by that abstraction. The whole question of where novelty in actors comes from, so central to any theory of evolution, never arises in the first place.

In this book, we take the following as our mantra: *In the short run, actors create relations; in the long run, relations create actors*. The difference between methodological individualism and social constructivism is not for us a matter of religion; it is a matter of time scale. In the short run, all objects—physical, biological, or social—appear fixed, atomic.[9] But in the long run, all objects evolve, that is, emerge, transform, and disappear. To understand the genesis of objects, we argue, requires a relational and historical turn of mind. On longer time frames, transformational relations come first, and actors congeal out of iterations of such constitutive relations. If actors—organizations, people, or states—are not to be assumed as given, then one must search for some deeper transformational dynamic out of which they emerge. In any application domain, without a theory of the dynamics of actor construction, the scientific problem of where novelty comes from remains unsolvable.

The example of the human body may help to fix the idea. Viewed from the perspective of ourselves, we seem solid enough: well bounded and autonomous. But viewed from the perspective of chemistry, we are just a complex set of chemical reactions. Chemicals come into us; chemicals go out of us; chemicals move around and are transformed within us. Solid as we may appear from the outside, no single atom in our body has been there for more than a few years. It is possible (and flattering) to see our physical selves as autonomous bodies exchanging food and other nutrients, but it is also possible to see ourselves as an ensemble of chemicals that flow, interpenetrate, and interact. Stability of the human body through time does not mean

[9] We ourselves are methodological individualists when the study time frame is short.

mechanical fixity of parts; it means organic reproduction of parts in flux. Viewed as chemical reactions, we are vortexes in the communicating material of life that wends through us all.

To explain the emergence of new organizational actors, we take as our starting inspiration—but not as our final model—biochemical insights about the emergence of life. At the theoretical level, our approach is a merger of social network analysis with autocatalysis models from biochemistry.[10] From social network analysis we appropriate an empirical commitment to fine-grained relational data on social and economic interactions through time. For us, emergence of organizations is grounded in transformations in social networks, which wend through organizations, bringing them to life. From autocatalysis we appropriate a commitment to discovering and formalizing processual mechanisms of genesis and catalysis, which generate self-organization in highly interactive systems. For us, nodes and ties in social networks are not reified dots and lines; they are the congealed residues of history—in particular, the history of iterated production rules and communication protocols in interaction. Learning at the human level is equivalent to co-evolution of rules and protocols at the "chemical" level. Actors thereby become vehicles through which autocatalytic life self-organizes.

We regard our infrastructural work of synthesizing social science with biochemistry as essential to defining rigorously the topic of organizational novelty (or more generally novelty of actors) in the first place. Through this, we hope to point the way toward a new path in social science—namely, toward a theory of the co-evolution of social networks.[11] Actors fall out as

[10] Autocatalytic theory, described below, is a branch (a chemistry branch) of so-called complexity theory. "Complexity theory" is an umbrella term that refers to a wide variety of mathematical models of self-organization dynamics in highly interactive and non-homogeneous systems. As is explained in more detail in chapter 2, while the individual models within this family are very precise, the umbrella term itself is not. Hence, despite its current fashion, we do not use the term *complexity theory* again.

[11] This ambition parallels the objectives of systems biology. The caution, if not disdain, that many social scientists have toward evolutionary theory is based on their unfortunate experience with Social Darwinism. If evolutionary theory were still as atomistic and as functionalist (if not Panglossian) as that, we would share their aversion. Most social scientists, however, do not appreciate how far contemporary biologists have gone beyond the usefully

derivations of that theory, but they are not the axiomatic starting points. In the rest of our introduction, after a brief overview of the book, we elaborate on this approach and show its empirical relevance. Readers more interested in the empirical cases can proceed directly to the chapters of most interest to them.

In our empirical case studies, we find that novelty in new organizational form often emerges through spillover across multiple, intertwined social networks. Hence not autocatalysis within one network but interaction among autocatalytic networks is the key to generating novelty. The empirical chapters in this volume cover a wide sample of historical cases about the emergence of new forms of economic organizations and markets. Generally, throughout the volume, *actors* refers to organizations and *relations* to markets. With our emphasis on multiple networks, however, a central finding about the production of novelty in the economic realm will be that other types of social relations—for example, politics, kinship, and science—structure the "topology of the possible," that is, the specific ways and trajectories through which old economic organizational forms can evolve into new ones.

The empirical case studies of emergence in this volume illustrate and develop our central insight about constructive feedbacks across multiple networks. Part 2, comprising four chapters by Padgett, analyzes the emergence of four organizational inventions in the history of early financial capitalism and state formation—namely, the medieval corporation in thirteenth-century Tuscany, the partnership system in fourteenth-century Florence, the joint-stock company and federalism in seventeenth-century Netherlands, and the Reichstag and political parties in nineteenth-century Germany. Padgett, along with Jonathan Obert in the German case,

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simplifying yet dangerously simplistic assumptions of previous generations. The cutting-edge issue in systems biology no longer is the evolution of gene frequencies; it is the evolution of genetic regulatory networks.

demonstrates that these organizational inventions in early capitalism and state formation emerged from dynamic feedback among economic, political, religious, and kinship networks.

The four empirical chapters of part 3 analyze organizational emergence, sometimes perverse, in the post-socialist transitions in Russia, China, and Eastern Europe. Padgett compares the political logics of economic reform under Stalin, Khrushchev, and Gorbachev in the Soviet Union and under Mao and Deng Xiaoping in China, documenting in each of these five cases the path-dependent coevolution between political mobilization and economic reform. Andrew Spicer carries the Russian reform story forward in his case study of the unexpected developments in the history of banking under Yeltsin. Valery Yakubovich and Stanislav Shekshnia examine a more successful case of market emergence in post-Soviet Russia: the telecom industry. David Stark and Balazs Vedres trace the development and reproduction over time of business groups in Hungary, with close attention to their interactions with domestic politics and with foreign multinationals.

Part 4, made up of six chapters, focuses on contemporary science and technology sectors. Four chapters by Powell and colleagues apply our theoretical framework to the high-tech case of the emergence of the biotechnology industry within the life sciences. The first chapter, by Powell and Kurt Sandholtz, focuses on the genesis of the first generation of biotech firms in the late 1970s and early 1980s, analyzing how particular attributes and practices were assembled to produce new organizational models for science. The second chapter, by Powell, Kelley Packalen, and Kjersten Whittington, traces the rapid growth and catalysis of these first-generation firms, over the years 1988 to 2002, into an expansive multiple-network organizational field with distinctive regional locations. They compare the networks of three successful biotech industrial districts with eight failures to congeal. The third chapter, by Powell and Jason Owen-Smith,

analyzes the open-elite recruitment dynamics of reproduction within this new industry. Jeannette Colyvas and Spiro Maroulis round out the biotech module with an agent-based model of the rapid spread of patenting in the life sciences in research universities. This chapter extends into new empirical ground the formal model of autocatalysis by Padgett, Peter McMahan, and Xing Zhong presented in chapter 3.

Focusing more on the information-technology industry, Lee Fleming and colleagues compare inventor networks in Boston and Silicon Valley, demonstrating the emergence of innovative cross-industry connectivity in Silicon Valley. This innovation stemmed from the career brokerage by IBM of postdoctoral scientists. Through detailed internal records, Fabrizio Ferraro and Siobhán O'Mahony trace the emergence and self-organization of an innovative open-source computing company called Debian, which is as much global community as company.

These empirically rich cases of organizational and market emergence are surveyed in short introductions to each part, which make explicit the links between theory and cases. The empirical chapters were selected on the basis of two criteria: (a) detailed multiple-network information, tracing not just actors but relations among actors; and (b) dynamic networks over time, spanning an observed organizational or market invention of interest. Readers interested in particular application domains may wish to focus on the section closest to their concerns. The rest of this introductory chapter elaborates the theoretical framework that has emerged from these detailed cases.

Our theoretical elaboration proceeds as follows. First, we describe the problem of organizational novelty in the context of multiple social networks. Second, we explain our core dynamic motor of autocatalysis both at the level of chemical and economic production and at the

level of the biographical production of persons through interactive learning, communication, and teaching. Third, we describe eight network mechanisms of organizational genesis that we have discovered in our case studies. Finally, we point to the important outstanding issue of structural vulnerability to tipping. The question of multiple-network poisedness is, for us, the next research frontier.

Innovation versus Invention

Sometimes defining the problem is half the work. To proffer a distinction we build on throughout this book: *Innovations* improve on existing ways (i.e., activities, conceptions and purposes) of doing things, whereas *inventions* change the ways things are done. Under this definition, the key to classifying something as an invention is the degree to which it reverberates out to alter the interacting system of which it is a part.[12] To some extent we understand micro-logics of combination and recombination. Yet the invention puzzle is that some innovative recombinations cascade out to reconfigure entire interlinked ecologies of "ways of doing things," whereas most innovations do not. The poisedness of a system to reconfiguration by an invention is as much a part of the phenomenon to be explained as is the system's generation of the invention itself. Invention in the wild cannot be understood through abstracting away from concrete social context because inventions are permutations of that context. But to make progress in understanding discontinuous change, we need to embed our analysis of transformation in the routine dynamics of actively self-reproducing social contexts, where constitutive elements and relations are generated and reinforced.

[12] We understand that these definitions invert the way that Schumpeter used the terms. We believe that our definitions are more consistent with typical usage in English than was Schumpeter's. See, for example, oxforddictionary.com. Semantic matters are always slippery and debatable, however. The main thing is that readers understand what we mean.

Figure 1.1 lays the groundwork for understanding this distinction between innovation and invention, viewed through the lens of multiple networks. In a cross-sectional view, all social systems look like this to a social-network analyst.[13] Each plane in the figure represents a different domain of activity. In the example of Renaissance Florence illustrated here, these are the economic domain, where goods are produced and exchanged among companies; the kinship domain, where babies are produced through marriage among families; and the political domain, where deals are made among factions within the state. Other domains not shown, such as religion and the military, could be added. Solid lines represent the "constitutive ties" of cooperation or partnership in production—firms, families, and factions, respectively. Such relations of cooperation are called constitutive because they teach the people participating in them production and communication skills. Ovals are placed around these units when they become corporate or formal, through having collective names. Dotted lines represent exchanges or resource flows between production units—products, wives, and deals, respectively.[14] Markets are sets of dotted lines within domains. The term "relational ties" is used when resource flows are recurrent and focused. The people participating in organizations and markets can be categorized in various ways, through either personal attributes or institutional memberships, as shown.

--- Figure 1.1 about here ---

Our social science disciplines usually segregate their intellectual activities by analyzing only one domain at a time, as if the other domains and disciplines did not exist. At best, external domains are conceptually black-boxed as reified "environments" without examining their internal structures. In contrast, the whole point of a multiple-network perspective is to

[13] This figure is a cartoon of the relational database structure of Padgett's actual Florentine data set. See Padgett (2010) for details.

[14] These three types of lines correspond to the three types of autocatalysis discussed later in this chapter. Dotted lines correspond to production autocatalysis; solid lines correspond to cellular or biographical autocatalysis; and ovals correspond to public names, emerging out of linguistic autocatalysis.

superimpose multiple domains, with their respective production and exchange networks, and to examine feedback dynamics. Vertical lines in figure 1.1, connecting superimposed dots, are people. Each dot in a plane is a role. In the economic domain, for example, the person may be a businessman; in the kinship domain, he may be a father; in the political domain, he may be a politician—all depending upon how he is attached to others in that domain. Properly speaking, individuals don't have goals; roles have goals.[15] Consistency of motivations across roles should in no way be presumed for complicated persons.[16]

It is well recognized by scholars in the social-network tradition that micro-patterns of topological overlay among different types of social networks can induce cross-sectional behavioral effects.[17] At the social psychological level, different ways of nesting various roles in a single person can induce role strain, autonomy, informational access, or even freedom from social control. At the transactional level, the embeddedness or multiplexity of one type of tie in another can induce trust, normative reframing, or changes in time horizons.

Our interest is in how multiple-network topologies can shape the dynamics of emergence and evolution of organizational actors over time. Innovation in our usage is recombination, through one of a variety of organizational genesis mechanisms of network folding.[18] Invention in our usage is the system tipping that might ensue, as a cascade from the original innovation out through the multiple networks that originally induced it.

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[15] Profit maximization, for example, might be the goal of a businessman. But that is not the goal of a more complicated businessman-father-politician ensemble person. For this reason, "methodological individualism" is a misnomer. "Methodological role-ism" is a more accurate description of modeling practices in the segregated world of contemporary social science.

[16] This caveat makes the imputation of any meta- or cross-role utility function to individuals problematic because Von Neumann-Morgenstern axioms are likely to be violated. Without a well-defined utility function, the definition of maximization becomes unhinged. Cross-role consistency is of course possible, but that would be quite a social achievement. In this sense, rationality (narrowly conceived as individual maximization) is socially produced.

[17] Granovetter (1985).

[18] We stick with the word *recombination* because that is so prevalent in the literature. But in our empirical cases the elements being recombined are not atomic entities, decoupled from their context, but rather nodes or ties in some network or other. For that reason, *network folding* more accurately describe the phenomena we observe than does the word *recombination*, which to our ears has atomistic overtones.

The network recombinant mechanisms of organizational genesis that we identify below involve transposing social relations from one domain into another. Sometimes this begins as a small-scale transposition, which then reverberates. Examples are marriage, university labs, or political patronage being used by local actors to reorganize a business. Sometimes this involves larger population transpositions, where entire subsets of new networks are rewired into old ones. Rewiring then transforms both sides. Whatever the variant, topological overlay defines the routes through which relational practices flow. Relational flow occurs either via strategically located persons operating in multiple domains or via biographies that wend their way across domains. Where you sit in a multiple-network array affects both whom you can reach and who can reach you. In systems biology, the reachability constraint that underlying genetic networks impose on phenotypic evolution has been suggestively labeled "the topology of the possible."[19]

Organizational innovation, whatever its source, must reproduce in order to survive. To reproduce and to grow, organizations must succeed in attracting resource flows (dotted lines) and people flows (solid lines) into their primary fields of activity. Economic companies must succeed in product markets. But because companies' component persons and resources are embedded in other domains as well, organizations actually must survive in multiple selection environments. Politics, kinship, and maybe even religion, armies, or science must reproduce for particular types of economic firms to exist. Treating multifaceted people as reproducing flows through organizations makes the point about multiple selection environments more transparent than does focusing on products and financial flows alone.

In terms of figure 1.1, our empirical cases reveal that organizational innovation is vertical transposition of relational ties and practices across domains. Organizational invention, if it occurs, is horizontal spillover into relational and constitutive networks within domains.

[19] Stadler, Stadler, Wagner, and Fontana (2001), Fontana (2006).

Organizational innovation becomes systemic invention (if it does) when local network transpositions spill over or cascade through reproductive feedback into the multiple global networks to which local relations are linked. People and skills are the usual channels through which these feedbacks are carried. If and when this chain reaction occurs, the selection environment itself for the organizational innovation is altered. This can lead to non-linear rates of tipping—in other words, to the dynamics of punctuated equilibria. Sometimes (though rarely) invention spillover may even readjust the differentiation of domains themselves, through restructuring vertical lines of multifunctional embeddedness.[20]

Other labels for network cascade exist in the evolutionary literature. Co-evolution is distinguished from evolution like this: the selection environment remains fixed in evolution but it adjusts in co-evolution. When a selection environment is fixed, the performance criterion for any subunit is given, and the concept of optimum becomes well-defined in principle (even if it is impossible to reach or even perceive in practice). When selection environments are endogenously molded by the innovations they select, however, performance criteria migrate, and "optimum" loses the supporting scale upon which it is defined. Co-evolution retains notions of relative-reproduction "fitness" between systems, but it does not retain the notion of an objective optimum. Social Darwinist dreams of Panglossian progress thereby usefully vanish into an ethereal mist.

To make these general observations about innovation and invention more systematic requires precision in the motor behind multiple-network feedback. In this book, that engine

[20] As explained in the section on catalysis, if the analyst looks at figure 1.1 from the top down, viewing through superimposed domains, then he or she sees figure 1.1 as a Venn diagram. Patterns of overlaps among domains in the Venn diagram are defined by patterns of multifunctional memberships of people in figure 1.1. Change patterns of multifunctional embeddedness, therefore, and one changes patterns of domain differentiation.

primarily is autocatalysis. Figure 1.1 is a cross-sectional snapshot from what is actually a movie through time. Autocatalysis brings this otherwise static picture to reproductive life.

Autocatalysis

Production Autocatalysis

One place to look for inspiration about processes of social emergence is the origin of life. Human beings, as mentioned above, appear to us as solid and sturdy objects. But viewed as chemistry, our bodies are just a complex set of biochemical reactions, which reproduce themselves over time, given appropriate inputs from other organisms. Our self-image of temporal continuity notwithstanding, we are not the coherently bounded objects that we think we are but a chemical process that renews itself for a while. From the chemical perspective, life itself can be defined as an interacting ensemble of chemicals that reproduces itself, in the face of turnover of its parts.[21]

Organizational actors are no different. The production and distribution of goods by firms are only half of what is accomplished in markets. Firms are also produced and transformed by the goods and people passing through them. Social structures should be viewed more as vortexes in the flow of social life than as buildings of stone. In organisms, social or biological, rules of action and patterns of interaction persist and reproduce in the face of continual turnover in component parts, be these cells, molecules, principals, or agents. In the flow of people through organizations, the collectivity is not renegotiated anew. Rather, within constraints, component parts are transformed and molded into ongoing streams of action.

[21] From the physics and biological points of view, additional criteria are sometimes added to the definition of life. Physicists (e.g., Nicolis and Prigogine, 1989) sometimes add the criterion of far-from-equilibrium throughput of energy. Biologists (e.g., Varela, Maturana, and Uribe, 1974) may include the criterion of permeable encapsulation, like a cell. The various definitions of life are discussed in more detail in chapter 2.

To implement this processual view of social structure, in part 1 we build relational micro-foundations, based on the biochemical literature on the origins of life. Autocatalysis is the core concept that we import. As reviewed in chapter 2, this concept was first developed and formalized by Manfred Eigen and Peter Schuster to explain the prebiotic chemical origin of life.[22] Abstracted from its chemical origins, autocatalysis can be defined as *a set of nodes and transformations in which all nodes can be re-created through transformations among nodes in the set.* In the original biological context, nodes were chemicals, and transformations were chemical reactions.[23] Chemicals bump into other chemicals, triggering reactions that make new chemicals. If a chemical reaction network contains an autocatalytic set within it, then it reproduces itself through time, given appropriate energy inputs. Positive feedback loops or cycles of self-reinforcing transformations lie at the core of autocatalytic sets. Such cycles are at the foundation of chemical growth.[24]

Given autocatalysis, reproduction can be sustained even in the face of turnover in network components: destroy a segment of the network, and an autocatalytic network often (not always) can reconstruct its deleted segment. Self-repair is the crucial dynamic feature of autocatalytic sets that gives the set continuity through perilous times. Autocatalysis, in other words, is the network definition of life itself. In this context, the origin-of-life problem is finding prebiotic experimental conditions under which an initial random set of chemicals can self-

[22] In 1967 Eigen received the Nobel Prize in chemistry.

[23] Autocatalysis or life, however, remains well defined even when entities other than chemicals are substituted into the "nodes" of the definition—for example, economic products, people, organizations, or biological species. When products are substituted, autocatalysis becomes: "A set of economic products and production and exchange rules in which all economic products are re-created through transformations and exchanges among products in the set." This is like the Leontiev input-output (ecological) view of an economy. When people are substituted, autocatalysis becomes: "A set of people and social interactions in which all types of people are re-created through social interactions among the people in the set."

[24] This is not to deny, of course, that negative feedback loops are also important to keep such growth bounded.

organize and reproduce itself into an autocatalytic set. The maintenance-of-life problem is finding conditions that support self-repair and resilience.

In chapter 2, Padgett reviews the biological literature on autocatalysis for the benefit of social science readers. In chapter 3, Padgett, McMahan, and Zhong develop an agent-based model that extends this concept to the realm of economic production. There, products are like chemicals, and production rules are like chemical reactions. Actors are holding bins for production rules, through which products flow and are transformed. Economic "life" is the self-organization, through differential reproduction, of technological webs of production rules and product exchanges. These webs of production and exchange wend through multiple heterogeneous firms, constructing and reconstructing those firms, keeping them materially alive. In chapter 4, Padgett extends the production orientation of chapter 3 into communication. Not only do production rules reproduce, but communication protocols do as well. Social interaction networks thereby endogenously co-evolve with economic technology. At the level of communication, social "life" can be considered to be the self-organization of interaction protocols into language communities. Actors, either people or firms, thus become the vehicles through which life self-organizes, both in production (chapter 3) and in communication (chapter 4).

Actors—again, be they people or organizations—become who they are through learning and teaching. Autocatalysis does not challenge this fundamental insight. It just operationalizes it and adds a more systemic emphasis on the network feedbacks induced in linked chains of learners. Actors learning through interaction is the same as production rules and communication protocols reproducing and passing among them. Through structured social interaction, endogenous or not, chains of rules and protocols assemble themselves via autocatalytic growth

into technologies (chains of production rules), markets (chains of exchanged products), and language communities (chains of communication protocols).

Autocatalysis suggests a modification in how social-network analysts should conceptualize and measure network ties. Autocatalytic networks are networks of transformations, not networks of mere transmission. Neither products nor information are inert sacks of potatoes passing through passive networks-as-pipes. Products are transformed through production rules, and information is transformed through communication protocols. Either way, social networks don't just pass things; they do transformational work. Under this view, diffusion should be reconceptualized from mimicry to chain reactions. The autocatalytic self-organization of these chain-reaction transformations is emergence.

The connection between these micro-processual points and the macro-architecture of figure 1.1 is as follows. Findings from the autocatalytic production models of chapter 3 include these: Technological complexity increases as spatial constraints on exchange interaction are imposed. Altruism evolves because it supports repair of cycles better than selfishness, but selfishness can gain traction through stigmergy. Intelligence increases the speed of convergence to evolutionary equilibrium but does not alter that equilibrium. The agent-based finding most relevant to figure 1.1, however, is that multiple, overlapping production networks emerge spontaneously, without requiring any intervention by the experimenter. The emergence of multiple, differentiated yet partially overlapping domains of activity (the planes of figure 1.1), in other words, is a surprisingly automatic corollary of autocatalytic processes. "Domains" are sets of production rules and products that are autocatalytic. "Overlapping domains" means that some products, production rules, and/or communication protocols in these sets are shared. Multiple overlapping domains emerge in autocatalytic models because shared rules and products create

synergistic feedbacks—both positive for stimulation and negative for regulation—between individual autocatalytic production networks. Because of such synergies, multiple networks that self-organize are reproductively more resilient than any one autocatalytic network alone.

Embedding of exchange of any sort (economic, political, kinship, or whatever) in multiple reinforcing networks means that innovations and inventions in any one domain are resisted. Resilient self-repair at the system level implies reproductive stickiness at the micro-level. The closer to the reproductive cyclic core of any autocatalytic system, the denser the networks of homeostatic feedback. This is why creative destruction is often an important prequel to innovation and invention.[25] This is also why invention, if and when it ever does break through, can appear as rapid "punctuated equilibria," with unintended spillover consequences for organizations in collateral domains. The problem of novelty would not be so difficult were not autocatalytic life in place to resist it. The further evolution proceeds, indeed, the harder it becomes to generate genuine novelty. Reshuffling and relabeling of superficially new things is breathlessly mistaken for innovation in advanced societies when actually that only reproduces the old.

Once the micro-dynamics of autocatalysis are folded into the network topology of figure 1.1, processes of network selection and organizational novelty become more well defined. Innovation or novelty in actors is a new partition of production rules or communication protocols into organizations or people. Organizational selection occurs whenever a new partition is reproducible through product and informational feedback with other interacting organizations of

[25] We modify Schumpeter's famous point about creative destruction, however, as follows: Unlike Schumpeter's famous characterization of "creative destruction" as the elimination of old businessmen and their replacement by new ones (Schumpeter 1947: 131-134; 1939: 87-101), we define "creative destruction" as the breakup of old networks and their replacement by new ones. Our version includes Schumpeter's version as a subset but is not limited to it. Many of our historical cases illustrate unintended innovation produced by conservative elites trying hard to resist it.

rules and protocols. Organizational novelty that survives without disturbing other partitions we label an organizational innovation. Organizational novelty that tips into disrupting other partitions, which collectively find their own modified autocatalysis, we label a systemic invention. The extent of spillover is obviously a matter of degree.

Autocatalysis is network self-organization and emergence, but that alone is not the same thing as novelty. Autocatalysis is our relational version of Darwinian selection—namely, successful reproduction that keeps networks alive, resilient, and maintaining themselves through perilous time. It operationalizes our point above that "to make progress in understanding discontinuous change, we need to embed our analysis of transformation in the routine dynamics of actively self-reproducing social contexts, where constitutive elements and relations are generated and reinforced." Network novelty, the Mendelian side, comes into focus when we discuss our eight network-folding mechanisms of organizational genesis. To fully understand organizational evolution, the relational analogues of Darwin and Mendel have to be put together.

Biographical Autocatalysis

In our extension of autocatalytic theory to social applications, we distinguish three types of autocatalysis: (1) Production autocatalysis, just discussed (see also chapter 3), is the production and transformation of products through skills within cells and relational exchange ties among cells.[26] Here products flow through skills, and skills reproduce within cells. Exchange ties emerge to reinforce the flow of transformed products into self-reproducing life. (2) Cellular or biographical autocatalysis, to be discussed in this section and in chapter 4, is the production and flow of skills among cells, through constitutive teaching between cells. Cells themselves learn

[26] "Cells" is our neutral synonym for actors, which can mean either people or organizations, depending upon the application.

new skills, die, and are replaced. Lineages of descent emerge to reinforce the flow of skills into inheritance across generations of cells. (3) Linguistic autocatalysis, adumbrated in chapter 4, means that words and symbols reproduce through conversational use in production. Linguistic autocatalysis does not play a central role in any of the organizational inventions we have observed empirically, but we fully recognize that the autocatalysis of language, and how this relates to organizational genesis, is an important topic for future research.[27]

The first type of autocatalysis, which produces products, is nested inside the second one, which produces biographies. More advanced autocatalytic systems are regulated through stochastically channeling biographies, whose intertwining directs the flows of skills and relational protocols.

The second level of autocatalysis emerges because of cell death and turnover. One of the main findings of Eigen and Schuster, reconfirmed in the agent-based models in chapter 3, is that autocatalytic life beyond four chemicals/products cannot be sustained in a random (e.g., gaseous or liquid) topology. They called this the "complexity barrier" to the emergence of life. This is why complex life beyond four chemicals is always spatially embodied. In an economic context, this is why production organizations, such as firms, exist. Given embodiment of a far-from-equilibrium vortex, cell death sooner or later becomes inevitable.[28]

Faced with cell death and turnover, autocatalytic systems need cell replenishment and renewal to survive. In biological systems, genetic inheritance and phenotypic development are there to fill this gap. In social systems, teaching does the trick of overcoming death. Teaching of what? In our framework, "constitutive ties" mean that cells teach other cells production skills

[27] A recent book by Padgett's former student and co-author Paul McLean (2007) points in a promising direction. Padgett and Massimo Warglien hope to develop agent-based models about linguistic autocatalysis in the future.
[28] Prigogine's famous phrase "far from equilibrium" (Nicolis and Prigogine, 1989) refers to physical systems, such as life, but also other systems that spontaneously self-organize through a continuous influx of energy beyond some threshold. Interrupt the energy influx and such systems drop back to equilibrium—that is, they die.

and relational protocols. Production skills have already been discussed: these are the rules or technologies that transform products into each other. Relational protocols are not literally the set of addresses or names of others with whom to have relational-exchange or constitutive-teaching network ties. They are the higher-order learning rules through which cells develop such lists of access from their own personal experience. Cell inheritance in the social context means passing production skills and relational protocols down from experienced cells to less experienced cells, including to blank cells. Teaching ties that percolate down induce biographies of descendants coming back up.

In this context of cell death and turnover, cellular autocatalysis can be visualized as a spiral through time of reproducing rules, analogous to the cycle in space of reproducing products in production autocatalysis. Even though particular cells come and go with finite lifetimes, collectively autocatalytic cells construct copies of their components through teaching. In the social examples in this book, this process of cells constituting each other happens gradually through interactional time, not all at once as in biological birth. Intertwined lineages of teaching are the social analogues of biological families.[29] Changes in lineages of teaching induce new types of biographies to emerge.

Cellular autocatalysis of cells and biographies usually crystallizes on a slower time frame than does production autocatalysis of products and skills. In our empirical cases, we often observe organizational innovation triggered by unanticipated transpositions of people from one domain to another, who carry with them production skills and relational protocols that mix with and transform skills and protocols already there. Organizational invention, following such innovation, is usually the slower process of the new innovation percolating around the networks in which it is embedded, tipping them into new topologies and interactional forms along the way.

[29] See chapter 4 for a formal model of this.

More radical episodes of this process lead to “innovation cascade.” Restructured biographies are the medium through which network spillover is transmitted.

In this book we often speak of a two-stage process of organizational genesis and organizational catalysis. Organizational genesis is the transposition of skills and relational protocols that triggers innovation. Organizational catalysis is the slower process of absorbing innovation into transformed collateral networks through restructured biographies. If this happens (which is rare because preexisting autocatalyses resist it), this transmutes organizational innovation into systemic invention.

Multifunctionality—the participation of cells, skills, and relational protocols in more than one domain—lies at the center of how domains intersect. Hence multifunctionality lies at the center of the topology of how organizational innovations, wherever they come from, diffuse or do not diffuse into systemic invention. In terms of figure 1.1, multifunctionality is the set of “social embeddedness” vertical lines of people participating in multiple roles. In terms of the Venn diagrams in the introduction to part 2 (early capitalism module), multifunctionality is the pattern of shared overlap among distinct autocatalytic domains. Innovation spillover across domains, if it occurs, occurs through parts in common.

Biographical restructuring is particularly consequential, therefore, when it rewires how multifunctional cells or people are assembled across domains. Our more dramatic cases of systemic invention show transformations not just in particular domains—economics, politics, kinship, science—but in generic ways that people interact, across multiple domains. Renaissance Florence, to take one example, innovated not just in economics. It also developed a new generic way of interacting across social classes—namely, a patron-client relational protocol—that operated in politics, economics, kinship, and art, transforming all of these domains in the

process. Early modern Netherlands, to take a second example, innovated not only in economics. It also developed a new generic way of interacting across geographical space—namely, a federalist relational protocol—that operated in politics, economics, and religion. Contemporary biotechnology, to take a final example, developed a new model for doing research and development—namely, privatized labs—that operated in markets, universities, and even in government. These are transformations not just in individual domains but in how domains fit together.

Cellular autocatalysis, to sum up, is the self-sustaining feedback of cells teaching each other production skills and relational protocols, within any one domain. Multiple-network cellular autocatalyses are the self-sustaining feedbacks of cells teaching each other production skills and relational protocols, in multiple domains linked through parts in common. Altering the first changes careers. Altering the second changes biographies.

Mechanisms of Organizational Genesis

Single autocatalytic networks generate life, but they do not generate novel forms of life. There is nothing outside of a single decontextualized network to bring in to recombine with what is already there. Self-organizing out of randomness into an equilibrium of reproducing transformations, the origin of life, was a non-trivial accomplishment, to be sure. But this is not quite speciation, which is the emergence of one form of life out of another.

Transpositions and feedbacks among multiple social networks are the source of organizational novelty. In the multiple-network framework, networks are the contexts of each other. Studying organizational novelty places a premium on measuring multiple social networks in interaction, because that is the raw material for relational recombination. Of course in any real

research project, one cannot measure everything, but that is a statement about research design, not a statement about reality.

In what follows, we extract and abstract the mechanisms of organizational genesis that we have discovered in our case studies. These genesis mechanisms involve network transpositions or linkages of one sort or another from one domain to another, which altered the flow of cross-domain biographies in reproducible ways. After describing the multiple-network genesis mechanisms that produced our observed organizational innovations, we then go on in each case to describe the catalysis mechanisms that elevated organizational innovation into organizational invention.

The word *recombination* is often used in the literature to refer to processes of generating novelty, but that word is too atomistic for our tastes. Here the people, practices and relational protocols being recombined are attached to networks, with percolation consequences. *Network folding* more accurately describes the novelty-making processes that we see.

The eight network-folding (and also network-tearing) mechanisms of organizational genesis that we describe briefly in this section are these:

1) Transposition and refunctionality

2) Anchoring diversity

3) Incorporation and detachment

4) Migration and homology

5) Conflict displacement and dual inclusion

6) Purge and mass mobilization

7) Privatization and business groups

8) Robust action and multivocality.

We regard this list of organizational genesis mechanisms as a start toward developing social-network analogues to Mendel's biological rules for recombining genes. The invention mechanisms are elaborated, and indeed were often discovered, in the empirical chapters in this volume.

Transposition and Refunctionality

Our first organizational genesis mechanism, transposition and refunctionality, is the movement of a relational practice from one domain to another and its reuse for a different function or purpose in the new domain. Transposition and refunctionality is not innovation in the usual sense of a new tool for an old purpose; this is innovation in the sense of a new purpose for an old tool.[30] Relations and relational protocols originally developed in one autocatalytic network are inserted into another network and reproduce there, possibly tipping those networks in the process.

In chapter 6, Padgett documents the transposition, via the city council in Renaissance Florence, of the master-apprentice relationship in domestic guilds to the international world of merchant-finance, thereby making the partnership system. In chapter 13, Powell and Sandholtz document the transposition, via venture capital, of the scientific life-sciences lab from the university to the market, thereby making the dedicated biotechnology firm. To show the similarity in process of organizational genesis between these otherwise disparate cases,

[30] Gould and Vrba (1982: 6) explain their term *exaptation* in the following way: "We suggest that characters evolved for other usages (or for no function at all), and later coopted for their current role, be called *exaptations*." This is essentially the same as our term *refunctionality*. Hence our research program for social science parallels that of Gould (2002) for biology. Gould and Vrba offer examples but no list of genesis mechanisms for how their exaptations are achieved. But like Gould, we emphasize the consistency of our search for historical mechanisms of speciation/genesis with Darwin's emphasis on natural selection. Like Gould, we also insist that natural selection operates at the network level of interacting systems, not only at the level of atomistic and individualistic genes.

transposition and refunctionality is diagrammed in figure 1.2a for Florence and in figure 1.3a for biotech.

--- Figure 1.2 about here ---

In the Florentine case, an employment relationship of master-apprentice was transposed, through the city council in response to the Ciompi revolt, from its original home in domestic guilds into the new more open world of international finance. Economic function altered thereby: a senior partner invested in a set of legally independent branch partners, who were traders and bankers. This transformed the master/senior partner from an entrepreneur into a financier. In outline, the partnership systems of Renaissance Florence resemble venture capitalists today.

Catalysis and reproduction of transposition and refunctionality in both the Florentine and the biotechnology cases were produced by the emergence of a new open elite of biographical flows, which broke down previous social boundaries. In the case of Florence, new-men bankers participating in partnership systems gradually intermarried with politically victorious segments of the old patricians. This class synthesis through social mobility made a new type of "Renaissance man," the merchant-republican. This restructured elite was based not on inherited blood and state service alone but also on patronage and aesthetic taste. Through intense social mimicry, the contemporary conception of "elite" became more a widely diffused ideal than a stable demographic reality.[31]

Figure 1.2b visualizes this organizational catalysis, which reproduced the organizational genesis diagrammed in figure 1.2a. In figure 1.2b and in all subsequent b figures, black solid ovals represent production autocatalyses, and blue dotted ovals represent cellular autocatalyses.

[31] See Padgett (2010) for elaboration on and statistical proof of these conclusions, based on two centuries of population and network data on changing social mobility and kinship in Florence. Padgett demonstrates that the driver behind social mobility between 1300 and 1500, particularly pronounced after the Ciompi revolt, was contradiction between three orthogonal and contending dimensions of social status: age of lineage, average household wealth, and membership in political factions during three intense crises.

As documented in chapter 6, restructured channels of political and social cooptation transformed Florentine social mobility and biographies, thereby elevating partnership systems from an influential organizational innovation in the history of business to a new constitutive network in Florence's social and political elite. This new merchant-republican open elite, in turn, stimulated and bankrolled the famous sequence of artistic and political inventions that we label the Renaissance. The organizational invention of partnership systems in Florence triggered not only new banking but also new elite network structures.

In the case of contemporary biotechnology, the academic science laboratory was transposed, through venture capitalists in response to new gene manipulation technologies, from its cozy home in universities into the new more profit-oriented world of the market. Chapter 13 by Powell and Sandholtz analyzes the origins of the first generation of biotechnology companies, founded by amphibious scientists who carried scientific practices into the world of commerce. The result was the creation of a science-based firm, which was the product of overlapping networks of science, finance, and commerce. The setting is the 1970s, a time when landmark scientific discoveries in molecular biology triggered perturbations in university science, pharmaceutical research, and venture finance. The novel collection of organizational practices that coalesced into a new science-based commercial entity, the dedicated biotech firm, proved disruptive, as patenting was added to publishing as measures of scientific output. Amphibious scientist-entrepreneurs introduced academic norms into the start-up world while unwittingly conducting commercial values and metrics into the academy.

--- Figure 1.3 about here ---

The case of biotechnology also illustrates the concept of open elite as a biographical catalysis mechanism, further emphasizing the parallelism across centuries of these two

seemingly disparate cases. In chapter 15, Powell and Owen-Smith analyze the emergence of a core group of diverse, highly interconnected organizations, which they also dub an open elite. The animating question is why this group of organizations, which constitutes a structural backbone of the field, has not become an ossified gatekeeper but remains engaged in expansive exploration. The answer is found in their multiconnectivity, the multiple, independent pathways that link diverse types of research-focused organizations in a wide array of different activities. The analysis sheds light on how a select group of incumbent elites can absorb novel challenges from upstart organizations.

Anchoring Diversity

In addition to open elite, the case of biotechnology also exhibits a second catalysis mechanism, that of regional agglomeration or industrial districts, as illustrated in figure 1.3b. Eleven regional agglomerations of biomedical research, development and finance in the United States are analyzed by Powell, Packalen, and Whittington in chapter 14: three successful cases and eight unsuccessful ones. From the perspective of dedicated biotech firms (DBFs), industrial districts catalyze DBFs, but from the perspective of the districts themselves, life-science regional clusters can be considered higher-order emergent organizations themselves.

The three successful regional biotech agglomerations in the San Francisco Bay Area, Boston, and San Diego all profited from intense contractual collaborations among a diverse array of organizational forms, most notably public research organizations (such as universities and research institutes), venture capital, and dedicated biotechnology firms, but also others. In contrast, contractual collaboration in the eight unsuccessful regional agglomerations was led by a single organizational form: pharmaceuticals in New Jersey and Philadelphia, financial

institutions in New York and Houston, the National Institutes of Health in Washington, D.C., supply companies in Los Angeles, and a DBF in Seattle. “Anchoring diversity” refers to the mediating role of community-oriented organizations—sometimes public research organizations, sometimes venture capitalists, sometimes DBFs themselves—in the cores of each of the three successful clusters. The activities of these so-called anchor tenants generated new organizations and fostered ties among others. Open norms of science, company spinoffs, and labor mobility are three of the network mechanisms that underlie the community-building orientation of these anchor tenants.

In chapter 17, Fleming, Colfer, Marin and McPhie also analyze comparatively the emergence of industrial districts in Silicon Valley and Boston, exploring not only biotechnology but all of their high-tech industries together. Using a data set of inventors that patented in the United States from 1975 through 2002, they observe dramatic aggregation of regional inventor networks, first in Silicon Valley and three years later in Boston. Despite considerable similarity in the number of patents, inventors, technologies, and firms and in the overall density of ties, the inventors in Boston were more fragmented and specialized by industry than were the inventors in Silicon Valley. Drawing on interviews with inventors who did—and did not—create ties across each region’s network components, they demonstrate the importance of “academic” institutions, both educational like Stanford and proprietary like IBM’s Almaden Labs, for biographical linkage, information flow, and commercial science. Such training institutions enabled the earlier aggregation of Silicon Valley by encouraging the movement of young inventors into innovative bridging positions. This blending of local organizations and industries through the biographies of scientists enabled the formation of rich and generative ecologies between academic and corporate organizations and technologies.

Incorporation and Detachment

Our third organizational genesis mechanism involves the insertion of a connected chunk of one network into another, at first without detaching it from its original network. A hybrid organization forms in the (perhaps tension-laden) incorporation overlap. The hybrid eventually detaches to find its own new exchange relations. In chapter 5, Padgett illustrates this incorporation-and-detachment mechanism through the creation of the medieval merchant-banking corporation. This was the first ongoing organizational form of international finance in Europe that involved sedentary merchants in offices. The pope triggered this emergence by mobilizing Tuscan merchants from his hometown Champagne fairs into papal administration for the Italian crusades. The concept of "corporation" in economics thus originally had religious overtones, as in an organ in the body of Christ militant.[32] Later merchant-banks detached from the Church to find their own way in new patterns of international trade, which they pioneered. The incorporation and detachment process is diagrammed in figure 1.4a.

--- Figure 1.4 about here ---

Catalyzed reproduction of this new organizational form proceeded through a cascade of induced innovations that percolated around the exchange networks in which the Tuscan medieval corporations were embedded. First, Tuscan bankers transferred their new state-finance methods to England, creating a new customs method of taxation there. Second, Tuscan bankers to the King of England used their newfound leverage over English wool to construct a textile industry back home, to compete with Flanders and to give themselves a more stable commercial foundation than the profitable but very risky state finance. Finally, successful merchant-bankers slowly transformed themselves into noble patrilineages, using a *consorteria* relational protocol

[32] The word *corpus* in Latin means body.

common to many noble social organizations in medieval times. Instead of “company out of family,” this was “family out of company.” Figure 1.4b is a visualization of this catalysis of merchant-banks through kinship. This organizational invention of a mercantile nobility set Italy onto a very different co-evolutionary trajectory than France or England.

Migration and Homology

The fourth organizational genesis mechanism that we document in this book is migration and homology, discussed in chapter 7 on early modern Netherlands by Padgett. The profoundly consequential modern organizational inventions of joint-stock company, stock market, and governmental federalism all were produced as by-products of this. The Dutch Revolt in the late seventeenth century triggered a massive migration of Protestant merchants and artisans from what is now Belgium into what is now Netherlands, within what was then the politically unitary Spanish Netherlands. Precocious southern merchants brought advanced commercial and financial techniques, as well as economic connections throughout Europe, with them from Antwerp to Amsterdam to mix with the predominantly shipping skills already there. Southerners, no matter how wealthy, were not admitted to native political structures of regencies, which were inherited from the decapitated Spanish. But they were blended with native elites in the two collateral pillars of the Dutch Reformed Church and the Dutch East and West India Companies, which were homologous to and modeled on the federalism of the Dutch Revolt itself. The first joint-stock company and the first stock market, in the Amsterdam bourse, were nautical extensions into overseas colonialism of the nascent Dutch federalist state. Padgett labels the three homologous pillars that reinforced each other to make the new country of the Netherlands “tripartite federalism.” The genesis mechanism is illustrated and the story is told in figure 1.5a.

--- Figure 1.5 about here ---

Biographical reconstruction to catalyze these organizational innovations into reproductive invention, Padgett argues, was accomplished through Calvinism. The Calvinist organizational system of consistories (boards of observant elders) was the midwife to bringing southerners and northerners into uneasy but ultimately successful communication and synthesis. “Lateral control,” Padgett’s label for public peer pressure, became a new generalized relational protocol through which the heterogeneous Dutch constructed their outward-looking mosaic. The final organizational invention of the Dutch central state bank, so influential for later British economic development, was essentially the consistory of the Amsterdam bourse. The catalysis of Dutch economics and politics through the Dutch Reformed Church is summarized in figure 1.5b.

Conflict Displacement and Dual Inclusion

The organizational innovation in chapter 8 by Obert and Padgett is nothing less than the formation of Germany. More particularly, organizational genesis here means the assembly by Prussia in the nineteenth century of geographically disparate German principalities under a new constitutional umbrella of Reichstag, Bundesrat, and chancellery. Organizational catalysis in this context means the emergence of political parties and mass interest groups to manage this constitutional core in the name of German nationalism. Dual inclusion is the stapling together by Bismarck of the deeply contradictory principles of democracy and autocracy through his mutual-control balancing of “Prussia is in Germany, and Germany is in Prussia.” This deep contradiction, built into the heart of the German state, drove forward the production of a succession of new political actors in German history.

Repeatedly in international wars with Austria and France and in domestic wars with Catholics and socialists, Bismarck used his characteristic style of conflict displacement to push forward institutional development. In a triad of mutually hostile relations, conflict displacement is the attack by an aggressor on a demonized other with the consequence of splitting a bystander, one segment of which joins into fragile alliance with the aggressor. Conflict displacement is a violent method of forming new ties by breaking old ones. Bismarck assumed the role of broker between the aggressor and the allied segment, but more deeply he assumed the role of charismatic hieratic authority that embodied the newfound unity of opposites.

Figure 1.6a diagrams how conflict displacement worked in the first episode of its use: Prussian war on Austria. Simultaneously with war, Bismarck offered universal suffrage to conquered northern German subjects in a new German Reichstag legislature, thereby splitting them in sentiment from their princes, who had been allied with Austria. Instead of Prussian conqueror, Bismarck received the attribution of German liberator. Defeated and isolated German princes were co-opted into a new legislative upper house, the Bundesrat, and prostrate Austrian status superiors were treated leniently in peace.

--- Figure 1.6 about here ---

To stabilize the reproduction of this dual-inclusion ensemble of Prussian autocracy and German democracy required not just clever tactics in war, but the reconstruction of particularistic subjects biographically into German nationalists. Figure 1.6b illustrates this. An economic foundation for this reconstruction preceded Bismarck: the *Zollverein* or free-trade customs union that connected agricultural east with industrializing west into a budding domestic mass market. Economic potential was turned into political reality through two steps: elitist political parties of

nationalism, of which Bismarck approved, and mass interest groups of nationalism, of which Bismarck did not. Early German political parties were parties of notables, suitable to Bismarck's elitist mentality. His otherwise successful conflict-displacement tactics, however, backfired seriously with Catholics and socialists, who responded to the conflict-displacement assaults on them by forming solidary mass political parties, an organizational portent of the future.

Conflict displacement was a powerful mechanism for constructing the German state, but that does not mean that it always worked as intended or that the resulting state functioned smoothly. Contra the mythology of Bismarck as genius, internal contradictions and pressures led to the explosive sequential production of new mass political organizations and movements, and ultimately down the road to World War I and beyond. They also changed Bismarck himself and what he was trying to achieve.

Purge and Mass Mobilization

In communism, dual hierarchy was the two hierarchies of Communist Party and central command economy arrayed parallel to each other with cross-cutting levels of overlapping inspection and control, like a ladder. In chapter 9, Padgett derives the political consequences of this multiple-network structure for the dynamics of economic reform under communism: under Stalin, under Mao, under Khrushchev, under Brezhnev/Kosygin, under Andropov, under Gorbachev, and under Deng Xiaoping. He shows that this structure imposed four and only four families of reform trajectory on leaders: mobilization of the top of the party, mobilization of the bottom of the party, mobilization of the economic ministries, and mobilization of economic factories. Reading history forward, not backward, Padgett interprets economic reform even under

Gorbachev and Deng as a political dynamic within communism, not as a teleological imitation of Westerners.

The second, most radical of these reform trajectories is "purge and mass mobilization." In this, upper ranks of hierarchies are purged (and sometimes worse) and bottom tiers, often youthful, are raised up to take their place. Stalin did this first with collectivization and then with the Great Terror. Mao did this with collectivization and with the Cultural Revolution. Gorbachev tried unsuccessfully to do this with democratization. Even post-Communist Yeltsin, analyzed in a complementary chapter 10 by Spicer, did this in an inverted way with privatization. The organizational invention of the central command economy itself was produced by the first two waves of these purges and mass mobilizations under Stalin. Figure 1.7a is a picture of Stalin's organizational intervention during the Great Terror.

--- Figure 1.7 about here ---

Catalysis of the central command economy was accomplished by two types of biographical reconstruction. First, the "circular flow of power" through the *nomenklatura* system was the appointment and promotion by leaders of their supporters to selectorates, which then ratified them as leaders. Originally implemented at the top in the Central Committee, this method of central control reproduced downward throughout the Soviet system into localized "family circles." Little Stalins often defensively resisted the center they were imitating, thus requiring more purge and mass mobilization by the center to counter the resistance that the previous round had engendered. Figure 1.7b is a simple visualization. Second, by his mass murder of his own Communist Party in 1937-38, Stalin created so many job openings that an entire "generation of '38" of politically educated young red engineers rose rapidly through the ministries and the Party to drive the Soviet economy toward massive industrial concentration. They used the huge

factories and cities they built to defeat Hitler and thereby to lock in their own economic system by stigmergy.[33] This generation of ’38 contained the entire leadership of the Soviet Union until Gorbachev.

Gorbachev was trying to reform and to revive communism, but he was driven quickly through the four reform trajectories that dual hierarchy presented to him until eventually he too was left with purge and mass mobilization. Democracy was Gorbachev’s final mass mobilization tool, but it backfired for him, even as it induced the greatest political and economic transformation of our time.

Privatization and Business Groups

In chapter 10, Spicer analyzes Yeltsin’s economic privatization program and its effect on the emergent stock market and banking system in post-Communist Russia. He demonstrates how little connection there was between utopian Western designs and Russian facts on the ground. Yeltsin’s preeminent political objective, which trumped all else, was to destroy the Communist Party before it destroyed him. Viewed as politics, privatization was an inverted version of purge and mass mobilization: using economics to smash politics, rather than the usual politics to smash economics.

Rather than an efficient means for capital-market investment, the first Russian stock market for privatization vouchers was an effective means for swindle, theft, and a concentration of economic wealth. Through multiple-network chain reactions that Spicer describes, the first organizational innovation of the stock market cascaded into a sequence of collateral

[33] As discussed in chapter 3, stigmergy is the construction of a physical environment by a social-insect community; this construction then guides the future social evolution of that community. In the case of the Soviet Union, stigmergy was massive economic concentration in gigantic factories and cities.

organizational innovations: the emergence of wealthy “new men” oligarchs; the emergence of a Yeltsin electoral political machine built upon these oligarchs; and finally the development of tight business groups, first through banks spun off from the state, and then through Yeltsin’s newly elected presidency. The case shows that organizational innovation and invention do not have to be confined to organizational forms that we approve of.

Two follow-on chapters examine the further evolution of business alliances and groups in post-socialist states, even though these chapters do not trace the evolutions of business groups back to their origins in privatization. Chapter 11 by Yakubovich and Shekshnia trace the emergence of the cell-phone industry in Moscow and St. Petersburg in the 1990s, Yeltsin’s time. The organizational focus is on explaining successful versus unsuccessful business alliances between fragments of the Communist state—both in telecom and in military research—and various foreign telecom partners. Compared to the economic disasters in most parts of the Russian economy at this time, the emergence of the Russian cell-phone industry is a success story—what Gorbachev promised but delivered too rarely.

Chapter 12 by Stark and Vedres traces the development of business groups in Hungary through the first decade after the fall of communism, again the 1990s. They reveal the emergence of a dense population of different forms of Hungarian business alliances and groups—some rooted in domestic remnants of the Communist state, some connected to foreign partners, and many hybrids that combine the two. Instead of a sharp divide between an inefficient post-socialist segment of the Hungarian economy and an efficient foreign-dominated sector, Stark and Vedres document blending of sectors through business partnerships and groups, a fact that they argue is conducive to fertile organizational innovation. For this book, the central point is that “market formation” in post-socialist states is a process of network evolution, in particular the

evolution of business alliances. Stark and Vedres also document the penetration of Hungarian political parties onto the boards of large Hungarian firms; this adds a multiple-network component to their business-group analyses.

Robust Action and Multivocality

Our final organizational-genesis mechanism is robust action and multivocality. Robust actions are noncommittal actions that keep future lines of action open in strategic contexts where opponents are trying to narrow them. Robust action may ensue when a central broker bridges two segregated blocs of supporters through distinct networks. The broker's identities are ambiguous, not in the sense of being vague or uncertain but in the sense that multiple audiences attribute different interests to the broker. Multivocality is the tactical capacity of robust-action brokers to sustain multiple attributions of identity through uttering sphinx-like statements that plausibly can be interpreted in multiple ways. Political polarization often drives both the structural process of segregation and the communicative process of inconsistent attributions. The archetypal example is Cosimo de' Medici, who used this tactic within his multiple networks to construct a centralized state in fifteenth-century Florence out of the pulverized social residues of class revolt and wars.[34]

In chapter 9, Padgett argues that robust action was also the successful network-bridging strategy employed by Deng Xiaoping in the 1980s to guide post-Mao China to economic development. Deng, like Cosimo, led from a backstage of informal power, not from formal office, and he issued only cryptic remarks about his reform intentions and policies, preferring to respond selectively to others' initiatives. The organizational invention produced by robust action

[34] Padgett and Ansell (1993).

in the early Chinese reform was local-government-as-entrepreneur, a combination of political patronage and profit orientation. As illustrated in figure 1.8a, market liberalization emerged from Deng's brokering among the residues of the Cultural Revolution.

--- Figure 1.8 about here ---

At the end of the tumultuous and debilitating Cultural Revolution, the Peoples' Liberation Army (PLA) was running the Chinese economy and government. Headed by elders from the Long March like himself, the post-Mao PLA was the original inherited power base for Deng. Viewed politically, decentralizing economic reform was a way for Deng to build a second patronage leg under his system of Communist control. The early household responsibility system in agriculture and local state businesses in light industry were popular reforms among wide segments of the Party and PLA base. Selective fiscal decentralization to those Party provincial secretaries who supported Deng politically built a patronage machine at the province level, just as Stalin had done in his first Five-Year plan and Khrushchev had done in his short-lived regional decentralization. Because of this conflation of markets within patronage and the Chinese decentralized state, what was good for politics was good for business, and what was profitable for business was good for political promotion. Ironically, Western economic advisers are everywhere to be seen in the failed Russian transition to a market economy, and they are nowhere to be seen in the successful Chinese transition to a market economy.

Chapter 9 also demonstrates that this robust-action approach of Deng Xiaoping to economic-cum-political reform was possible only because of the radical administrative decentralization that Mao had engineered during the Great Leap Forward and the Cultural Revolution. Even though Mao opposed markets with every bone in his body, Mao's administrative reforms made accessible what Deng achieved. Gorbachev's fundamental problem,

in contrast, was that he was following Stalin rather than Mao. Figure 1.8b illustrates the comparative network point that Chinese informal political networks were organized vertically into factions, whereas Soviet informal political networks were organized horizontally into family circles. These networks channeled and indeed stimulated what the respective Communist leaders did, so much so that it is as reasonable to say that the systems constructed their leaders, as it is to say that the leaders constructed their systems. In the short run, actors make relations; in the long run, relations make actors.

Structural Vulnerability

In this volume, we usually do not examine prior structural vulnerability to innovation and invention, although this is a crucial part of our theoretical framework.[35] This is the next research frontier. Certain network configurations of interacting rules, protocols, persons, and organizations are more poised to tip, in response to perturbation, than are others. Studying this empirically requires going back in time well before the original innovation ever occurred. Sometimes time-series data like that are available, but sometimes they are hard to assemble, in part because organizational innovations often document themselves but not their old-fashioned predecessors. With formal modeling, the topic is easier to investigate, though those results are only suggestive.

One finding in the autocatalytic simulation models of chapters 3 and 4 is that reproductive stability of multiple-network systems is associated with redundancy, a dense spaghetti of overlaid and intertwined production networks with feedback cycles at their cores.

[35] Of the many empirical analyses in this book, the linked Communist cases in chapter 9 and the sequence of German episodes in chapter 8 come closest to qualifying as *longue durée* trajectories, where innovation episodes shape subsequent innovation episodes over decades and generations. Padgett's numerous empirical network studies of Renaissance Florence will also qualify once these are plugged into each other to make a sequence and a book.

Sometimes redundancy means the simple replication of networks of production rules, each copy distributed over different people. Sometimes redundancy means replication of multifunctional rules or people that bridge between networks in similar ways. Either way, redundancy is associated with reproductive stability because even if one of these autocatalytic networks is destroyed, there are other similar networks around to keep the ensemble going until a replacement is grown. Conversely, lack of redundancy is associated with reproductive fragility. This finding about redundancy suggests that sensitivity to system tipping—dramatic network cascades that we associate with organizational inventions—increases as redundancy is thinned out. Too much thinning and the system will collapse, but some threshold level of network thinning may move a highly redundant system toward being poised to tip.[36]

There are a number of possible ways that thinning can occur, setting the structural stage for invention. Political crises are one. The invention of the partnership system in Renaissance Florence logically had nothing to do with the Ciompi revolt. Nor did Deng's economic reforms logically follow from the Cultural Revolution. But both of these crises weakened the reproductive power of the previous multiple-network system. Crises alone do not predict what will happen next. That depends upon what the residues are, and how those are rewired into new autocatalysis.

Two metaphors may help fix our idea about the causal connection between political crises and organizational innovation. A meteor killed off the dinosaurs. Does that mean that an exogenous contingency caused the demise of that species? Yes and no. Over the millennia, many meteors struck the earth, but only that one caused the extinction. The structure of an ecology that receives a shock is just as important to system response as is the shock itself. Likewise, many

[36] See footnote 25 for a comparison of our network version of "creative destruction" to Schumpeter's famous person-centered version.

political scientists argue that wars cause state formation. But some wars produce state formation, some cause collapse, some trigger revolution, and many do nothing. More than the perturbation itself is needed to explain emergence, even though perturbations are often involved. A second metaphor is the diamond cutter. Hit in one direction, a diamond cannot be broken with a sledgehammer. But tap the diamond along the lines of its natural cleavage, and it splits easily. Multiple-network social systems are like that. Perturbations often appear in the background of our organizational invention cases. But in differently interconnected systems, the same shock does not produce the same effect. Searching for simple input-cause and output-effect is a fantasy in densely connected feedback systems. Analyzing the percolation of perturbations through existing networks, no matter how data intensive, is essential for understanding system response to that perturbation.

Crisis, however, is not the only way in which redundancy can be thinned. The open-elite mechanism of organizational catalysis points to personnel turnover as another method for keeping organizational and production networks flexible and adaptive. This insight, however, needs to be treated with caution. Simply increasing the rate of hiring and firing is hardly an intelligent prescription for organizational learning. If the rate of turnover exceeds the rate of teaching, then degradation, not learning, ensues. Also there must be enough redundancy in the core of the organizational field that others can quickly take the place of nodes that exit. Because of this stable core, the open-elite method of fluidity is likely to generate more incremental innovations than is the crisis method of creative destruction.

One subtlety in managing fluidity that chemical engineers have brought to our attention is annealing. The more explosive the mix of elements being combined into hybrids, the more important it is to blend them in an oscillatory manner. Increase fluidity, decrease fluidity,

increase fluidity, decrease fluidity. There is a time for exploration, and there is a time for consolidation. Done right, with sensitivity to the details of what is happening, this can lead to dampened oscillation and to successful hybridization. Done wrong, with insufficient sensitivity to context, this can lead to amplified oscillation, which is explosion.

A third way of thinning redundancy is counterintuitive in the sense that it involves making new ties, rather than clipping old ones. The autocatalytic models in chapter 3 highlight the evolutionary role of parasites. These are chains of production rules that function as "free riders"—namely, others support their reproduction, but they do not support the reproduction of the rules that support them. Healthy autocatalytic systems can tolerate plenty of this, with no threat to their cyclic core. The reason that parasites can lead to tipping and invention is that they might grow to form a new bridge of symbiosis between two autocatalytic networks previously interactionally distinct. Since they are parasites, they are more free to wander than are the rule chains upon which others depend. Thinning can happen as a second-order consequence of parasites because a new bridge formed by them can tip local competitive balances on either side of that bridge, leading to growth of one local network at the cost of another. Parasites may grow into becoming multifunctional.

A fourth mode of thinning redundancy that lies outside the autocatalytic models in this book is neutral drift. In models of neutral drift,[37] there is a sharp distinction drawn between genotype and phenotype. This distinction is equivalent in our terminology to relational networks of production rules versus constitutive networks of social persons. The phenomenon of neutral drift emphasizes that there are a number of functionally equivalent ways of genetically making the same phenotypic product. If selection operates on phenotype, not on genotype, as Darwin insisted, then all of these functionally equivalent ways are neutral from the point of view of

[37] See Ansel and Fontana (2000) and the literature cited therein.

selection. The micro rules are thereby free to wander randomly in evolution within selection constraints on their final products. Neutral drift is the network analogue to atomistic random mutation.

The relevance of this to the topic of organizational invention is that, just by chance, production-rule ensembles might reconfigure themselves within fixed phenotypes (or social networks) to become poised to tip into a nearby autocatalytic set. In the language of dynamic systems analysis, this is moving to the boundaries of basins of attraction. This creates a new phenotype. A new phenotype, so to speak, randomly bursts out of the chrysalis of the old. Of course there is no guarantee that this new phenotype can reproductively survive in the network of other phenotypes in which it finds itself. But to the macroscopic observer, this will appear to be almost spontaneous generation. In our chapters we have no examples of this, but we admit neutral drift as a logical possibility.

Much work on structural vulnerability remains to be done, especially on the empirical side. Studies of innovation and invention, including our own, are biased toward looking at successes more than at failures. We are proud to have included cases of failure as well as success in our case studies, but the ratio of studied failures to actual failures certainly is skewed. We do not apologize for this sample bias, because much can be discovered this way about mechanisms of organizational genesis and catalysis. But we fully appreciate the need for complementary research designs that focus as much on the contextual detail of multiple-network systems before their innovation and invention, as on the contextual detail of systems during and after their tips.

Conclusion

History is littered with the emergence of new organizational forms that altered the trajectory of the societies in which they appeared. Yet the emergence of novelty, especially

novelty in human actors like people and organizations, is undertheorized in the social sciences. Novelty is fundamental to any analysis of evolution, yet that usually enters in from off the stage of our own imagination before our existing analytical tools can go to work. This book develops theories, models, mechanisms, and empirical cases in an effort to fill this gap in our collective understanding, especially in the domain of the emergence of new forms of organizations and markets. Each of the parts in this volume contains an introduction to clarify the connections between the overall framework in this introductory chapter and our detailed examples of organizational emergence. Both theory and cases benefit from a multidisciplinary perspective, because organizational novelty comes from feedback among multiple social networks and domains. Chemistry, especially regarding the origins of life, does not provide all of the answers, but it at least asks the right questions—for social science as well as for biology.

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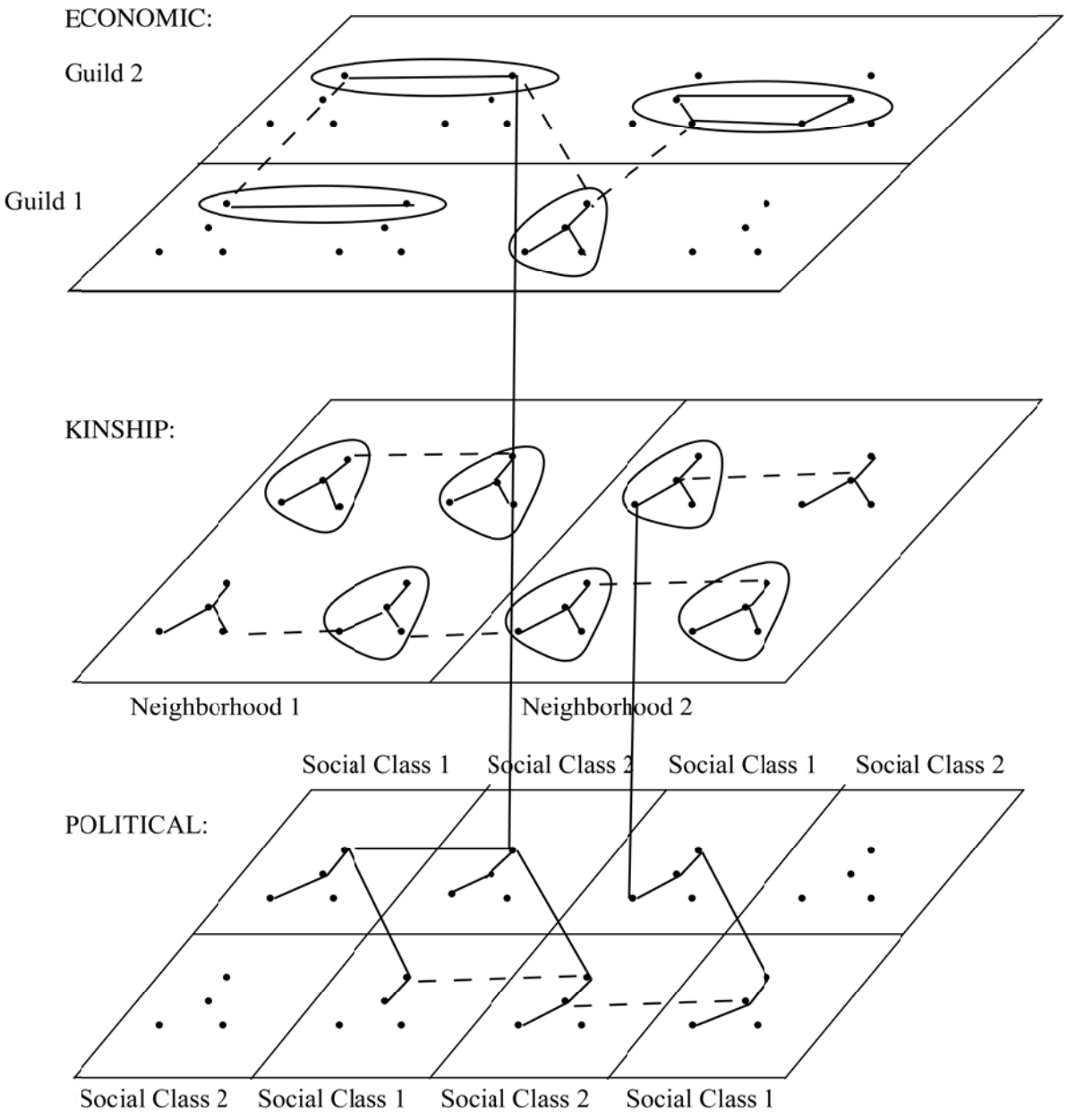
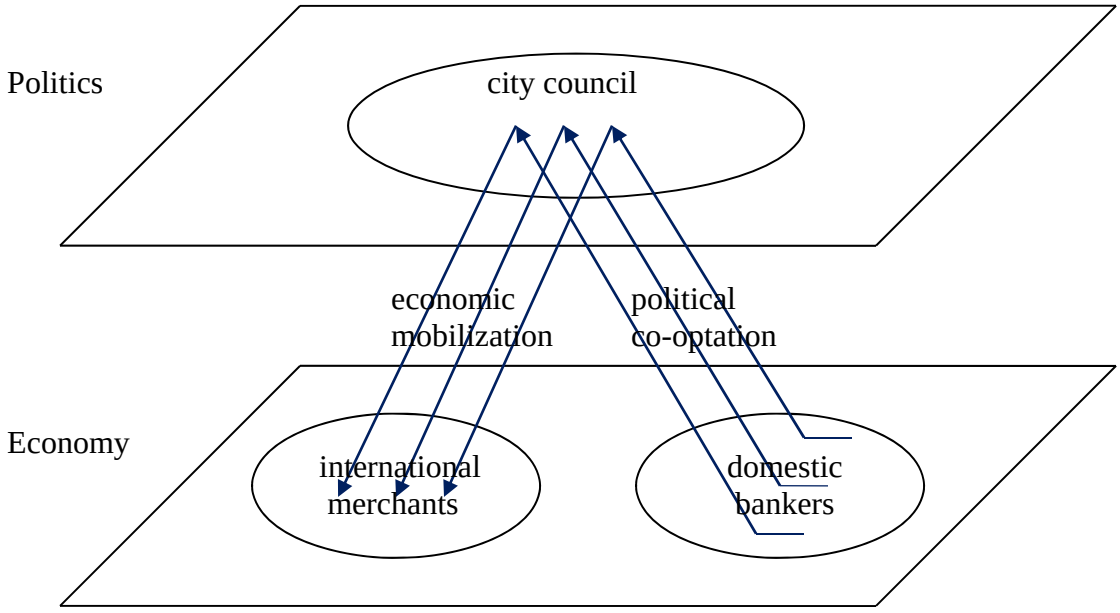
Figure 1. Multiple-network ensemble Renaissance Florence



Note: (a) Solid lines are constitutive ties. Dotted lines are relational social exchanges. Oblongs are formal organizations (families and firms.)
(b) People in multiple roles are vertical tines connecting corresponding dots in the domains of activity in which people are active. (Only two are shown for illustration.)

Figure 1.2a. Partnership systems in Renaissance Florence: Genesis

Transposition: CIOMPI REVOLT



Refunctionality:

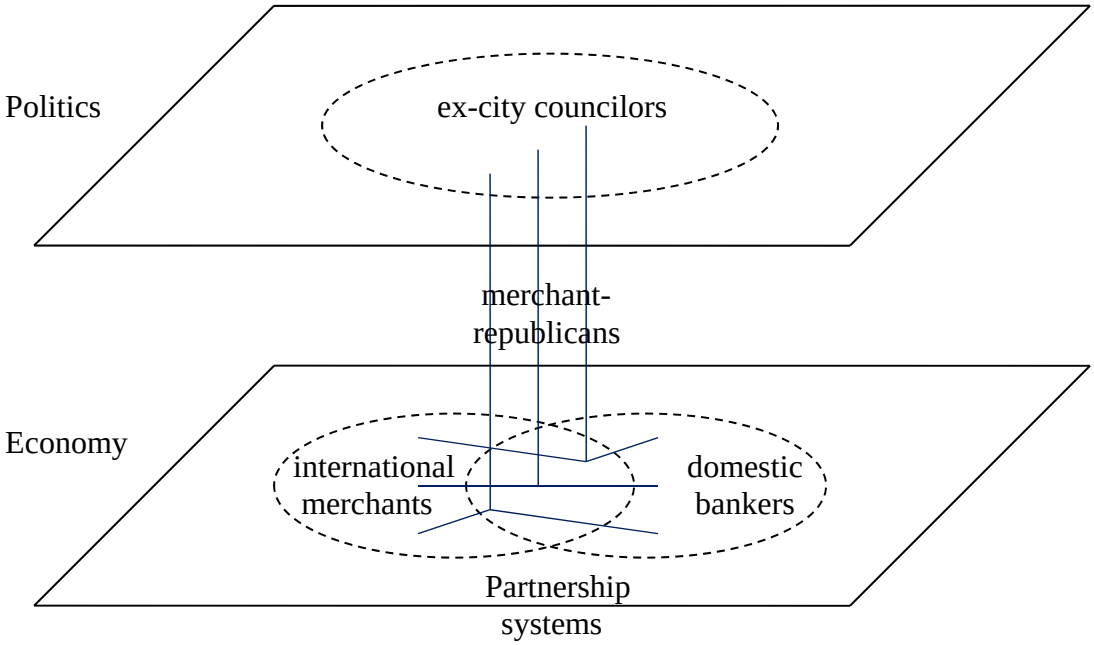
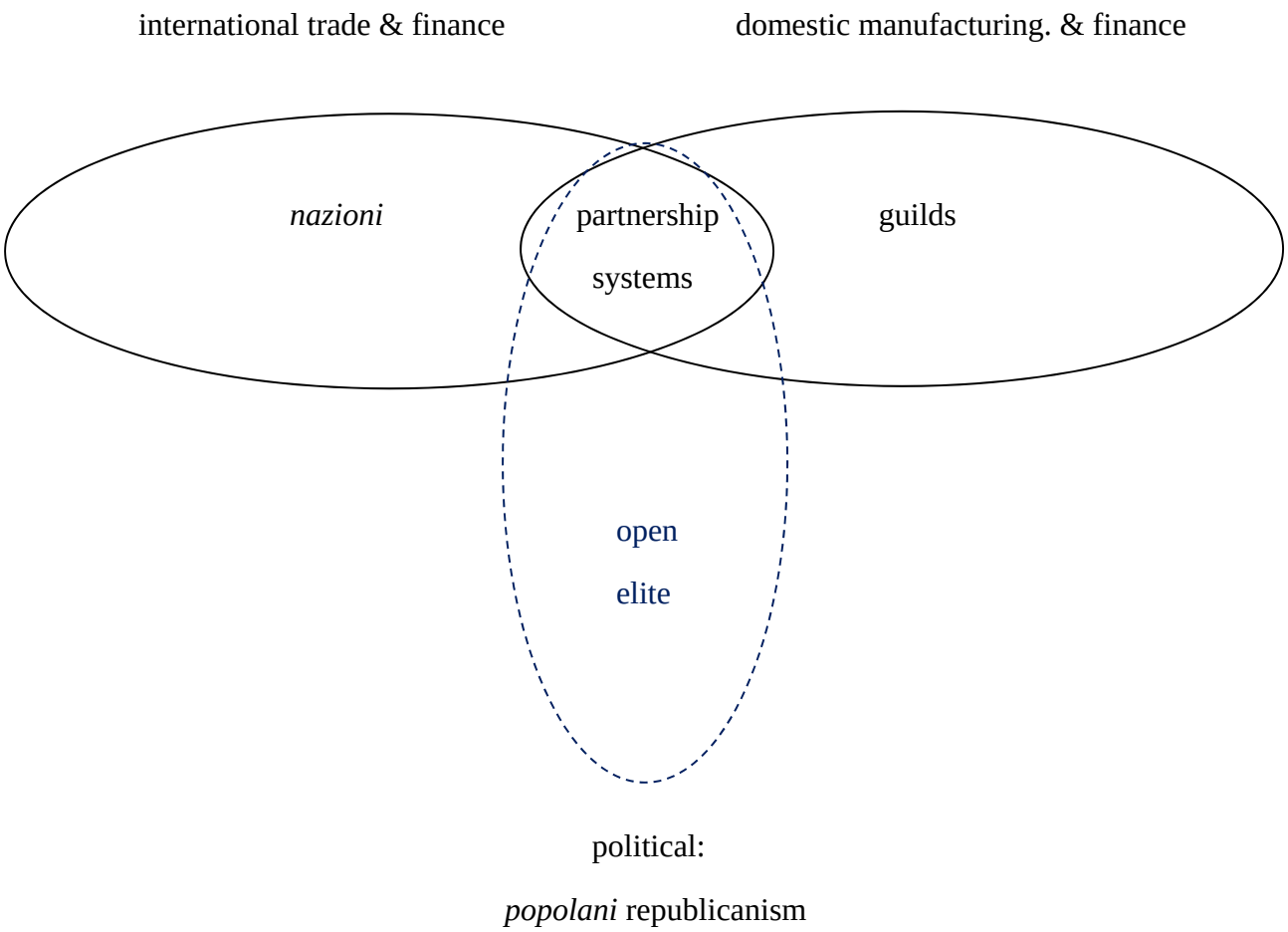


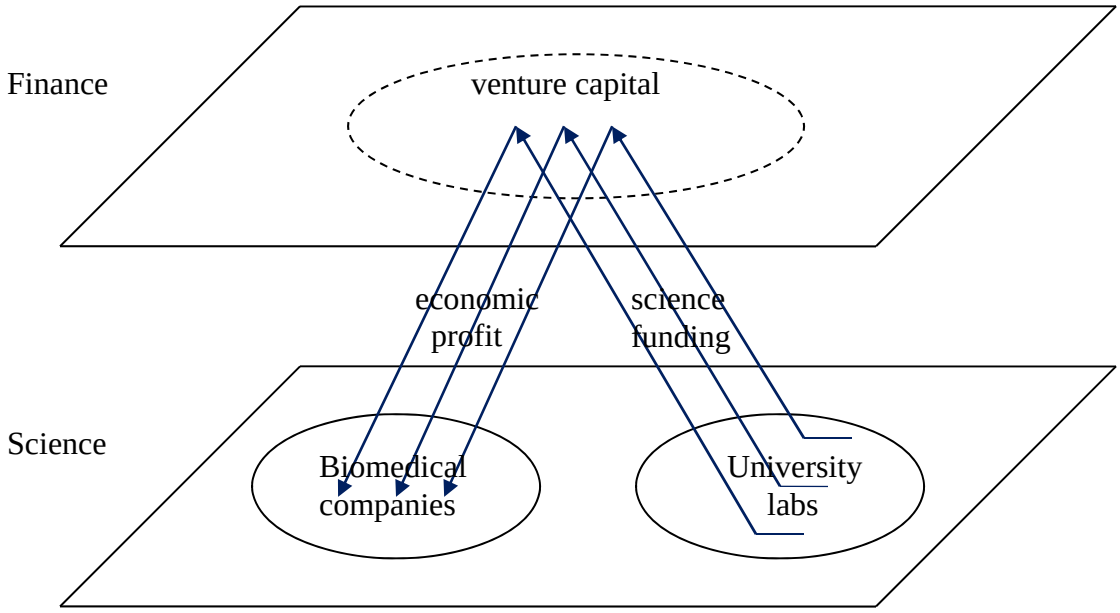
Figure 1.2b. Partnership systems in Renaissance Florence: Catalysis



Note: Venn-diagram representations perceive figure 1's domains vertically from the top down, looking through the planes superimposed. In this and other b figures, solid ovals refer to production autocatalysis, and dotted ovals refer to cellular autocatalysis.

Figure 1.3a. Dedicated Biotechnology Firms (DBF): Genesis

Transposition:



Refunctionality:

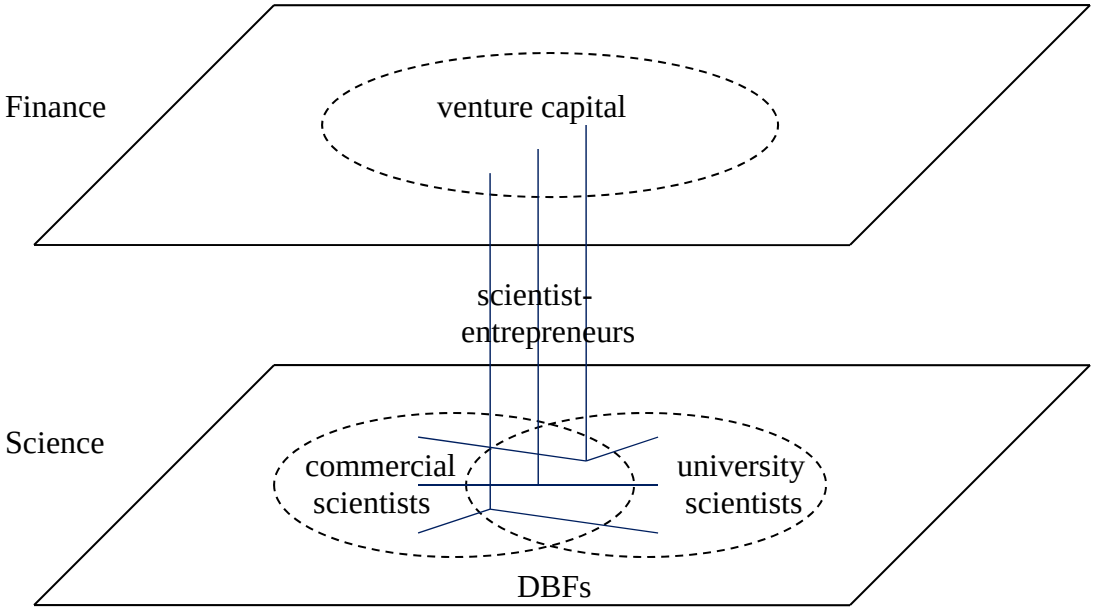


Figure 1.3b. Dedicated Biotechnology Firms (DBF): Catalysis

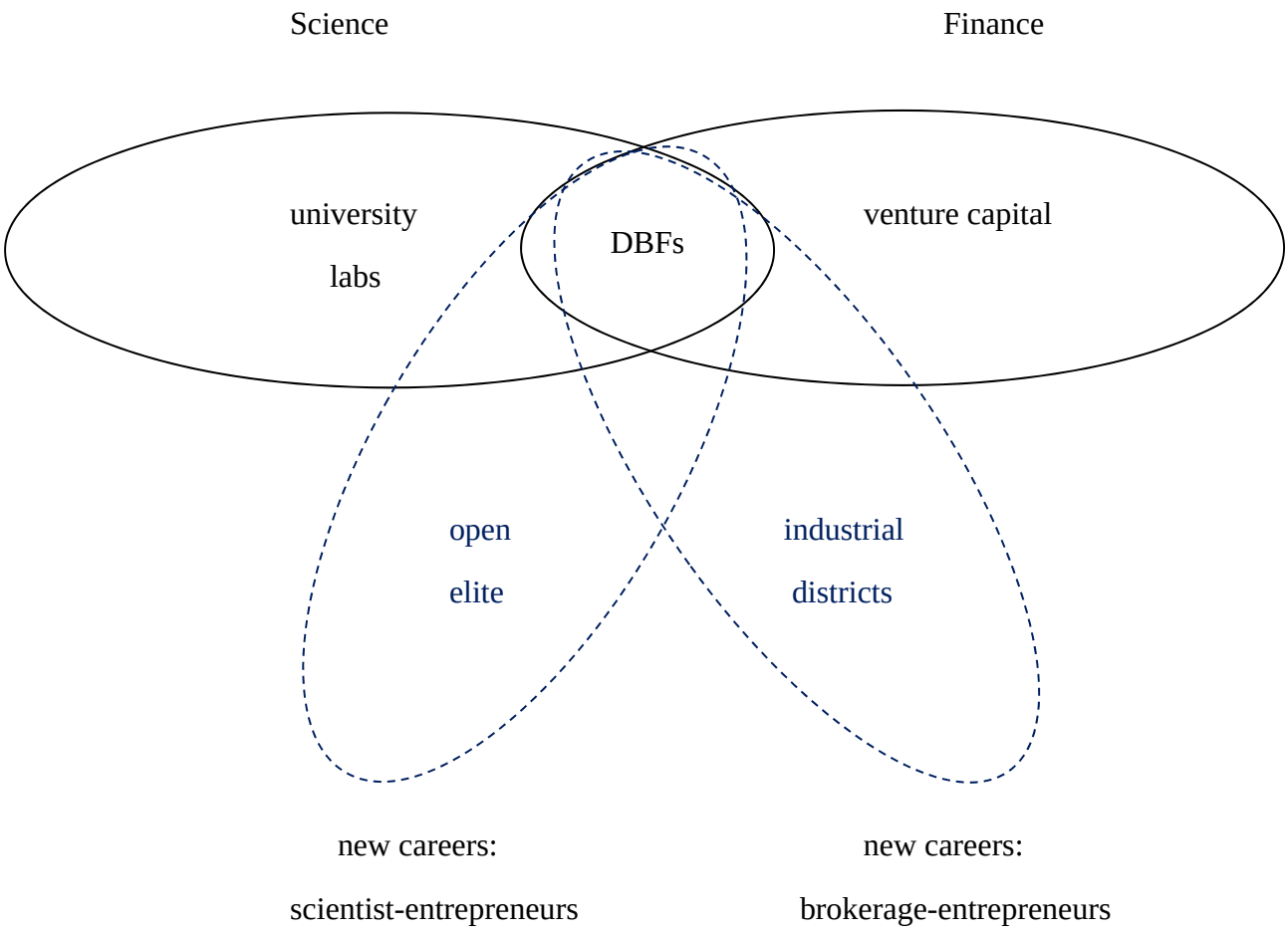


Figure 1.4a. Medieval Corporations in Dugento Tuscany: Genesis

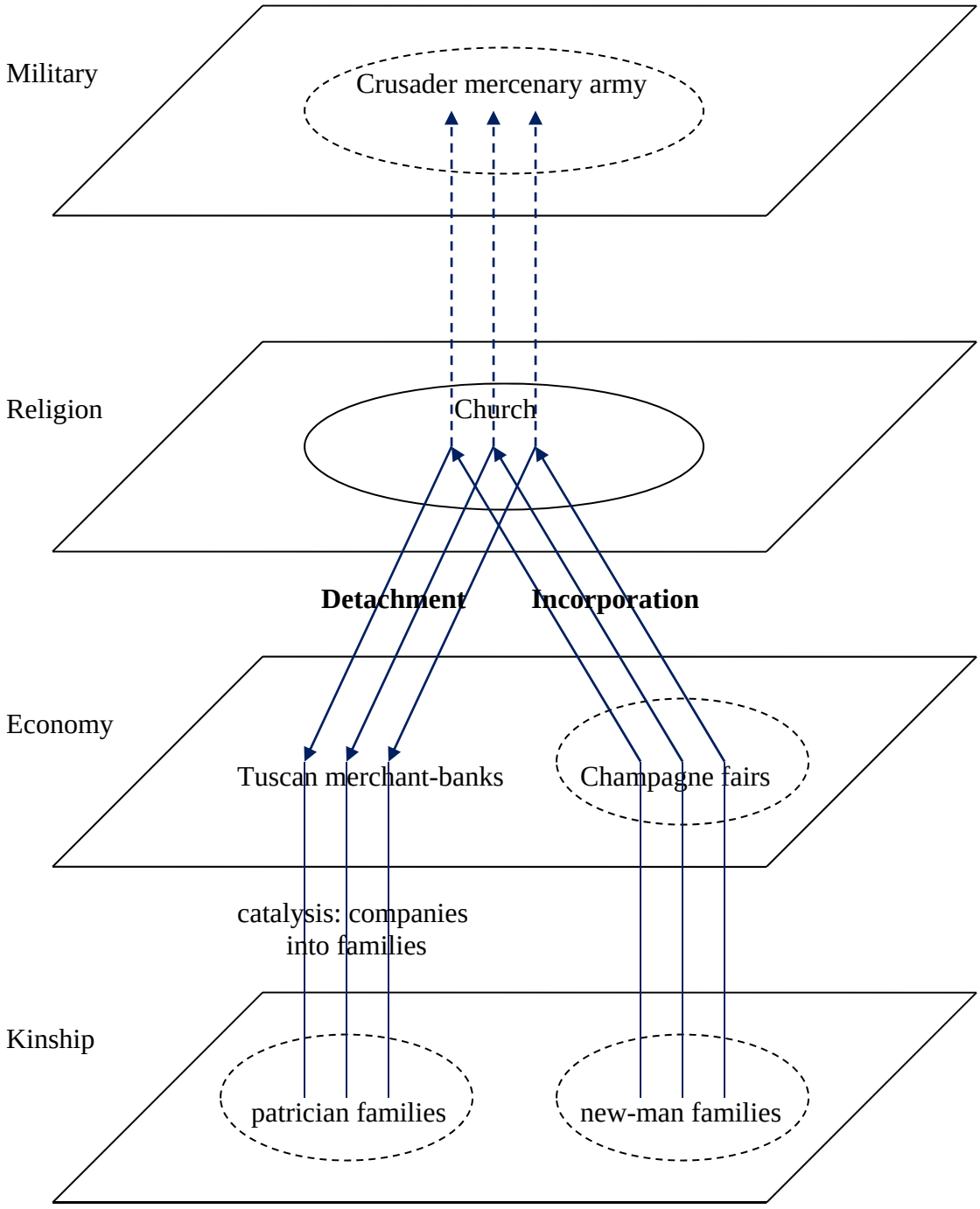


Figure 1.4b. Medieval Corporations in Dugento Tuscany: Catalysis

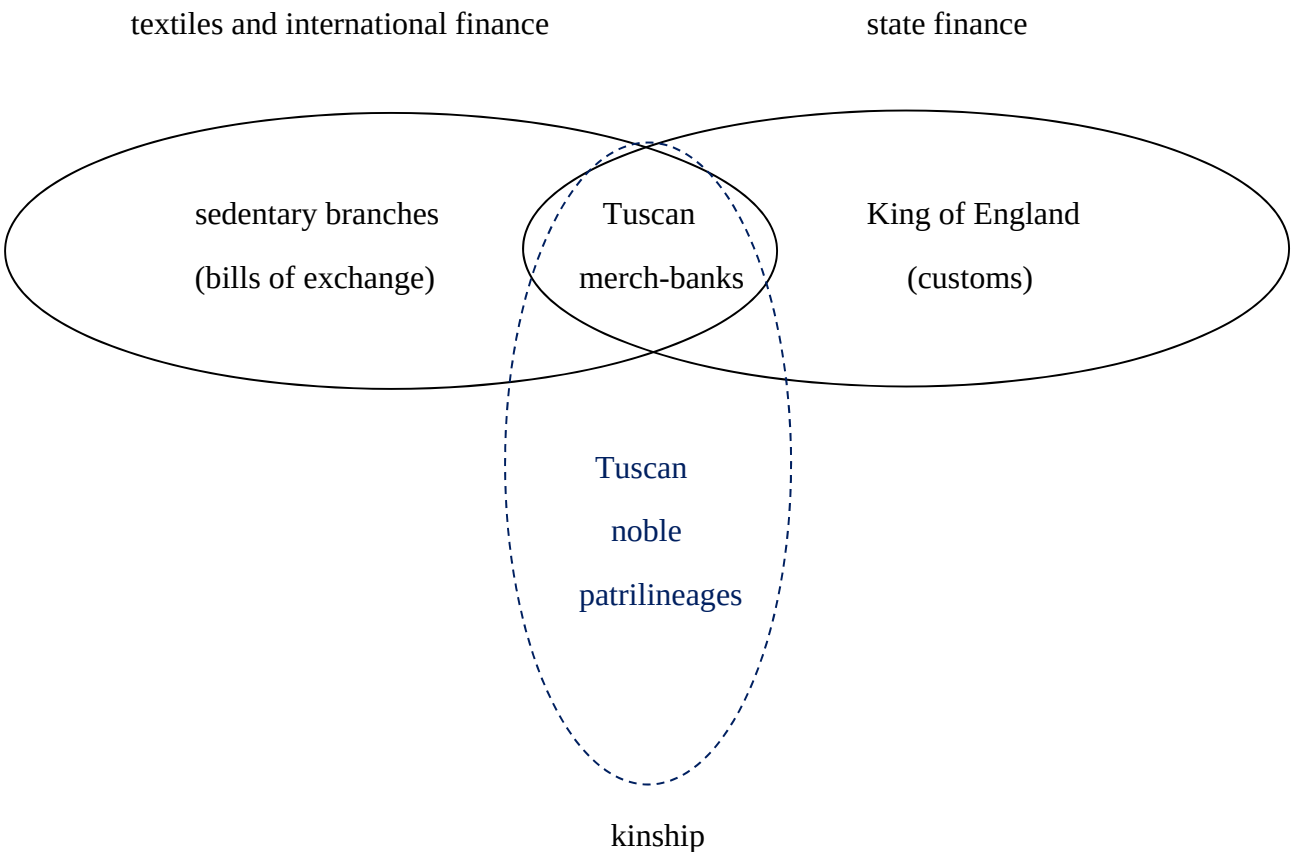


Figure 1.5a. Joint-stock companies in early-modern Netherlands: Genesis

Migration and Homology: THE DUTCH REVOLT

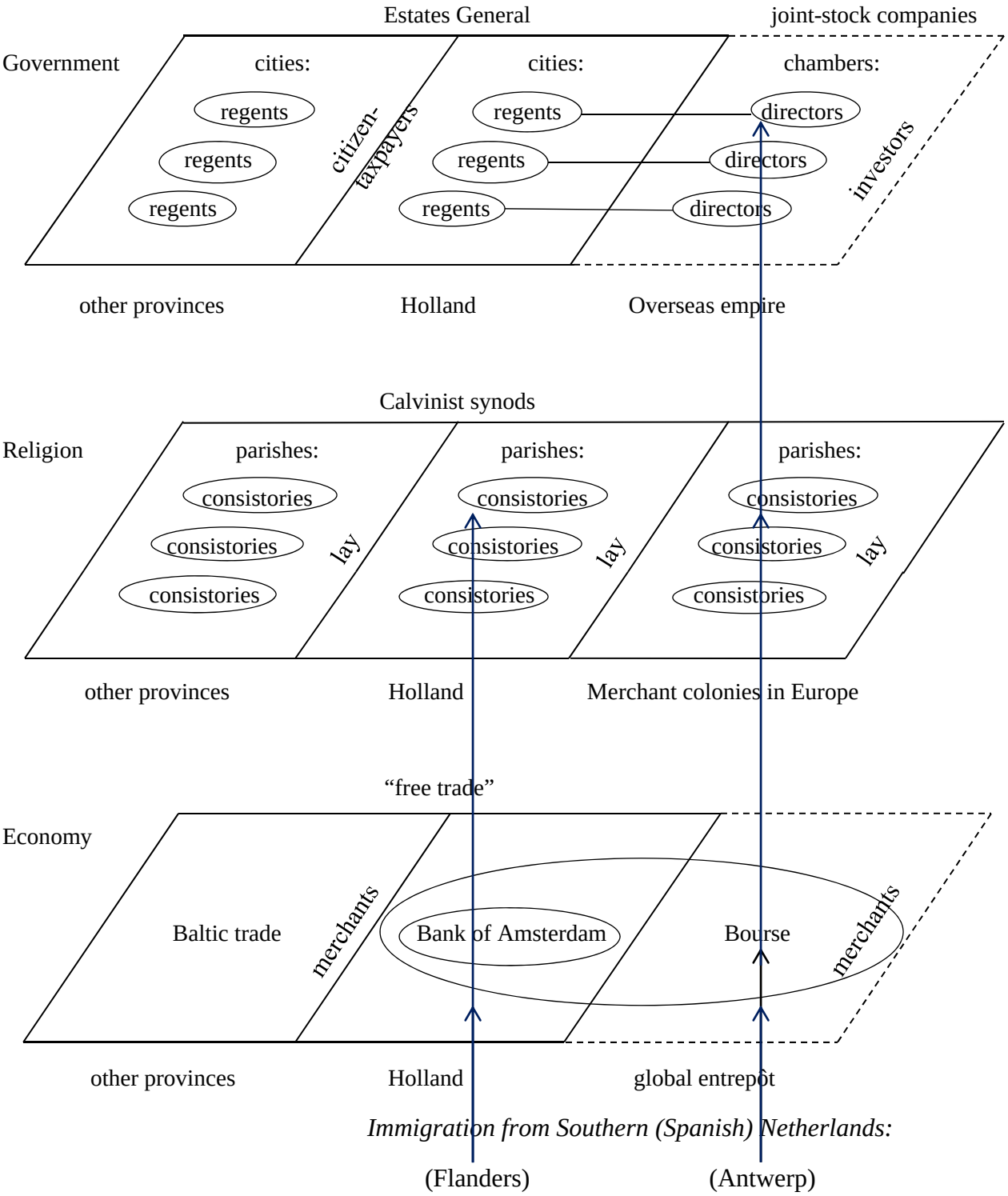


Figure 1.5b. Joint-stock companies in early-modern Netherlands: Catalysis

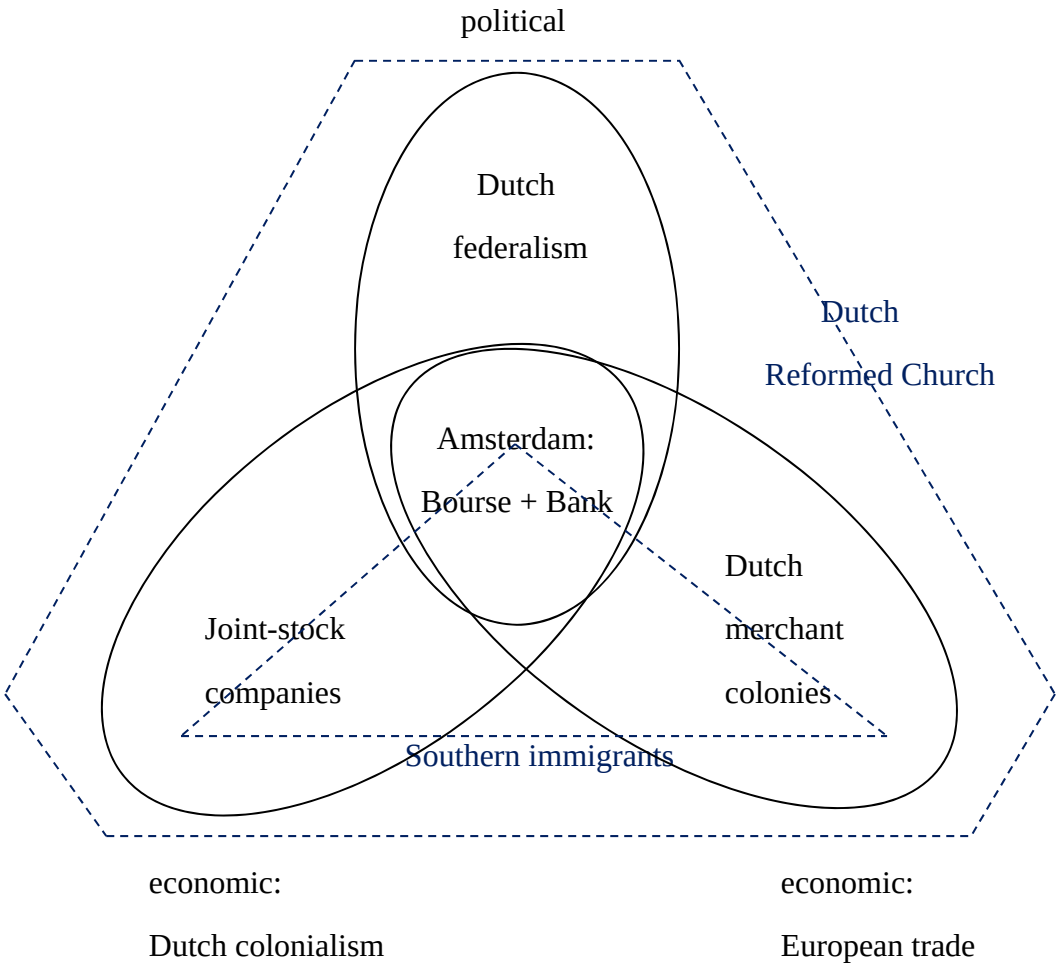


Figure 1.6a. Nineteenth-century Germany: Genesis through Conflict Displacement

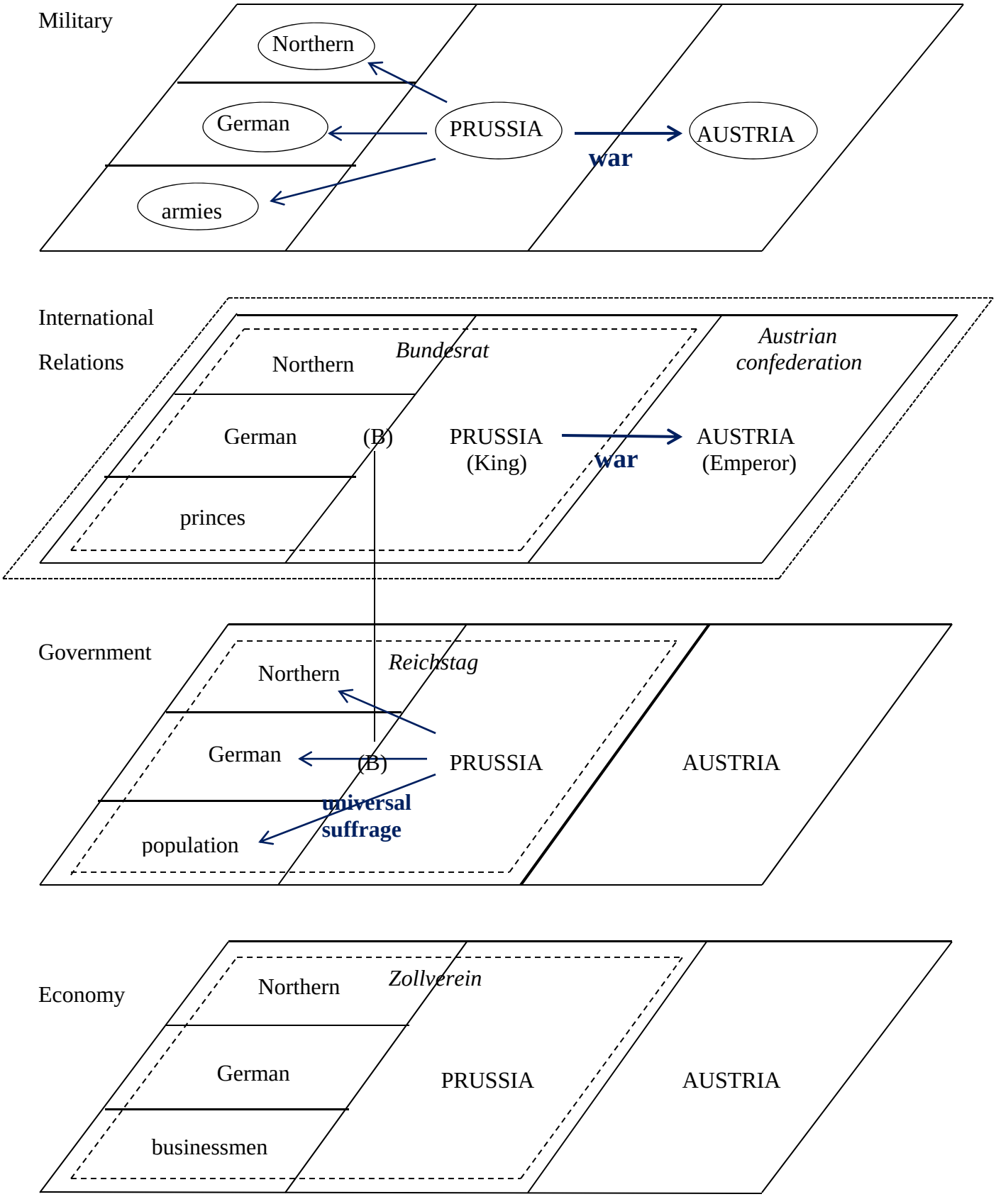


Figure 1.6b. Nineteenth-century Germany: Catalysis

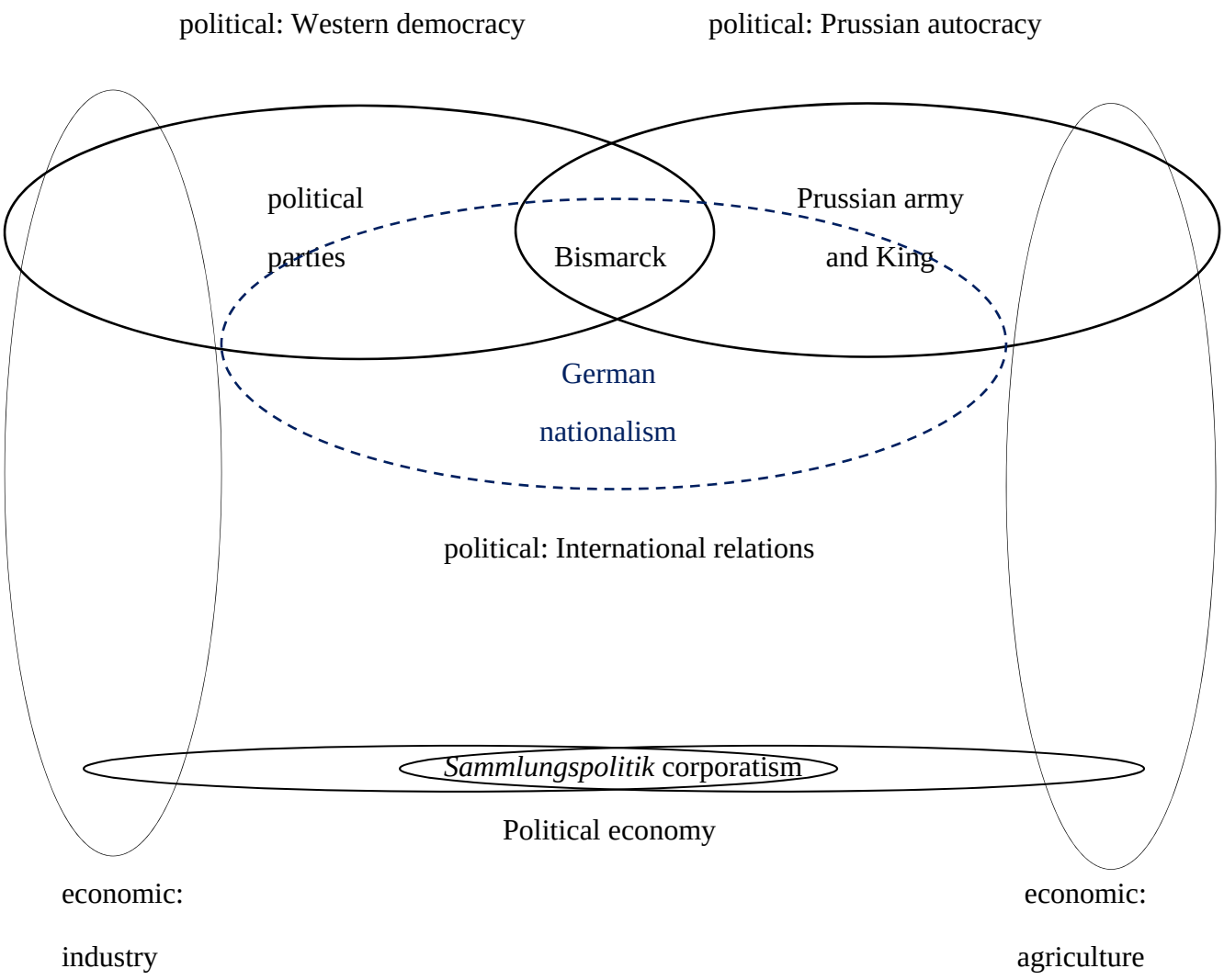


Figure 1.7a. Soviet Central Command Economy: Genesis

Purge and Mass Mobilization: THE GREAT TERROR of 1937-38

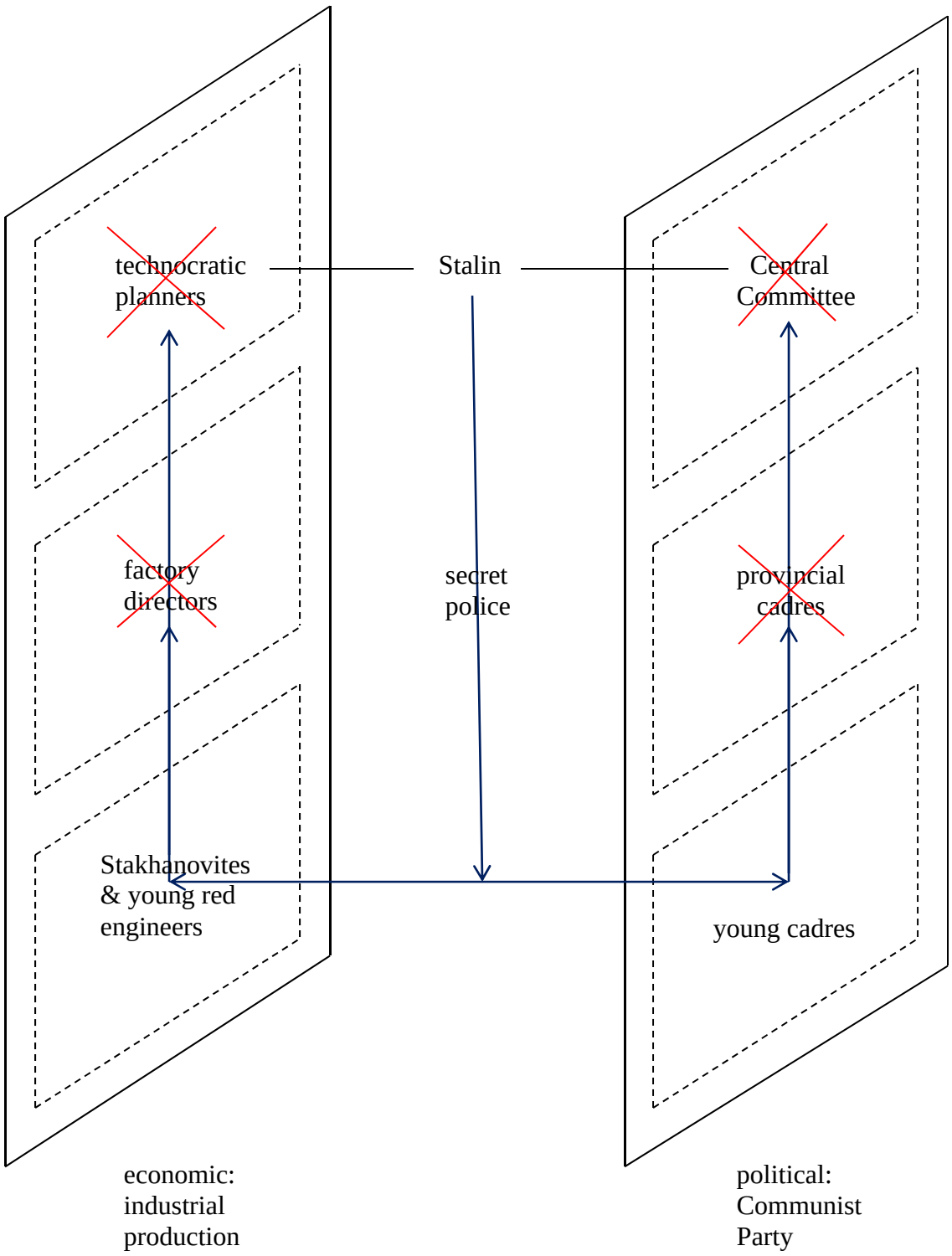


Figure 1.7b. Soviet Central Command Economy: Catalysis

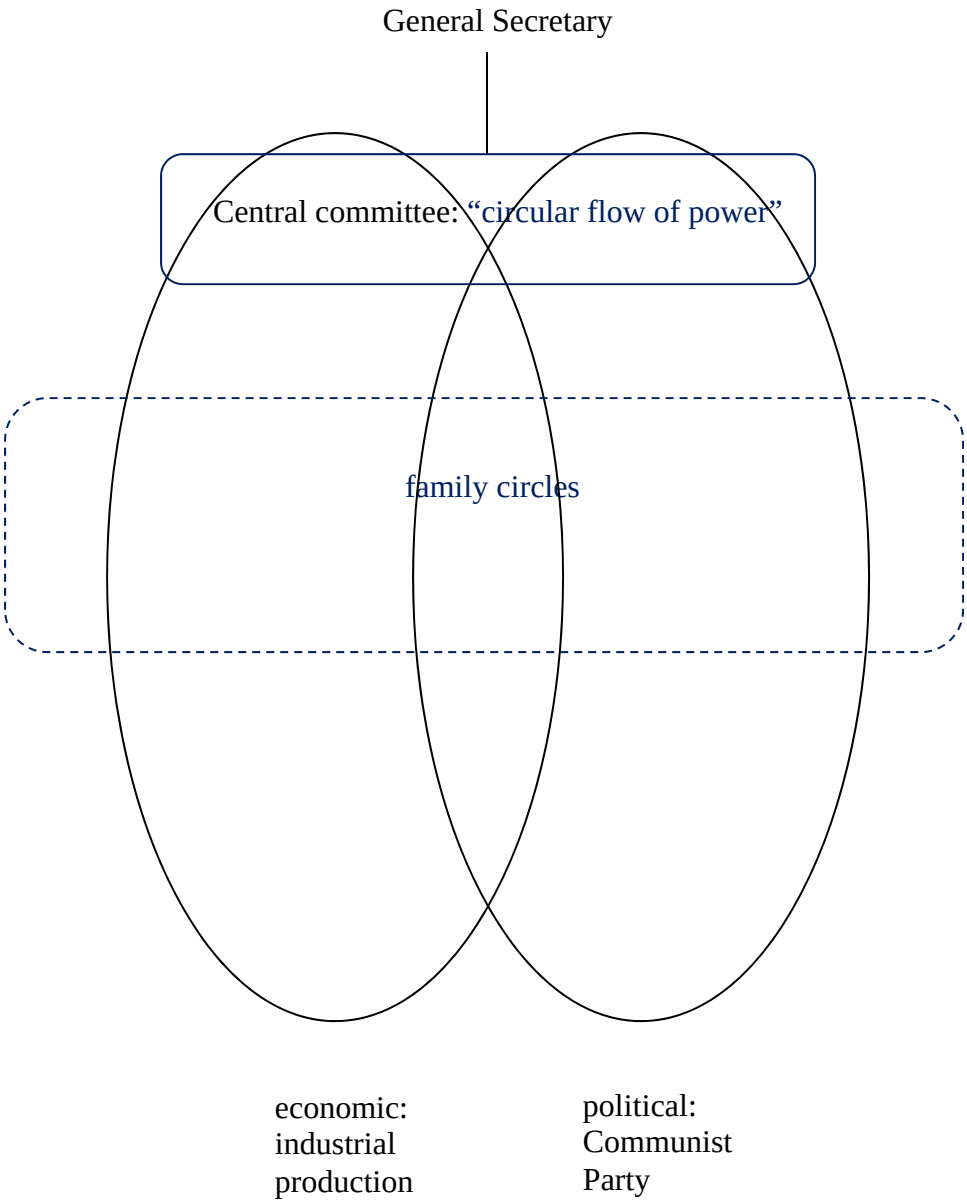


Figure 1.8a. Chinese Market Economy: Genesis

Robust Action and Multivocality: MARKET LIBERALIZATION: 1978-93

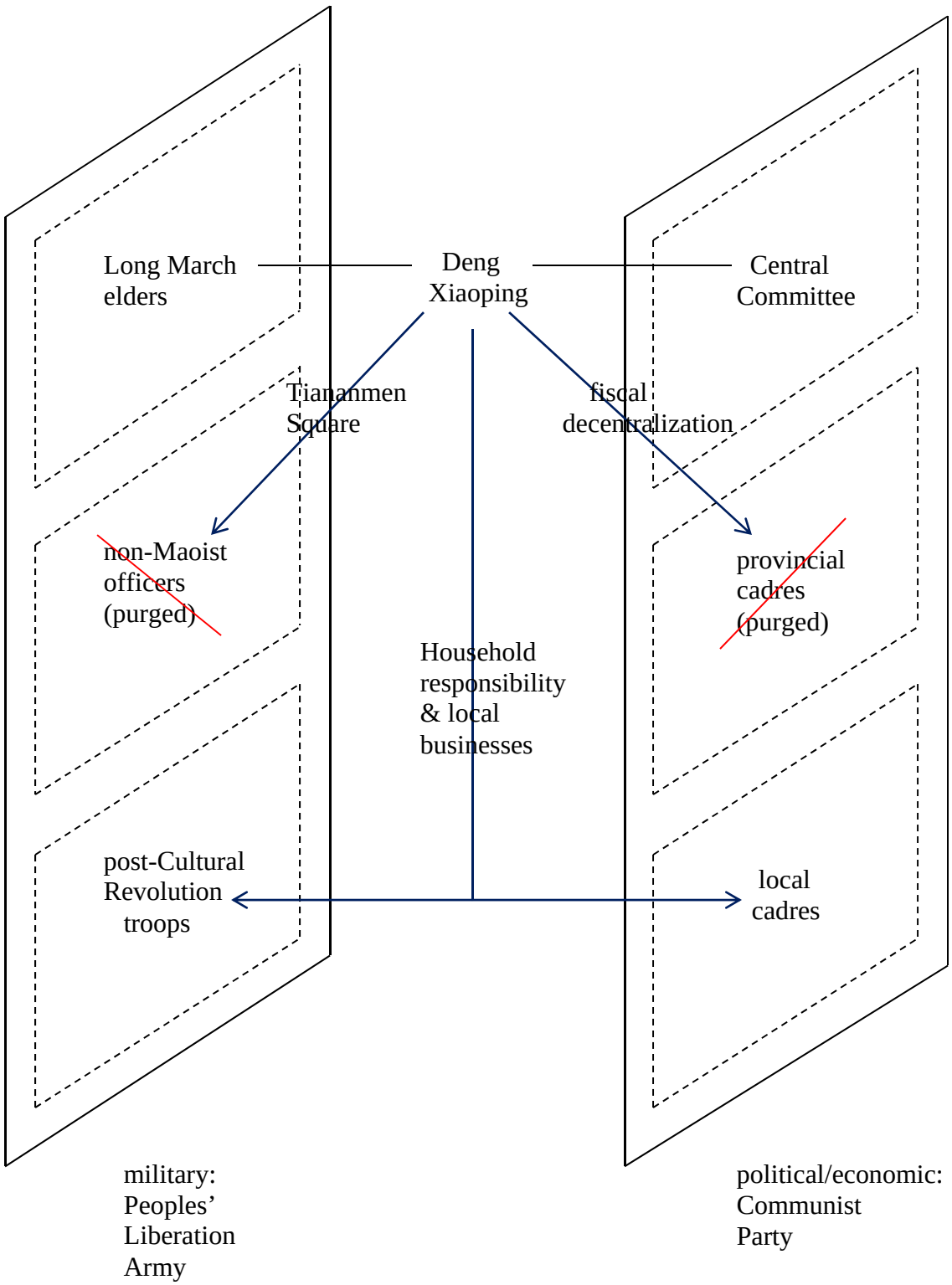


Figure 1.8b. Mao's Communist Economy and Party: Catalysis