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What Is Biotechnology?: Biotechnology Development And The Dynamic Process Of Constructing Industrial Boundaries

A Dissertation Presented

by

Monique Centrone

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Abstract of the Dissertation

What Is Biotechnology?:
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This dissertation investigates how the concept of biotechnology was developed and institutionalized between 1955 and 2005. Biotechnology is viewed as a socially constructed phenomenon, a frame through which national and local governing bodies could plan for industrial renewal during a period of economic upheaval.

In the examination of a top-down diffusion process, The Organization for Economic Cooperation and Development (OECD) was shown to have presented biotechnology as an "enabling technology". This new frame provided a solution to the problem of economic decline and meshed perfectly with the political tone and perceived economic and technological needs of the 1970s and 1980s. The frame thus allowed the alignment of global and local actors around a common vision. The OECD inscribed the meaning of the new genetics within the setting of larger global economic problems as well as future directions for the international community. In this way, the OECD built the cognitive foundation of biotechnology industry development. Conference proceedings data reveals a rich body of transnational organizations that engaged the framework. Organizations coupled many meanings to the frame over time. NGO work developed alongside explicit government attempts to plan the path the industry's development. In all, keywords like "biotechnology" are shown to have cultural power, working to garner institutional energies around particular projects. They will have this effect based on how they mesh with existing cognitive frameworks and how they couple to "real life" activity. Findings validate a novel approach to the study of transnational culture.

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Chapter 1: Introduction and Literature review

Biotechnology is a term that usually brings to mind the continuing debates over genetic engineering within the public discourse. The discourse concerns the implications of applying a scientific technique, genetic engineering, to create new products or processes, in a society where such innovation brings up fundamental questions about the nature of life and its industrial uses. While seemingly innocuous and, in some cases, noble ambitions, the will to “build” a better tomato, create pest-resistant crops, to cure diabetes or do a prenatal genetic screening are confusing and often politically divisive topics because they present new situations whose social and ethical foundation have not yet been fully stabilized. Despite this, techniques of genetic engineering --which introduce foreign DNA into a cell’s genome in order to confer new traits— are used in many areas of scientific research, both for the purposes of developing basic science knowledge as well as for industry.

Distinct from this public discussion is another that concerns the industry developing genetic engineering’s abundant field of application. The biotechnology industry has its own stock index with the NASDAQ, its own scientific journal *Nature Biotechnology* (one of many) and news of factors affecting the industry’s performance, such as the completion of the human genome project, the change in the U.S. Food and Drug Administration rules, the larger economic climate, always finds a place among important economic news. While a failed genetic treatment or a new drug might be cause for concern or elation, respectively, among the relevant public, the business community sees these events as yet more factors that could drive or stifle further investment, in the ongoing need to create economic value.

One stabilized quality of biotechnology, one that is no longer questioned or noteworthy is that genetic engineering is a broadly applicable resource capable of invigorating a broad number of industrial sectors –food, medicine, agriculture, energy, environment, paper and pulp, forestry and a many others. Biotechnology covers so many areas of research and development at this juncture that it is impossible to have a concrete discussion about the industry without specifying the sector or the application. This broad range of application hardly seems worth discussion today. The applicability is, it would seem, clearly an aspect of the "hardware", an inherent part of the technology itself. This assumption underlies the considerable national attention that biotechnology has received, where nations hope to derive economic growth from the industry. The fact of biotechnology as such, as an "enabling-technology", is a perfect "black-box", where one only needs to focus on the its inputs and outputs, rather than its internal complexity (Latour, 1999).

However, it was not always the case that nations cared about biotechnology. In the course of the research presented below, I open this black box to examine the "ideas" aspect of this process, the symbolic dimensions by which nations adopted this industry as a resource for growth. Cultural factors within technical process are often neglected because they require "insider" knowledge, both technical and professional insight. Yet they are fascinating as they reveal micro level social processes and their entanglement with technical objects.

Previous studies of the industry miss the cultural elements in the creation of biotechnology as an enabling-technology. A process of social construction is first evident in the variety of social arenas in which the industry was being discussed, and how differently it was discussed from one arena to another; second, these studies miss the power elements that were employed in a top-down program to develop an industry that was promised to affect the economic growth of nations in the long-term. These elements are neglected within the current approaches that have been used to investigate the industry's development within both social and economic theory.

Among the approaches to biotechnology that have been advanced, economic geography examines how different factors influence the development of industries within a local setting, a process referred to as regionalization. Various business studies (Cooke 2001; Cooke 2003; Gertler 2003; Gittelman and Kogut 2003; Malerba and Orsenigo 2002; Prevezer 1997; Prevezer 2001) investigate industrial development, often with an eye toward setting the optimal conditions for it, as in the case of Michael Porter, a business management scholar at Harvard and guru of the biotechnology industry (Porter 1980; Porter 1983; Porter 1985; Porter 1986; Porter 1990; Porter 1998). In this vein, the industry research is dominated by prescriptive examinations that are, more than research investigations, part of the project of biotechnology development, recipes for applying the right combination of policies to create regional clusters of industrial activity (Storper 2002). Studies of biotechnology with a more critical eye have examined discourse within particular local settings (O'Mahony 1999; Thackray 1999) and with organizational development and industrial structure in the context of technological change (Powell 1992; 1996). Scholars of science and technology studies (STS) have provided some important analyses of scientific controversies that resulted from the introduction of genetic modification including the consumption and sale of genetically modified foods, the effect of state access to genetic information or the role of the public sphere in developing a bioethics framework (Bauer and Gaskell 2003). Other studies include government regulation, risks and public understanding from a cultural perspective (Krimsky 1991), the legal aspects of genetic ownership (Kevles 1998) and the industry-university dynamic that grew during the early phase of the industry (Kenney 1994). Many of these studies illuminate relevant dimensions of the growth of "high-technology", organizational dynamics, important actors in regionalization, as well as the relevant questions the public should ask concerning biotechnology. It is a fruitful research site for any number of explorations. However, none of this research, or any case studies on biotechnology has engaged the problem of the scale of and the planned nature of biotechnology development.

This dissertation addresses culture by questioning how biotechnology spread internationally. The empirical analysis illustrates a transnational cultural process -- the creation of a new transnational policy agenda-- and how this developed within the world-system of organizations. Within the Organization of Economic Cooperation and Development (OECD), the research shows how a new mission for nations to develop their economic growth was outlined and vigorously promoted. A new long-wave of economic development would be possible through biotechnology. During this process, nations came to embrace and constitute the opportunity of biotechnology with tools given by the OECD. This research also supports an analysis of the development of a frame —-biotechnology as an enabling or general-purpose technology-- that was molded by various professional organizations within the transnational community. In this context, the range of organizations using the term "biotechnology" –scientific societies, industry, universities, scientific journals, intergovernmental organizations and research foundations-- coupled biotechnology to a vast variety of research areas, taking their cue from the new framework that biotechnology was about anything that could conceivably be applied from the field of academic biology.

The framing of biotechnology, developed in the late 70s and the early 80s, portrayed it as a broadly applicable industrial resource that had the potential to fuel a new wave of transnational economic growth, whereas previously it was seen as a single industry resource, initially fermentation technology and later, agriculture. The empirical and analytic work in the following chapters captures the most recent construction of the concept of biotechnology at the level of an international governmental organization, the OECD, and then it illustrates using quantitative analysis how new meanings were added on to the frame over the course of twenty-five years by the rich variety of transnational organizations that were using the term *biotechnology*. Viewing biotechnology as a keyword, a cultural signifier, in the tradition of Goffman (Goffman 1974), Williams (1976) and others allows a cultural analysis which can illustrate how keywords work within the context of discursive or cognitive frames. The longitudinal analysis of biotechnology as a keyword demonstrates an arc of use of the term and having mobilized a number of meanings over time, it begins to fall out of use.

While there may be implications for other areas as well, I concentrate on results that pertain to cultural theory and institutionalization as applied to transnational processes. These areas have developed the cognitive dimensions of social change that allow investigation into the mechanisms of power that are structurally deeper, analytically less visible than the standard mechanisms that are examined in, for instance, political science, which has traditionally focused on grand strategy and military power. I will argue however that even these theories require further elaboration of the international cultural context or processes that they employ, a goal of this research.

Overall, this research is of practical importance as it explains the role of an intergovernmental organization (IGO) in transnational governance (Djelic and Sahlins-Andersson 2006). Understanding the mechanisms by which IGOs function to manage development, especially without legally binding capacity, is crucial to understanding the current context of social change.

The intellectual foundation for this argument is to be found in the body of theory that addresses the transnational context and cultural process. To that end, a relatively new thread of research in political science evolves the approach to transnational processes, picking up on the revolution of social constructivism in social theory, bringing in new actors and mechanisms that challenge the state-centered view of the transnational sphere. This move helps to account for the scale of the biotechnology project and the particular transmission of ideas that happen between states and IGOs within the context of top-down processes. World society theory (sociological institutionalism in a transnational setting), with a focus on the NGO sector is the relevant context for thinking about how NGOs, one of the important actors in the biotechnology diffusion process, worked with the biotechnology frame. The substantive content of the biotechnology frame, biotech as an enabling technology, is derived from an economic theory from evolutionary economics that is described as techno-economic paradigms. A more convincing and elaborate approach to long-waves of economic growth is most succinctly addressed by Giovanni Arrighi (Arrighi 1994). A world-systems theorist that provides a more comprehensive view of economic change, he contextualizes technology as merely a single factor of many that lead to successive stages in the world-economic system. His work, while not focused on culture directly, provides the important foundation for understanding the conjuncture of events that made the view of biotechnology as a fuel for economic growth so compelling. Moreover, his work allows a critique of the enabling-technology frame used for biotechnology as technologically deterministic and technically flawed, from a cultural perspective.

All of these theories gravitate around the cultural production of frames, first theorized by Goffman (Goffman 1974) and elaborated by Snow and Benford (1986; 1988; 1992) and a great number of others thereafter particularly within media studies (Schudson 1989). While it is an oft-employed concept, seemingly to the degree of being colloquial, it remains theoretically useful as a way to address a process of social construction and the agency implied by the concept. Building on Snow and Benford's research that was applied to social movements participant mobilization, frame analysis is a way to order the exploration of meaning in the study of culture. It is a useful ameliorative to the limits of world polity theory in their dominant method of cultural analysis.

Together, these theories are examined to synthesize a macro-cultural conception of culture in the context of top-down processes, in this study the OECD project to develop a global biotechnology market. The constructivist movement in IR theory, contemporary cultural theory, World systems and World-society/polity theory are discussed toward this end to arrive at a more complete understanding of the diffusion of biotechnology industry discourse, the subject of this dissertation.

The remainder of the dissertation is organized as follows: presented first Is a review of the relevant literature. Subsequently, an empirical chapter that examines the role of the OECD and creation of a new biotechnology frame is presented. Thereafter, another empirical chapter explains how transnational organizations, not limited to NGOs and IGOs worked with this new discursive frame from 1975 to 2005. Finally, I present research conclusions and a synthesis in the last chapter.

International Relations Theory and the Introduction of Constructivism

Traditional International Relations (IR) theory was transformed by the introduction of a constructivist perspective. When rationalist perspectives failed to explain such world events as the collapse of the Soviet Union, scholars began to explore the utility of this perspective through the lens of sociological institutionalism[1].

[1] The definitions of Institutionalism are so varied depending upon the academic discipline that it is beyond the scope of this discussion to describe See DiMaggio, Paul J. and Walter W. Powell. 1991 for the new-institutionalist perspective. See John Campbell (2004) for an extended compilation of institutional theory in a transnational setting. The term as it is used here considers the reciprocal constitution of actors and structure to explain the nature of social life, in the tradition of Pierre Bourdieu. By “sociological institutionalism” I refer to the use of the “new institutionalist perspective”,

The discussion here follows a constructivist perspective and examines the impact of this approach as it expanded the view of the way states "learn". In sum, constructivism provided new mechanisms to explain how states come to understand what are their interests. National interests are seen as created rather than given, suggesting the role of actors beyond the nation-state, such as non-governmental organizations (NGOs) and intergovernmental organizations (IGOs). NGOs and IGOs work, along with nation-states and other actors within the world-system, to inform nations on policy developments. Such policy initiatives may or may not become part of state structure depending upon a number of factors, including but not limited to the timing of the process within the larger historical context, objective material conditions and the fit between newer ideas and the existing cognitive framework that orients action. These are factors that are important for institutionalization more generally. In this research, I focus on structural, cognitive and timing factors to argue that biotechnology was constituted in the course of a rich mix of organizations that built the industry in the process of conceptualizing it.

Until the late 80s, rationalists, also known as realists[2] or neo-realists (Ruggie 1998) dominated International Relations (IR) theory asserting that state behavior resulted from efforts to maximize power in the international arena. While the idea that states are the central pillars of governance within and across national boundaries is still shaping IR literature (Martin in Djelic and Sahlin-Andersson 2008:

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where institutions are defined as rules, norms or conventions that *influence* action (the extent to which institutions determine action varies depending upon the specific formulation and the user).

[2] The difference between the two designations may result from the origin of the critique: a sociological critique of "rationalists" who use rational-choice theory; a critique of the "realists" from schools that have embraced more fully the constructivist perspective.

8), constructivism has taken IR theorists into cultural territory to question many of the foundational assumptions of rationalist theory[3]. What is at stake in this turn is the role of the symbolic realm, the nature of power and the thick environment in which states are embedded that informs policy creation Without reviewing what is a very widely reviewed discussion at this juncture (Chandler 2004; Djelic and Sahlin-Andersson 2008; Ruggie 1998), the goal will be to touch upon its major points as a departure for a more detailed engagement with world polity theory.

There are several related theoretical issues that constructivists have identified as problematic in IR theory. First, is the positioning of nation-states in the transnational arena[4]. Rationalists take nation-states as central actors within the international setting. While this view is not unfounded in that states are the largest organizations internationally and the most powerful in a military sense, it is limited by the fact that there is a rich field of international organizations, with whom states regularly interact, that remains unexamined. There is no "ethos" of the transnational setting to which states refer to legitimate, validate or learn. As a result, the array of influence that could be studied within this environment is lost.

Relatedly, state behavior is seen by rationalists as a result of endogenous demands and conditions. Cross-border uniformity of state institutions is not

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[3] Peter Haas (1992) views as exemplars of Neo-realist thought Robert Gilpin, *War and Change in World Politics*, Stephen D. Krasner, *Structural Conflict* and Kenneth N. Waltz 1979), *Theory of International Politics*. Boli and Thomas (1999) see Morgenthau Morgenthau, H. J. 1960. *The purpose of American politics*: Knopf. and Aron Aron, R. *Main currents in sociological thought*: Transaction Publishers. as classic IR realists. Meyer sees Keohane (1983).

[4] Djelic and Sahlin-Andersson Djelic, Marie-Laure and Kerstin Sahlin-Andersson. 2006. *Transnational Governance: Institutional Dynamics of Regulation*. Cambridge: Cambridge University Press. following Hannerz Hannerz, U. 1996. *Transnational connections: culture, people, places*: Routledge. prefer the term "transnational" over "global" as the latter has become too laden and at the same time, too vague. The scale it covers is almost grandiose, while the former is containable in that it refers to national and supra-national level phenomena without purporting to cover everything. It can also incorporate actors other than nations Katzenstein, P. J., R. O. Keohane, and S. D. Krasner. 1998. "International organization and the study of world politics." *International Organization* 52:645-685.

considered part of a larger, connected transnational process. Rather, state action occurs as a series of separate and isolated incidents where dissimilar states respond in similar ways to similar conditions. That differences in history and national level institutional styles differentiate state behavior (Dobbin 1994), renders cross-national uniformity all the more striking. Transnational isomorphism occurs across government structures because of environmental pressure --ecological, technological or market pressures-- and transformations go in the same direction, generating partial convergence over time" (Djelic 2008). Ruggie submits that "the only institutions that neo-realists deem worthy of consideration are traditional alliances; otherwise, institutions such as the major economic institutions (Gilpin 1975; Krasner 1978) are viewed as mere emanations of state power or as window dressing (Mearsheimer 1995)" (Ruggie 1998: 7).

Regarding a conception of power, traditional IR theorists view states as rational actors that seek to maximize their power and influence (Chandler 2004: 26). Power tends to be viewed as an end in itself rather than as a means to other objectives, a subject to which I will later return. Power is a fixed interest included with a strict set of state concerns is assumed, normally some combination of power, security and wealth (Finnemore 1996). As a result, the international system emerges as a somewhat static collection of states that interact only to maximize power, their main interest, in terms of traditional security, the defense of one's territory.

The most elemental assumption of traditional IR theory is that the balance of power attained in the interplay of states is achieved in order to prevent anarchy. This is clearly teleological in that it attributes as a cause, the unintended consequence of the balance of power. Moreover, as it portrays state action as a continuous power play, this view ignores the important bureaucratic dimension of state interaction which includes ongoing relationships and networks that contribute to cooperation. An application of the foundation of markets from micro-economics, the state system is thus a by-product of individualistic state actions to fulfill their own internally defined interests, (Finnemore 1996; Ruggie 1998).

Constructivism opened theoretical possibilities from what were the formerly normative, positivist, functionalist approaches to the transnational setting. Theorists in this approach tend to de-centralize the state. While states remain primary players, they interact with a variety of other actors that seek to affect policy change. Introducing symbolic elements into the model of transnational learning processes is the first step in the analysis of the complexity of state action. In doing so, we can begin to call into question the assumption of uniform interests of states. Theorists of the constructivist school (Ashley 1984, 1986; Kratochwil 1986, 1989, Wendt 1992, Finnemore 1996, Onuf 1997; Haas 1992 Katzenstein 1996, Ruggie 2004, Sikkink 1991) explore how symbolism, identity, norms, that is culture, plays a role in institutional processes concerning state-making[5]. Wendt argues (1999) that it became apparent that the inter-subjective conception of states was important in explaining national behavior as the Soviet Union collapsed. According to this line, when the Soviet Union could no longer be perceived as a threat, the U.S. changed its policy and the Cold War was over. Thus, a shift in identities played a crucial role.

[5] State-making is considered a process that continues beyond a state's founding as it adds and takes over forms of governance like sovereignty and discipline from other institutions. More than a finite process, state-making is considered an evolution. See the essay "Governmentality", Foucault's explanation of the development of nation-states Burchell, G., C. Gordon, and P. Miller. 1991. *The Foucault effect: Studies in governmentality*: Harvester Wheatsheaf..

Before the Soviet collapse however, security interests, such as the threat of nuclear war, were essentially obvious and non-controversial (Finnemore 1994). The Cold War was an overarching framework that provided polcy direction for both nations and likely others. Despite the overall framework that the Cold War provided for strategic interaction in security, many policy interests and strategies were not provided within the frame, for instance environmental policy.

Whereas rationalists take national interests as endogenously formed and given, constructivists have addressed interests critically, attempting to locate their origins. And the formation of interests remains taken for granted in realist/rationalist perspectives. Underlying the use of fixed interests is the assumption of the basic similarity of all states. In this myth, the historical tendency has been to focus on Western nations to the detriment of less developed nations and how they fit into the system or alternatively --going back to Gerschenkron's (1962) Economic Backwardness in Historical Perspective-- to see LDCs as proto Western nations that would develop along the same path or leap-frog to the present through the introduction of western technology.

Alternatively, constructivists emphasize the embeddedness of nations within a context that informs preferences and that this dynamic has constitutive and empowering effects. The transnational setting is empowering in that generates elements –reports, reviews, statistics-- that orient action by constructing an understanding of the situation, a frame. The results of scientific research provide the state with policies and protocols that induce state action and can ultimately alter state structure. On a cognitive level, constitution occurs through the enactment of frames and scripts (Jepperson 1991). In this way, the state is not a given entity but it is made and remade over time in a dynamic process that involves a variety of actors, both internal and external, that inform the nature of state preferences. Ultimately, in the analysis of state interests, the division of international and domestic spheres is unhelpful (Chandler 2004; Djelic 2001: 25)

Constructivists consider the formation of national preferences a process of learning and socialization. This process can occur through an expert community as described by Peter Haas. In an alternative version of regime theory, Haas' concept of "epistemic communities" (1992) deftly captures the interaction of states and organizations in the international community and shows that states also seek to reduce uncertainty by accessing expert knowledge. Epistemic communities are "networks of knowledge-based experts…that articulate cause and effect relationships of complex problems, helping states identify their interests, framing the issue for collective debate, proposing specific policies and identifying salient points for negotiation" (Haas 1992: 2). Essentially, knowledge networks develop around specific projects, plans or topics that become a resource for international policy coordination. Individual actors straddle the national and transnational by participating in the bureaucratic and knowledge producing activities of both, either through membership or employment in international organizations. Through this participation, actors come to embody "…common cognitive and value schemes often associated with complex socialization processes and generally translated in "expertise", shared interests and projects" (Djelic and Sahlin-Andersson 2006: 11).

Epistemic communities are an important mechanism for the transmission of preferences to states. An epistemic community may "…in fact add to rather than detract from the speed of diffusion and the global pervasiveness of standardized models and blueprints. (Finnemore and Sikkink 1998 in Djelic and Sahlins-Andersson 2006). Haas is quick to point out however that "…the extent to which state behavior reflects the preference of these networks remains strongly conditioned by the distribution of power internationally…bounded by the international and national structural realities" (Haas 1992:7) [6]. Thus, while Haas provides a mechanism for the diffusion of ideas, he maintains emphasis on economic or material structural elements.

The communication of preferences can also happen through intergovernmental organizations (IGOs), whose members are nation-states, or through international non-governmental organizations (INGOs). The transmission of ideas in this context requires both a mechanism as well as the authority to inform nations on policy. Ruggie (1994) views authority as a subjective understanding of actors, an internalization of the authority of another actor, which marks compliance. He emphasizes lateral relationships of actors in the course of international organization and therefore views authority not as a relation between superordinate and subordinate but as "transordinate" because of the collective nature of the international sphere. International regimes, for Ruggie similar to epistemic

[6] At the same time, Haas seems to want to move away from the overly deterministic power arrangements of core and periphery that are ascribed to the within world-system. Similar to other IO's in world polity theory, epistemic communities function somewhat independently of the states that comprise them. I would argue however that power structures exist prior to epistemic communities and thus even at the individual level, such knowledge networks cannot escape those structural realities.

communities, thus represent a loose structure of actors that recognize authority and act in concert with it. In this context, IGOs gain the legitimacy to speak on certain matters within their chosen domain of expertise.

Ruggie may go too far in his view of transordinate relations. What he calls "compliance" can also be thought of as hegemony, from Arrighi, the "power that accrues to a dominant group by virtue of its capacity to place the issues around which conflict rages on a universal plane" (1994: 28). A Gramscian conception of power (1971) applied to relations between states, it is similar to a general formulation of symbolic power from Bourdieu (1991). It is the power to convince others to act in accord with another's, or against one's own interest, a form of domination.

In realist/rationalist perspectives, international organizations are reduced to the members that comprise them in that the organization is subject to the control of the most powerful ones. The view that IGOs perform in this manner is one of the more obvious, though not completely misguided notions that stems from IR theory, as I will discuss in the OECD chapter. However, the mechanism of control over the IO is much more subtle than the way IR theory might predict. It occurs through hierarchies of influence within the standard procedures of the organization itself and through funding of the organization (Marcussen et al. 1999; Marcussen 2004b).

While IR theory may view international organizations as ultimately servants of state interests in how they provide rules of the game, supply information, monitor behavior or create transparency (Finnemore 1996:13), this is still toward the aim of preventing anarchy. Further, it suggests none of the life of an IGO and the selfinterested nature that accrues over time in the struggle to maintain its relevance in the increasingly crowded transnational sphere of IOs and NGOs (Meyer and Boli 1998). Finally, it neglects how an IGO may inscribe power arrangements within routine procedures in bureaucratic organizations.

In sum, constructivism in IR theory brings the discussion of the composition and transnational environment forward considerably to the extent that its approach overlaps in a number of ways with world polity theory. While the goal of this area of research is still to explain the transformation of the state, the transnational field now includes a new set of actors, a redefined concept of interests and their origin and, a new concept of (soft) power. It is thus to world polity theory that I now turn.

World Polity/Society

One of the strongest assertions of culture as integral to transnational constitution and institutional processes has been put forward by John Meyer and colleagues (Meyer 1987; Watson 1992; Bull and Watson 1984; Meyer et al 1997). World-polity theory emphasizes the increasing globality (Albrow) of culture (Robertson 1992; Thranhardt 1992; Featherstone 1990; Lechner 1989; Hannerz 1987).[7] World society theorists hold that the transnational setting has a distinct culture which "defines the nature and purposes of social actors and action" (Boli and Thomas). This would suggest a structurally dominant model, however the authors assert a "tool-box" conception of culture (Swidler 1986) where actors draw upon and

[7] I borrow Albrow's term here as a mere descriptive. World-polity theorists would disagree with his assertion that the de-centralization of the state is accompanied by a de-rationalizing process; in fact they see a deepening of rationalization, following Weber.

select from shared cultural models and principles. Together, these two pieces suggest a more mutually constitutive model of actor and structure (Bauman 1973 Sewell 1992, Swidler 1986).

World society theory focuses methodologically on non-governmental organizations (NGOs), though it asserts the dominance of intergovernmental organizations (IGOs) and transnational corporations (TNCs) (Boli and Thomas 1999: 19). INGOs are documented to be part of an interconnected world society for at least the last one hundred years. As with constructivist IR theory, these organizations function as a cultural context for the transnational community, supplying the purposes and meanings of action, models for global organizing, forms of discourse and communication and avenues for influencing states and other actors (Boli and Thomas 1999: 34). In essence, NGOs shape frames of understanding, ways of talking and thinking about the world. Models have consisted in appropriate educational structures, democratic processes, and human rights.

The main target of INGO activity, among the variety of actors within the international community, is the nation-state. In this context, the state remains an important actor yet it moves within a dense medium of organizations that contribute to behavior, both internally and externally. States are subject to redefinition and change when frames that guide action change (Boli and Thomas 1999:13). INGOs enact (Jepperson 1991), codify, modify and propagate world-cultural structures and principles. These principles, or properties are universalism, individual rights, rational voluntarism (the basis of conformity to the reasoned argument), a rationalized view of progress and world citizenship. The state emerges from their analysis as “a less dominant and self-directed actor…" (Boli and Thomas 1997: 7). Overall, state-making is considered an exogenous process where the flow of information is top down rather than bottom-up.

World polity theory is an important theoretical advance in the challenge of explaining institutional and policy similarity rather than variation, but there are a number of limitations. Two of these limitations have been pointed out previously (Campell 2002; Lamont 2000), but I argue here that that these two problems, a discussion of power and the issue of competing frames result from a third issue, which is the data source.

The data for the analyses of NGOs, the heart of world culture according to world polity theorists, comes from the International Yearbook of International Organizations. These data, compiled by the Yearbook by the Union of International Associations and supported by the Economic and Social Council of the United Nations offers variables such as the founding year, aims and type of membership of both international non-governmental organizations as well as intergovernmental organizations. In the absence of any other supporting analysis, it is difficult to make assertions about the world polity when only the non-profit sector is covered (Boli and Thomas say they remove IGOs and transnational corporations from the data). This is unfortunate, because transnational corporations and intergovernmental organizations are both available from the International Yearbook.

While asserting the importance of multinationals, research tends not to fall on the actual role played by them and their affect on the state. They are excluded from the analysis because the authors attempt to isolate the role of NGOs separately from other structures, in particular state structures, in the world-system. This could be justifiable if, as I will discuss below using Kane (1991) and Mohr (1998), they were extracted for analytic purposes to examine an effect, and then results interpreted within the full context of the social field. However, this is not the case. This move is akin to removing all but one value of an independent variable, when the data are readily available, and drawing conclusions based on a single value. The evidence, as it is used, is an important resource as it substantiates polity structuration for a very important actor in the world-system, the NGO. If it were possible to expand the set of organizations around a particular phenomenon, it would add valuable information to discussions of transnational culture. At this juncture in the development of world polity theory, it is possible to document a new sector and how it varies over time and this fact alone is seen as a cultural context. In that setting, documenting a growing set of NGOs around a new phenomenon stands in as a cultural analysis. I suggest that what they are viewing in the structure of NGOs is actually a culture-structure (Kane 1991, Mohr 1998).[8]

Culture can also be examined more closely in the “aims” part of the data offered by the International Yearbook and these are shown to be of import in understanding changing sectors, for instance the institutionalization of health as a social concern (Inoue and Drori 2006). This cultural analysis suffers from the same problem of the data not capturing the full range of organizations centered on the new theme in the world polity and needing to set the change within cultural context for the larger events that gave rise to it. Again, given that NGOs have been shown to

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[8] As I refer to it later, a culture structure may be thought of as an embedded social space where enactment of beliefs occurs.

comprise the majority of organizations in the mix of world society, the approach is not wholly unjustified. But, this can be improved upon, since we are forced to ask if sheer number of NGOs alone is enough to call it culture and if, for those types of organizations other than NGOs that may not have such a populist presence in the world community, have perhaps another means to influence nations that remains untheorized.

As previously mentioned, these data limit results in two other ways. The first: since the selection criteria for inclusion in the analysis is set by the founding year of the first organization that lists the new phenomenon as an aim, a cultural analysis is limited to the moment after competing frameworks that originally led to the growth of the sector are stabilized. That is, the data will bypass the frame selection process (Lamont 2004). There is no possibility of examining what led to the founding of the first organizations within the scheme of the data more broadly.

The data bypassing the selection of frames is related to the final criticism that, in accounting for the development of a new transnational phenomenon with these data, an analysis of power is neglected. Again, this may be an issue of how the data do not allow for the analysis of competing frames (Campbell 2002; Lamont 2004) or it may be that it misses an analysis of influential members in the transnational sphere aside from states because it doesn't look at the interaction of NGOs with other organizations besides states and sometimes IGOs. Admittedly, an analysis of power is primarily not the goal of the world society scholars, who have strongly contrasted themselves from a tradition of state dominated analysis where power implies intentionality and coercion (Drori 2003 Finnemore 2003). In the move away from traditional analyses of inter-state relations, and therefore the power of nations, the cultural power within the context of civil society hardly seems worth explaining. But cultural or symbolic power (Bourdieu 1991) that permits an actor or an authorized representative of a global region (the OECD region, European Commission for instance) to impose a certain vision, or particular frame, of some aspect of the social world is clearly a natural extension of this work. A cultural analysis without a discussion of power is difficult to think of as cultural.

Instead, the concept of authority supplants one of power in this school. Boli and Thomas don't explicitly refer to soft power, a concept employed more frequently in theories of transnational governance, but it seems to be a similar concept (Sikkink 2002) to their authority[9]. "Rational voluntarism" is the basis of *authority* of the INGO. They indicate that "in the absence of rational legal authority to make or enforce law, INGOs "employ limited resources to make rules, set standards and propagate principles…" (Boli and Thomas 1998: 14). Boli and Thomas characterize three forms of authority. Autonomous authority is when NGOs have a direct effect on institutional outcomes, without the assistance of the state. Collateral authority implies a working partner in the polity to affect an institutional outcome while Penetrative authority entails the presence of the state, a direct lobbying effort on the state to affect

[9] The concept of "soft power" emerges with the constructivist turn, coupled with the need to explain the role of a fast growing INGO sector. Soft power refers to mechanisms whereby international actors exert influence without coercive or physical resources such as a military, oil or minerals that would play a role in leveraging action. Such power may be thought of as a type of influence although this suggests the specific and intentional character of power. A related concept, "soft law" is another approach to integrating the effect of IOs into an international setting. Soft law refers to international rules that are not legally binding Mörth, Ulrika. 2004. *Soft Law in Governance and Regulation: An Intedisciplinary Analysis*. Northampton, MA: Edward Elgar Publishing, Inc. Among a few possible definitions of soft law, Mörth refers to soft law as "rules of conduct which, in principle, have no legally binding force but which nevertheless may have practical effects. This review agrees with those that would completely avoid the term 'law' for this form of power Morth p.7).

outcomes, pushing new views into areas where they did not originate independently, as was the case for instance with INGOs in the spread of environmental policy discussion, resulting in states taking more seriously environmental policies (Frank et al in Boli and Thomas 1999).

However, legitimate authority is an institutionalized form of power, recognized as authority by those who are regulated by it (Hall and Biersteker 2002; Shelton 2000b; Goldstein et al 2000; Herititer 2003 in Mörth 2004). While this concept is more specified than Ruggie's constructivist concept of compliance based authority, it is more or less substantively identical in how it misses the symbolic power aspects of consent and compliance as analyzed above. Taking this even further, symbolic claims to leadership (Arrighi 1994) or representation (Bourdieu 1991) are always more or less fraudulent in Arrighi's terms. The authority of science is the legitimate voice that is lent to agents in the construction of representations as they are used by INGOs. The "authority that underlies the performative efficacy of a discourse is…that which allows a perception to be imposed, or…which allows the consensus concerning the meaning of the social world which grounds common sense to be imposed officially" (1991:106). This is not to say that, as a result, the consenting are necessarily in a worse position, but that this is a face of power that requires theorizing as such.

In sum, an enriched field of actors emerges from a re-examination of transnational dynamics and this variety bears upon how we explain action and implementation. Even the terms used to describe transnational phenomena are indicative of the evolution of theory on the transnational sphere. Realists normally refer to the international sphere of states as a “system”, as opposed to “community” or “polity” of the constructivists or new-institionalists --a much more social concept. Community and polity alone suggest a more interactive relationship in which states participate. While the term “community” may seem to suggest a harmony that doesn’t hold in reality, it implies all the necessary interaction --exchange, competition and cooperation-- that does exist without reducing transnational action to impersonal factors of a static system. However, the analysis here indicates that there is room for understanding different forms of power, soft power or symbolic power, within the context of constructivist international relations or world polity theory.

Global economic and technological contexts: World systems theory versus evolutionary economics

World society critiques world systems theory as reducing structure to only economic or military processes dominated by major world powers or to simply value orientations. However, world systems theory as defined by Giovanni Arrighi (1994) provides a most compelling account of world structure by pointing to one of the overarching drivers of change: capitalist development. While world society theory explains constitutional processes as a result of NGO activity, this heavy emphasis ignores those processes as they pertain to capitalist structure.

Economic theory lies at research core of the biotechnology project that was advanced by the OECD. As the basis of a project to create economic growth, these economic theories requires some attention both because a sociological critique shows them to be flawed and because it is necessary to fully illustrate the leap from theorizing technology in economic change to the political creation of a system around a new technology with the hope of achieving that effect. While that doesn't seem to have been the goal of Nelson and Winter (1982), the most recent rendition of evolutionary economics, it is more uncertain in the case of Chris Freeman, a British institutional economist whose work almost exclusively describes technology's driving role in economic change (1977; 1987; 1991). His first paper regarding long-waves of economic growth was written for the OECD in 1977 and he has worked with them on many other reports including another biotechnology report in 1989. Carlota Perez, another institutional economist seems to be a relentless promoter of her research, consulting with dozens of firms, regional, national and transnational organizations, including the OECD.[10]

This section will outline these theories and the central concepts that caught the attention of economic policy planners. It will first provide an overview of the most sound and complete political-economic account of the period in which biotechnology promotion began, offer a summary of the essential concepts and describe the technological determinism of this model. This will bring the argument to a more pointed discussion of cultural theory.

Arrighi (1994), Blythe (2002) and many others have outlined the economic turbulence of the 1970's that serves as the backdrop to the new view of biotechnology whose emergence coincided with the first OECD promotion of biotechnology. The basis of these views is not extractable from this history of capitalism. Historical capitalism, in his approach, has been marked by cycles of

[10] See carlotaperez.org for the astonishing breadth of material.

material (trade and production) and financial expansion (pure capital accumulation) guided by a political hegemon that leads the global economy. Such expansion ultimately precipitates a crisis of over-accumulation, a period of chaos during which global competition dramatically increases in search of new ways to profit. During the downturn, there is created --reinvented or innovated-- a new way of producing or organizing capital that has the ability to galvanize the world economy again under the appropriate political guidance. The time between hegemonies is a period of economic chaos, a search period for economic actors in need of solutions. With a new hegemon, the cycle of continuous change along a new path on enlarged foundations begins again. Our current economic predicament could also be seen in this way with the decline of the American hegemony[11].

Arrighi's work is, to be sure, deeply connected to Marxist explanations of capitalism, but his conception of innovation, the cyclical nature of capitalism and the evolution of the system all can be traced back to the work of Joseph Schumpeter (1912, 1950) whose work was revived by Winter (Winter 1971; Winter 1964) starting in the 60s and 70s. Nelson notes (1990), along with Storper and Walker (1989:66) that all contemporary general accounts of the capitalist engine are based upon Joseph Schumpeter's work. Cyclical dynamics, what he called business cycles, entail expansions and contractions of the economic system every 50 years, based on the Kondratiev cycle[12]. Schumpeter also introduced the idea of the necessity of imperfect competition in the capitalist system described below in greater detail.

[11] Blythe is in general agreement on the contours of the 70s crisis, but he characterizes the 1970s in terms of a reformulation of Polanyi's "double movement" (Polanyi, 1944)
[12] There were other competing cyclical explanations but the Russian economist Kondratiev was deemed the most accurate by Schumpeter.

Taken together, innovation of both technologies and organization, the evolutionary nature of capitalism as well as its cyclical nature, and imperfect competition, are part of his overall concept of “creative destruction”. Creative destruction describes the continuous process of renewal of productive capacity and the concomitant destruction of old capacities (and firms) as the basso continuo of capitalism.

Technological opportunity, a central tenet of imperfect, or Schumpeterian competition, is competition in which firms are unequal in the resources they have to maximize profit[13]. This is considered an economically volatile condition yet important to the dynamism of an industry because it gives firms incentive to innovate. For evolutionary economists, this is thought of as “dynamic equilibrium”, contrasted to “static equilibrium” or the conditions under which firms have similar resources to the extent that there is no incentive to innovate. Technologies, as they serve the productivity of firms, have a fixed set of productive possibilities that they offer firms over the course of their “lifespan”. Firms work within the set of opportunities given by the current technology, similar perhaps to a Kuhnian paradigm (1964), innovating until which point opportunities are exhausted: technological opportunity is then seen as “constant”. New technologies can raise technological opportunity by creating new production possibilities.

Yet Arrighi’s theory doesn’t place technology at the center of his model. He uses Marx’s general formula of capital (MCM’) and this underlies his cycles. These cycles consist of a phase of material expansion followed a phase of financial expansion that leads the entire capitalist system on a radical period of restructuring and reorganization. Each cycle leaves the system on a new and enlarged

[13] As an aside, this concept actually justified the presence of monopolistic structures.

foundation. He says “growth and innovations in particular industries or in particular national economies…has no immediate relevance” (Arrighi 1994: 9).

Neo-Schumpeterian theorists of the Kondratiev long cycle (1927) posit that technological change is at the heart of cyclical dynamics, following Solow (Solow 1956; Solow 1957) Nelson and Winter (Nelson and Winter) and others. Perez (1985) (Freeman and Perez 2004) and Freeman (Freeman and Louçã 2001; Freeman 1994, 2001) see the economic system as changing through successive techno-economic paradigms consisting of a technological system with a complementary social-institutional system that nurtures it. The model is one of technological diffusion based on low and declining cost, unlimited supply, potential for pervasive influence and a generally recognized capacity to reduce the costs and change the quality of capital equipment (Perez 1985: 444). Each technological paradigm is marked by its key factor, such as steel or electronics, as well as an organizational scheme that exploits it such as the assembly line or flexible production. This combination diffuses through key sectors sweeping away old methods because of superior productivity. Following a period of diffusion and growth, decreasing returns on the innovation lead to a decline which sets in motion a new wave of innovation in search of competitive advantage. This innovation is frustrated, however, because existing institutions cannot accommodate the new key factor. The resulting crisis is resolved only when a new institutional structure is erected that is compatible with the new enabling technology.

In their assertion that social and institutional factors play a role in the productive employment of technical innovations, Perez (1985), Freeman and Louca

(2001) improve upon more simplistic views of technological change. By including history in their model of change and by emphasizing a structure of human use and innovation, they move away from change as an autonomous process. Despite this, without a more serious concept of action that includes contingency, their model is still marred by technological determinism. An explanation of economic change here should refer to the focus that leads to the investment at the beginning of each cycle. This argument wrongly assumes that investors recognize inherent virtues of a particular technology and follow through with the massive infusion of capital necessary to nurture it, unprompted. This approach ignores the process whereby the relevant scientific techniques and literatures undergo a process of translation (Callon 1986; Latour 1989) so that they become available conceptually to the actors required to invest in the opportunity. In highly specialized domains, the evaluative knowledge is available only to the affiliated experts. This reality requires a mechanism that can create the unanimity across diverse actors: scientists, investors and politicians. Translation refers to a process of mediation, of interpretation of objectives, expressed in the 'languages' of the different intermediaries engaged in a project or process of innovation –intermediaries who do not at the outset share the same bodies of knowledge or general opinions. This space, in between the production of scientific research and the interpretation by various audiences is the research site of cultural analysis.

These theories, while at the theoretical margins of their own field of economics,[14] were the foundation of new government perspectives and policies in the revitalization of industry and economy. Thus emerged the "national innovation policy" framework (Nelson 1993) (Lundvall 1999; Lundvall et al. 2002) written about by Winter's colleague Richard Nelson. The use of these theories was an attempt to see in advance the possibility and create new technological opportunity.

Cultural theory

Constructivism was primarily a cultural turn in international relations. In IR theory, the symbolic realm of ideas, discourse and identity was neglected in the struggle to negotiate the moves of the world's large powers, the Soviet Union and the United States. IR theory treated the interaction of nations as an agent-oriented, normative, functionalist "grand strategy" versus the more analytic version that began to incorporate a structural view of the nation-state system beginning with Waltz (1979) and Krasner (1982)[15].

Constructivism however, has in a sense failed to advance the view that culture as such is an important factor in international relations. Norms, rules and ideas *qua* culture and how they constitute actors and macro-structures such as the economic system or the system of nation-states isn't accounted for as culture, even

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[14] Winter in a 1987 essay clearly sees his and Nelson's evolutionary model as taking much more into account than did the dominant paradigm of neoclassical economics. Freeman and Perez, both take history and institutions into account in ways that neo-classical theory does not yet their model is still overdetermined.

[15] This school of international relations is often referred to as regime theory. A regime is defined as "sets of implicit or explicit principles, norms, rules and decision-making procedures around which actors' expectations converge in a given area of international relations (1983: 3) in P & D (1991)

by such forward thinking IR theorists as Martha Finnemore whose most recent instantiation of IR theory takes culture into account in a way that has recruited a good deal of followers in the study of political economy[16]. Although Arrighi's analysis leaves the space for it, the import of culture isn't examined by World-systems theory, the most complete formulation of the interstate system within the context of the *longue durée* of historical capitalism[17].

The use of a specifically cultural perspective is likely neglected on the macro-level in particular by Meyer and colleagues with World Polity theory, because it is an area of sociology that might be defined more precisely as a perspective with its own methodological approach --Interpretive sociology going back to Max Weber-- rather than a substantive topic such as Latin American studies or sociology of education. It is a perspective in the sense that the theorist believes that it counts in the investigation and this structures the type of analysis and selects for the audience who also shares the perspective.

Relatedly, while cultural theorists have studied specifically cultural phenomena and have applied techniques in the analysis of meaning across a number of different social fields, cultural theory seems hampered with debates that are likely seen as arcane and overwrought by observers –structure and agency will likely be picked apart for the next twenty years. At the same time, scholars outside of cultural theory have a hard time working empirically with the analysis of meaning that is at the heart of cultural theory and it is unclear if it could ever be of help. John

[16] As Finnemore is an IR scholar rather than a cultural theorist, this is not to be considered a flaw. Her work should be considered a paradigm example of cultural theory applied to transnational behavior.
[17] I have argued earlier in this review that Arrighi's elaboration of the concept of hegemony is an important cultural analysis in world-systems theory.

Campell, a new institutionalist has devoted much to sorting out different forms of discourse to use them in the analysis of policy trends, yet the conceptual tools he develops do not make the analysis any easier (2004). The work on the analysis of meaning within cultural theory therefore remains somewhat isolated. The methodological terrain has been opened somewhat recently, as I will describe below, but for the most part, it has been difficult to see how to capture cultural phenomena quantitatively[18]. In areas of economics for instance, the remaining variance not explained by quantitative models often becomes the "cultural" part of the analysis introduced *post facto*.[19]

The introduction of cultural principles is not framed as culture, but as "institutionalism", broadly defined. This may have resulted from the association of cultural theory with European/continental theorists, while institutionalism has mainly been an American phenomenon. New institutionalism has elaborated the way in which culture as ideas, logics and identities is assimilated into organizational structure (Powell and DiMaggio 1991). Therefore, the complex of symbolic elements –textual or performative representations- is more easily thought of as "institutions or institutional" rather than cultural. Ultimately, both new institutionalists and theorists of "practice" (Bourdieu 1977; Bourdieu and Wacquant 1982, DeCerteau 1984) concern themselves precisely with the means by which actors create structures during unsettled times or reproduce them in the course of daily life. Cultural theory in this way has many points of entry into the larger body of sociological theory in describing

[18] See Bourdieu's body of work for his continuous emphasis on contextualization of quantitatively measured "objective realities". See Mohr Mohr, John. 1998b. "Measuring Meaning Structures." *Annual Review of Sociology* 24:345-370. for a discussion of quantitative methods to analyze culture.
[19] See the literature on measuring the economic effects of computing in business firms, particularly E. Bryniolfsson from MIT. Unexplained variance is seen as "intangibles" or as "human capital".

how culture and structure work together. This is a positive turn, yet some consolidation could advance the use of cultural theory across disciplines. I do not hope to solve this problem here but to gain entry to cultural theory directly in order to study transnational culture processes quantitatively yet avoid the problems discussed in examining transnational culture through the changing level of NGO participation.

Ultimately then, the use of culture is brought into analyses as institutionalism when the theoretical frameworks used quite clearly resonate with the work of prominent cultural theorists as Lamont, Sewell, Swidler, Bourdieu, Swartz, and Mohr on whose work new-institutionalists rightfully draw. While it is easy to make too broad a generalization here, cognitive frameworks employed in the course of ongoing social action are what is most often meant by “institutions”. The terms however remain extraordinarily fuzzy. Powell and Dimaggio in their introduction to *The New Institutionalism in Organizational Analysis* use the terms *structure* and *institutions* interchangeably (Powell and DiMaggio 1991: 5), while Boli and Thomas in a mission statement on world society theory use the terms *culture* and *institution* interchangeably (Boli and Thomas 1999: 13). John Mohr, the cultural sociologist “emphasizes institutional (cultural)” meanings (Mohr 1998:346); Turning directly to cultural theory to apply new methods from that area to understand transnational processes in ways that go beyond the current conceptions of culture in world polity is thus a goal of this research. Although new-institutionalists have also done good cultural work (Friedland and Alford 1991), an examination of methodological developments in cultural theory will allow us to bypass the need to view culture through institutionalist theory, which is how scholars outside sociology normally access cultural theory.

Quantitative cultural theory and the analysis of meaning

While there has been a move toward the inclusion of culture in all of the theory reviewed here, a thread within cultural theory has developed that seeks to formalize the analysis of culture within sociology.

Structure need not be material and economic. Structures of knowledge and intersubjective understanding shape and motivate actors according to what is right, good or appropriate action (Finnemore 1996: 15). Structures (as opposed to actors) Finnemore uses the term “international structure of meaning”. By this she intends to contrast a structure of power held by states. She indicates that such a perspective is paramount under the conditions where domestic politics and local conditions lack explanatory value and where many dissimilar nations behave in similar ways. This brings up the issue of what would be necessary for culture to be a convincing causal explanation.

There are different criteria for how “causal” scholars expect culture to be in explanations of social evolution or change. For Ruggie (1998), ideas don’t have to be causal- they are simply the “reasons” for action. Boli and Thomas tell us that in the sociological dialectic of agent and structure, the discussion is not about which comes first but how they are reciprocally constituted, obviating the need for causal explanation. Ann Kane (1991) defines “analytic” versus “concrete” autonomy of cultural to explain that culture must be theorized as analytically distinct to give it causal status as an explanatory factor. John Mohr presses for an analytic separation of “cultural elements” in the analysis of meaning and a recontextualization of elements to be fully explanatory, overcoming the dualism of the autonomy of culture versus the embeddedness of meaning in networks (Lamont 2000). This dissertation follows the direction of Kane (1991) and Mohr (Mohr 1998a; Mohr 2000), asserting the possibility of extraction of cultural elements to examine their effects yet interpreting results in context.

A review of cultural theory suggests that it should be easier to see culture as an independent, structuring force by examining the early phase of the institutionalization process, where institutional production or realignment takes place (Swidler 1986). In the early phase of institutional formation, the discourse itself will be in flux, and we can isolate the changes it undergoes in order to examine this effect more closely (Sewell 1985). In contrast, culture seems to exert a different effect during a stable or “reproductive” phase when it is a more embedded aspect of the social system. In the application of this principle within the world society context, one should look to the historical period where there was a convergence of INGOs and IOs and TNCs around a particular discourse to establish the founding of a new transnational phenomenon. Thus, while periodization of research is an obvious issue when asserting the reciprocal constitution of agency and structure, specifying phases of cultural transition can assist in the task of breaking down a broader analysis in time.

To do this, Kane describes a “cultural structure”, what Mohr refers to as a “structure of meaning”. These structures must specify the symbolic elements or the internal logic of the problem, establishing how the symbolic processes work (1991:56). The culture structure may be thought of as an embedded social space where enactment of beliefs occurs. Likewise, Bourdieu (1977) in addition to Kane and Mohr, reminds us however we must complete a cultural analysis by recontextualizing the symbols because language is a representation of authority, manifesting and symbolizing it, but having no meaning on its own without the social position, the authority of the speaker. To this end, I have located a culture-structure, with which to explore biotechnology discourse, the ongoing set of conferences within which the variety of transnational organizations met to explore the new opportunity in biotechnology.

Keywords are words or phrases that are mobilized by various social actors in moments of change. Their meanings may be competing because they are often ambiguous. People search for and create new meanings to structure their lives in times of change and keywords assist in this process by orienting action (Ghaziani and Ventresca 2004). A keyword can be thought of as having symbolic capital (Bourdieu 1977) in that it offers the user status or recognition of one sort or another within its field of use. Recent keyword analyses have examined the terms *revolution* (Sewell 1996) and *business model* (Ghaziani and Ventresca), Blythe (2002) shows specifically how economic ideas undergo change during times of economic upheaval, in his case, *liberalism* during the 1930s and the 1970s.

In this context, keywords will chronicle social change (Ghaziani and Ventresca 2005; Swidler 2001b; Spillman 1997; Wuthnow 1987) because during these periods, there is a cacophony of contested use. Their analytic value lies in how they illustrate the demarcation of boundaries. In this way, they fit Mohr's definition of cultural elements, or cultural items that can be extracted from a social system that allow an examination of meaning.

Keywords seem to work closely with frames. They are a lens through which to understand framing processes and therefore cultural processes. Frames, as defined by Snow and Benford (Snow et al. 1986), are an important theoretical approach to communicate the socially constructed nature of a phenomenon. They also detail the specific properties of what makes a good frame. Snow and Benford (1986, 1988) use Goffman's definition (1974): "Frames denote schemata of interpretation' that enable individuals to locate, perceive, identify and label occurrences within their life space and the world at large. By rendering events or occurrence meaningful, frames function to organize experience and guide action whether individual or collective."

According to Snow and Benford, there are three tasks when constructing a frame: it must be a diagnosis of some event or aspect of (social) life as problematic and in need of alteration, illustrating causal factors; it must provide a proposed solution to the diagnosed problem that specifies what needs to be done and there is usually a direct correspondence between the diagnostic and prognostic framing efforts; finally, a frame must be a call to arms or rationale for engaging in ameliorative or corrective action. As an extension of this, frames often contain guidelines for action.

Snow and Benford are careful to note that the mere existence of a frame does not automatically grant institution-building properties. The more integrated the diagnostic and prognostic and action aspects of the frame are, the higher the probability of frame enactment, or the potential that the frame will induce social action. Moreover, they draw on Gramsci's "political education" to indicate that frames, a form of political education, similar perhaps to the socialization potential of the epistemic communities or the transnational setting more generally as mentioned above, must begin with and be linked to the nature and structure of the belief system that is the object of transformation, in order to be successful. While we must recall that this concept was applied to social movements so that it may have a degree of intentionality that is not present in the creation of cognitive framing processes -- where the connection to belief systems touches the less articulated aspects of consciousness-- it is apt to describe the mobilization of actors around policy efforts (Strang and Soule 1998).

Having said that, a successful frame will, as such, have centrality, relative to the central values of the belief system, in terms of both priority and intensity; it will also have range in terms of the extension toward multiple beliefs within the system. If a framing effort is linked to only one core belief or value that is of limited range.

Knorr-Cetina provides another way to look at frames, or what she refers to as "fictions". These are socially constructed modes of enchanting the world, "…symbolic technologies embedded in or constitutive of the performance of modern institutions" (Knorr-Cetina 1994: 7). The concept of fictions are focused less closely on participant mobilization in the context of a social movement, but are very similar ultimately in the way that they are a call to action for the purposes of inducing institutional development or change.

To help in the analysis of frames and fictions, a number of scholars have devised sets of analytical tools: Schudson (1989), for example, emphasizes the importance of : *retrievability* or how available concepts are for an audience, and also, *rhetorical force* makes objects memorable and/or powerful. Barthel in turn, suggests that cultural phenomena must also be *robust* in the sense that they enable a variety of potential directions for action and that they should be *replete with moral significance* (Barthel 1997).

Together, these tools will allow a synthesis of the analysis of meaning and structure in the exploration of biotechnology discourse and diffusion.

Conclusion

In this review, the range of theory that supports the following research, and to which it will contribute, has been described. International relations theory and constructivist IR theory, economic theories –evolutionary economics and its foundation in Joseph Schumpeter and Arrighi's geo-political account of the history of capitalism, World society and the cultural theory which ties it all together, have been covered. This expansive body of theory is required to explain biotechnology as a political, cultural and technological construction.

Theoretically, I have suggested the concept of power be expanded to include the authority to define problems and their solutions and to influence policy directions.

This is a cultural power and it has the opportunity to mobilize actors and institutionalize practices.

Chapter 2 The role of the OECD in the construction of biotechnology as an enabling technology

> "…Biotechnology has more potential to reshape the world as we know it than any other technology besides nuclear power"
>
> Al Gore (Panem 1985:2).

> "It can be a risky bet. Biotechnology isn't a proven moneymaker; in aggregate the industry posted $5.8 billion in net losses in 2000…"
>
> (Hamilton 2002)

Since the 1980s, there has been an international race to erect a biotechnology industry within, mostly Western and Asian, national borders. Western governments in particular are thoroughly convinced that the sector holds immense promise for the future of their economic growth because they see it as potentially re-invigorating a broad range of techno-economic settings. This conviction underlies the international pursuit of "first mover" advantages through local industrial development. The OECD played an important role in developing and elaborating this view and has done extensive work to contribute to the industry's flowering. The race to develop biotechnology is particular, deriving from the extraordinary level of attention biotechnology has received relative to the uncertainty and the unpredictable nature of the payoff. An early analysis, in 1986, suggested that biotechnology "could become one of the locomotive technologies that will pull the global economy out of its present doldrums" (Kenney 1986: 240). But its performance thus far indicates that biotechnology's contribution to national economic growth does not forcibly support this prediction.

How, then, did the decision makers in so many nations come to believe in the power of this industry? I argue that within the OECD region and likely further than their borders the OECD became a mechanism for the creation of international consensus, around the potential for biotechnology during the 1980’s, the early phase in the growth of the biotechnology industry. They did this by helping to establish and diffuse the frame by which nations came to embrace the opportunity of biotechnology. The OECD’s frame for biotechnology as an “enabling” or a “general-purpose technology” conditioned national development efforts, precipitating a widespread international response, even for those countries that were very unlikely to benefit from investments in the industry.

The “general purpose” or enabling thesis implies that biotechnology is inherently the solution to a system-wide economic need because of its broad applicability, and will therefore initiate a "long cycle" of economic growth (Freeman and Louca 2001; Makasheva 1998; Perez 1985). Alternatively, this analysis reveals how the OECD situated biotechnology as a concept for the international community as a solution to the larger changes that nations perceived as taking place within the economic world system. I conclude that the end of a “long cycle” in the world economic system can not account for the development of the biotechnology industry; this perspective explains little regarding how widespread investments in infrastructure, including basic science, regulation, facilities and the like are initiated on such a scale. Rather than a purely technical or a system-driven process as described in accounts of the techno-economic paradigm, I indicate that the development of biotechnology has been a cultural and political process, facilitated in large part by the OECD.

National Biotechnology Strategies

That biotechnology has enjoyed such extensive political and institutional support across so many national borders is even more striking in light of the diverse ways in which states tend to recognize and support industry within their borders (Dobbin 1997). In Europe, an inventory of public biotechnology programs (1999) was undertaken by the European Commission's Science Research Development Biotechnology Programme. The report itself is an extraordinary illustration of the coordination among western nations, striking in the level of effort to create a new industry. It outlines many of the major initiatives undertaken by seventeen European nations to develop a biotech industry. In all nations described in this report[20], "government bodies, through ministries and departments, play a key role in biotech policy definition and making" (Enzing et al: 11). Despite the diversity of the institutions involved --private business, universities, national research laboratories, etc. --each of the seventeen nations created a variety of organizational tools to encourage the growth of a biotech industry.

For the stimulation and coordination of scientific activity, some nations, notably France, Germany and Ireland, have coordinated national biotechnology

[20] See Appendix for a list of included nations.

programs that function through public research institutes. These programs intend to "…provide incentives for research centres to work on specific areas and to structure networks of collaborations" (Enzing et al 1999: 20). Others nations have created new biotechnology research centers and institutes, although to a large degree "…existing centres have been labeled 'biotech centres' in order to focus them" (Enzing et al 1999: 20). The creation of gene centres "…provide(s) 'biotechnology platforms', i.e. technical devices such as sequencing and computing capabilities, genetic material management to public and private research" (Enzing et al 1999: 21). These centers are important for using the growing data available from whole genomes, including the Human Genome Project[21]. Within the university as well as within the industry infrastructure, this process has the effect of centralizing certain well-established and common procedures followed across laboratories in order to facilitate the speed of scientific production.

As regards funding, the report notes that during 1994 to 1998, thirteen of the seventeen nations allocated funding for biotechnology research and development. Six countries of the group had a single, broad nationally centralized program, while six others had several programs running simultaneously (Enzing et al 1999: 23). Another more recent report indicates that seven of the same nations described in the EU study, Ireland, Germany, Australia, the United Kingdom, Finland, Canada and Belgium each spent more than 5% of their Research and Development budgets on biotechnology funding in 1999, with Belgium spending 13.8% (van Beuzekom 2001: 36). Competing with funding for military research, other high-tech sectors, as well as

[21] A major public-private partnership undertaken to characterize all of the genes in the human genome. This will be the basis for the next fifty or more years of research on basic human biology and disease.

with other scientific disciplines, and other state social services and infrastructure, this figure is particularly high. In absolute terms, Germany, for instance, spent in excess of one billion dollars on biotechnology research and development (van Beuzekom 2001: 36).

In nations that lacked explicit national level coordination of policies, there were initiatives in the EU that took place through myriad national departments and ministries[22]. All nations within the report had policies implemented through Ministries of Education, of Science, of Research through funding of basic research and university infrastructure. Other supportive ministries included that of agriculture, health or the environment as well as the Office of Science and Technology (UK) (p.11). "Funding of industry initiatives, biotech SME's start up and development, R & D joint projects, technology transfer and industry-research networking incorporate a bigger diversity of actors that include the ministries of trade, of industry and of economy."

As this suggests, strategic coordination for the industry has not been restricted to the scientific sphere. By 2002, the scientific journal *Nature Biotechnology* reported that along with the industry association "…European governments have called on the European Commission to ease the regulatory approval regime for biotechnology products and to push for EU-wide implementation of a revised patenting system. These and other suggestions have were considered

[22] While a number of nations do not have a single, centralized coordinating institution set up for the purpose of developing biotech, this should not be viewed as a lack of interest in the industry. Coordination or lack of it doesn't necessarily correspond to the presence of absence of interest in biotech, but rather to the variation in the unique configuration of institutions for each nation, as well as variation in national policy styles. Initiatives taken through multiple national agencies may indicate an even more thorough-going penetration of the commitment to biotechnology than does a singular coordinating mechanism.

for a new policy, the ‘Strategic vision on life sciences and biotechnology,’ drafted by the EC…as a part of the Lisbon process launched at the EU summit at Lisbon in 2000, which aims to make Europe a highly competitive knowledge-based economy within ten years.”

The effort was just as comprehensive outside Europe. In the United States, in addition to many similar policy efforts to those described, there have been broad educational initiatives. These included increased funding for university-based molecular biology training programs, the establishment of biotechnology Masters Programs and also the integration of biotechnology into elementary school science programs[23]. Moreover, federal organizations in the United States, such as the American Association for the Advancement of Science (AAAS) and the National Academy of Sciences (NAS), an independent organization that makes policy recommendations at the federal level, both offer fellowships and post-doctoral positions for scientists to gain experience and understanding of the policy making process and the concerns of the federal government regarding the sciences. Such programs respond to the industry’s need for specialized labor considered crucial by the industry. In locating actors at the border of the political and scientific fields, they create the institutional role for those actors to bridge the two communities and promote the interests of each field. Likewise, the structural location of these actors allows them broader repertoires with which to create innovative solutions to

[23]In the United States, The Biotechnology Institute was established. A national non-profit organization for education and research about the present and future impact of biotechnology, its mission is to “engage, excite, and educate as many people as possible, especially young people, about biotechnology and its immense potential for solving human health and environmental problems.” The main vehicle for this program is a colorful magazine “Your World: Biotechnology and You” which is sponsored by National Organization for Microbiology.

problems under the conditions of change, or within the context of planned change (Cambell 2003; Emirbayer and Mische 1998, 1007; Morrill forthcoming; Piore 1995; Rao et al.2000)

Asian Pacific governments matched the European commitment where extensive funding and institutional capacity building has been the focus of Asian pacific nations starting in the 1980's.[24] Singapore for example developed a very centralized program that worked through its Agency for Science, Technology and Research (A*STAR) and through its Biomedical Research Council (BMRC). The BMRC brochure notes that "the biomedical sciences have been identified as one of the key pillars of Singapore's economy…To achieve its aim, the Singapore government has taken the lead by establishing a Ministerial Committee…comprising leaders of government agencies in Singapore…[With A*STAR, it will] develop and promote initiatives in R&D industry development, education and healthcare" (inside front cover). Like that of the U.S. organization AAAS, this initiative incorporated "human capital initiatives" such as 5-year national science scholarships, public outreach campaigns and centralized data banks.

China had not yet planted biotech crops for human consumption, but one article claimed it was second only to the United States regarding the advanced level of its biotechnology programs (Barboza 2003)[25]. It had over 20,000 people employed

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[24]The following discussion is informed by a variety of sources since, at this time, there are no large-scale studies for the Asian economic region similar to the EU report. While the sources are mainly journalistic and lack primary data, they are sufficient in the current discussion to illustrate the pervasive nature of national effort.

[25] This is certainly an empirical question. Many nations have claimed to be second to the U.S. by some industry variable. Allan Rock, Canada's Minister of Industry claimed in the industry magazine Biotecanada (p. 21 June 2002) that their industry is second to the U.S. measured by their number of biotechnology firms. And it became something of a joke at the "Global Forum" of the June 2002

in about 200 government labs. The national expenditure on biotech research tripled in the late 1990's and was projected to reach $1.5 billion for the five years ending in 2005. Other Asian nations approached China's level of commitment; Japan and South Korea each expected to spend over $300 million a year on biotech research in 2003 (*ibid*:2), and Taiwan's Vice Minister of Economic Affairs announced in late 2000 that 5 billion dollars would be invested in their industry over the following five years (Nystedt 2000:17).

In addition to the massive increases in funding, another important trend in the industry all over the world was the attempted creation of biotech "hubs." These hub initiatives were meant to create the critical mass of scientific discovery, entrepreneurial incentive, legal talent and manufacturing experience all in one location. This was considered the crucial lesson of regions such as Silicon Valley. Malaysia created their industrial park outside Kuala Lumpur called "biovalley" and Indonesia set up its own called "bioisland" (NY Times Feb 21, 2003). Singapore has its "biopolis" on the island One-north, India has "Genome Valley" in Hyderabad, Taiwan wanted to turn its territory into a "Green silicon Island" (Nystedt 2000:17), and Saudi Arabia has "Jeddah BioCity". It should come as no surprise then that land developers are an important and highly respected presence within the industry community. And these hubs would not have been created without strong public

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meeting of the Biotechnology Industry Organization Malerba, Franco, and Fabio Montobbio. 2003. "Exploring factors affecting international technological specialization: the role of knowledge flows and the structure of innovative activity." *Journal of evolutionary economics* 13:411 (24 pages) Additional Info Springer International. when (during a two hour discussion) industry representatives from each nation opened their successive presentations with the suggestion that their industry was second only to the U.S.

support both for the use of land as well as the policy that creates advantages to investment in both the bio-parks and in the region more generally[26].

Overall, many nations have shown unequivocal support for the industry through regulatory, fiscal, funding and educational policy. It has become a veritable paradigm for the way that nations invest in their future. The variety of measures employed by national governments in this policy arena moves far beyond those steps taken for a more generalized science policy --the "science for development" model-- that beginning in the 1960's led to widespread increases in funding for basic science in hopes of inspiring national economic development (Drori et al. 2003). This diverse and expansive level of support would suggest that nations had some guarantee on their investment. However, there is much evidence to indicate otherwise.

Obstacles to Industrial Development

Despite the plethora of national attention and effort, little either in the history of biotech or in the literature on industrial dynamics justified the universal optimism about its future.

The policy paradigm nations used to create biotechnology policies has not been empirically substantiated to have its intended effect. The National Innovation Systems approach underlies the constellation of biotechnology, and other industrial

[26] See the article Despite Odds, Cities Race to Bet on Biotech June 11, 2009, NY Times which describes how billions in tax-payer dollars are going to build facilities in places like Schreveport LA.

policies in nation-states[27]. It indicates that there is an optimal institutional architecture for industry development at the national level (education, tech transfer, tax incentives). However, the centrality of a nation's institutions in affecting its economic performance[28] had yet to be decided. Early proponents of the concept of national innovation systems suggested, in a more recent review of seventeen national innovation systems that, while the connection between national policies, industrial development and national economic growth is now taken for granted, the relationship is not well understood (Nelson 1993; Lundvall 1992). Beside the well-accepted strategy of research and development funding, little that nations had done in the realm of biotechnology policy altered this business portrait[29].

By 2003, despite the fact that the valuation of biotechnology firms was still largely measured by value of capital investment rather than real productivity, there was no evidence that government commitment would relent[30]. This valuation criterion simply ignored the absence of unmarketable products. Clearly, every firm, if it is to succeed, must bring a product as rapidly as possible to the market. However, if a biotechnology start-up is fortunate enough to put a product into production, it takes years to do so because the techniques it uses are state-of-the-art and have not been routinized. Start-up firms are funded on the promise of revenue that would in principle derive from such projects. But this revenue is hardly certain since

[27] See the European Commission's report (1999) *Inventory of public biotechnology R&D programmes in Europe* Vol.1, section 2.1 "About national systems of innovation" where the commission notes that "…the relevant set of institutions pre-conditions the tools which allow the implementation of biotech policy" (p.9).
[28] Performance as measured by the growth of income and productivity.
[29] Even the contribution of university based R&D to national economic growth remains questioned by some. See Drori, Meyer, Ramirez and Schofer, 2003.
[30] According to the EC Report on the industry, Finland was the only nation that felt its efforts were not worth continuing.

"relatively few research projects lead directly to new products" (Cortright and Mayer 2002:20).[31] In contrast, electronics companies make improvements on a technology that is already proven and manufacture products that already have a market. Some genetic engineering companies have immensely powerful tools but no commercial products; others have products but no markets (Kenney 1986: 135)[32]. As a result, despite soaring valuations, most biotech firms even in the United States, considered the world leader in this industry "…operate at a loss, spending large amounts on research and development years in advance of earning any sales revenue" (Cortright and Mayer 2002: 3). By 2001, despite soaring valuations, there was still no nation or supra-national region that had earned income on biotechnology.

Table 1: Net Income Biotechnology Sector, by Region

	Global	U.S.	Europe	Canada	Asia/Pacific
Net Income ($M)	-5,933	-4,799	-608	-507	-19

Source: Adapted from Ernst and Young, Beyond Borders: The Global Biotechnology Report 2002 (p.10, Table 1)

Consensus within the business and government community attributed this slow pace of product development to the risks involved in using genetically modified

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[31] An Ernst & Young study Ernst & Young, LLP. 2000. *Convergence: The Biotechnology Industry Report Millennium Edition*. indicates that for every 5,000 to 10,000 chemical/biological compounds screened, only one will make it through the "pipeline" as an approved FDA drug. The industry evaluates potential productivity by number of products in the pipeline, with more recognition given to those firms with products in clinical trials.

[32] Firms without saleable products stay afloat by spending borrowed money or through revenue from research contracts with Pharmaceutical MNC's or chemical manufacturers. In the latter scenario, they must guard against the selling of the company's primary idea known as "selling of the company's birthright." (Kenny 1986: 158-159). Compare this to the machine industry in the 1880's who, in its expansion, like the producers of perishables and semi-perishables, were financed from within as they expanded and so had no need to go to capital markets for long term credit Chandler, Jr. Alfred D. 1977. *The Visible Hand: The Managerial Revolution in American Business*. Cambridge: Harvard University Press..

(GM) materials. Careful attention to regulation of GM products required a balance between recognizing the considerable safety hazards potentially involved in genetic modification, against the need to avoid tight regulation that could inhibit the exploitation of fruitful lines of research. This problem is illustrated by the events in September 1999, when an experimental subject died during a gene therapy trial at the University of Pennsylvania. The incident ended in accusations that the Recombinant DNA Advisory Committee of the National Institute of Health (NIH) did not do enough to protect patients. U. Penn's clinical trials research was shut down indefinitely as the NIH conducted an investigation into the problems in the gene therapy clinical research protocols, and the Food and Drug Administration developed new guidelines for how clinical trials would be monitored. They specifically did not call for a moratorium on the clinical trials—instead, they relied on the willingness of some universities to put their trials on hold to review procedures[33].

Additionally, controversial issues such as stem cell research have highlighted the disadvantages of over regulation, given the competition that it provokes on the international level. Following President Bush's declaration in August, 2001 that stem cell research would be banned in the U.S. (except for work with the existing sixty cell lines), Australia announced the building of a stem cell research center and both Japan and the U.K. announced the possibility of stem cell research within their borders. The latter states' response to Bush's action was a clear message to global

[33] Such events indicate clearly why agricultural products were the first ones developed in the industry: they "are not subject to as stringent health and safety testing as products applied to humans" Kenney, Martin. 1986. *Biotechnology: The University-Industry Complex*. New Haven: Yale University Press..

firms and investors that stem cell research was protected in their regions[34]. The same dynamic was observable regarding GM foods whose sale was prohibited in Europe but not in the U.S. Such controversies are particularly noteworthy compared to the relatively quiet introduction of chemical innovations which "…have had a limited visibility because of the intermediate good nature of most chemical products" (Rosenberg 1994: 77) Given these factors, it is not surprising that average product development time ran between twelve to sixteen years from a discovery at the lab bench to an Federal Drug Administration product approval (Ernst & Young 2000: 46). Product development was and remains an expensive and lengthy process and therefore, risky one if a final approval FDA approval is not granted.

Moreover, despite the claims of the OECD, economists, entrepreneurs, nations and other international organizations, the biotechnology industry failed to show the type of outcomes typical of other "enabling" technologies.[35] Enabling technologies "are rooted in fundamental technological advances that open up whole new arenas of production and new possibilities in older lines of industry (Storper and Walker 1989: 107). A technology may be categorized as enabling when, for various reasons, it becomes widely available and affordable, and thus becomes an irresistible choice for firms. The English inventor Henry Bessemer for instance, with his "tiltable converter" along with other add-on innovations, "made it possible to supply cheap, high quality steel on a vast scale so that…the railway network switched over from iron rails to steel rails and the ship-building industry from iron

[34] Industry, academic science and a number of state governments, such as California and New Jersey attempt to circumvent the federal ban by raising private and public funding for this research.
[35] Enabling technology is synonymous with base technology and general purpose technology. Energy sources and materials are good examples of enabling technologies.

plates to steel plates in a relatively short period" (Freeman and Louçã 2001: 220). Ultimately, steel replaced iron in almost every application.

Enabling technology, as explained by Nathan Rosenberg (1994) generally reduces the price of the products it impacts while maintaining or improving their quality, thus leading to "an expansion in the size of their market and therefore also to an expansion in the rate of capital accumulation, output growth and technical progress" in these target or "forward" industries. "The induced responses would depend upon the number of industries into which the innovation enters as an input, its substitutability for other inputs, the proportion of total costs it accounts for, [and] …the extent of cost reductions it imposes upon the product. More important [is] the induced creation and diffusion of new products and processes that, in their turn, would bring about the widespread adoption of the original innovation" (Rosenberg 1994: 76).[36]

By 2003, there was no tangible evidence that biotech was having this broad impact. The price of the few existing biotechnology products had not begun to decline and since biology requires expensive, well-regulated facilities, a highly educated, skilled labor force as well as expensive materials and equipment, there was little sign of any such decline in the foreseeable future. The broad based applicability seemed to exist only as a vision, fueled by the experience of other base technologies such as steel, electricity and later the example of semi-conductors. In absence of this evidence, it was difficult to imagine a change akin to what the Bessemer process brought in the 1850's and 1860's in steel output. In short, biotech

[36] This explanation pertains only to the aspect of growth or peak of growth in the model of the "long cycle" but not to the downturn or trough at the end of it.

remained ill suited for substitution in its target sectors. While proponents continued to portray biotechnology as an enabling technology, it showed no signs of offering firms a comparative advantage as a primary input.

National commitments to the industry could only be grounded, therefore, on the conviction that energetic government support would bring biotech's potential as an enabling technology into maturity. This is contradicted however by the accepted wisdom regarding the complexities of industrial development. Knowledge-based industries usually develop as a "cluster", that is, a dynamic regional economy characterized by a high level of cooperation among heterogeneous institutions of different size --universities, legal firms, research hospitals, large pharmaceutical corporations, small and medium size enterprises, public works-- all in close physical proximity (Maskell 1993; Powell 1993). This environment is one in which technological learning is considered optimal because knowledge is shared quickly through extensive interconnections.[37] In economic geography, this is called "territorialization" and an activity, such as the production of biotechnology products, should be "…fully territorialized when its economic viability is rooted in assets (including human practices and relations) that are not available in many other places and *cannot easily or rapidly be created or imitated in places that lack them*" (Storper 1999: 3). Focusing upon the organic nature of a firm level development process

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[37] Further, there is some contention regarding the historical significance of network-based industries as an organizational form unique to the 20th century or to a particular sector such as high-technology. A number of scholars interpret the "cluster" as a more general characteristic of young industries. Storper and Walker's work, for example, indicates that the territorial cluster is not unique to high-tech industries but is characteristic of all *innovating* industries (1989:106). "There is, therefore, no reason to treat high-technology sectors as fundamentally different from other industries in terms of the way technical change affects their locational dynamics." Such organization has been present in many sectors and at different historical periods. Prevezer, Martha. 1997. "The Dynamics of Industrial Clustering in Biotechnology." *Small Business Economics* 9:255-272..

suggests in particular that while such factors as capital investment are important for continued growth (Massey 1979, 1984; Storper and Walker 1989), explicit attempts to set the right institutional conditions for territorialization at the (nation) state level misunderstands the nature of the development process by overemphasizing the transferability of institutions from one context to another. Thus, while the national level remains an important background context for industrial development --because the complex of national laws, funding, business practices and other national factors--impact upon development trajectories, the "industrial region" is the appropriate unit of development, because of the spatial aspects to industrial growth and change.

Together, these factors indicate that, contrary to the level of excitement for the industry, the institutional obstacles to building the industry would likely be insurmountable for those nations without existing capabilities. Adopting biotechnology is hardly a rational means-ends calculation as rationalist theories would predict. For some nations, the biotechnology industry is a true gamble for long-term national investment. Why, then, have nations invested so many financial and political resources in this endeavor? In keeping with the suggestion that it is impossible to understand an institution adequately without investigating the historical process in which it was produced (Granovetter and Swedberg 1992), it is appropriate to go back to the moment where the understanding of biotechnology as an enabling technology was first generated within the international community.

The OECD's Role

I argue that the Organization of Economic Cooperation and Development (OECD) played a key role in constructing consensus about the viability of the biotechnology industry. They accomplished this primarily though a cultural process whereby they established the enabling technology frame (Snow et al.). This frame subsequently became the basis for a wider international movement toward industry development, as shown in the following chapter. Through their effort, the OECD seemed to make biotechnology "…conceivable and above all credible and thus created the collective representation which contribute[d] to its production" (Bourdieu 1991: 128). Having observed scientific developments in a handful of nations, the OECD became a force in spreading the possibilities of the industry by mobilizing member nations toward development[38]. The content of the frame is paramount: the OECD defined biotechnology as an enabling technology. This was key in establishing the geographically expansive awareness for the development of an industry that is indeed increasingly regarded as global in scale[39].

The OECD is an international organization founded in 1961 whose members are 30 nation states --primarily Western nations-- though it maintains active relations with 70 non-member nations, NGO's and civil society[40]. As indicated in the OECD's Convention, it hopes to contribute to the highest sustainable economic growth and

[38] My present goal is not to assess the reasons why biotech activity existed in the original few nations it did (France Germany U.S. …) although this is an important beginning to the story. The process of biotech policy expansion seems to have commenced when the OECD fixed itself on the industry as it existed already in that initial group. Thus, ascertaining why and how what is thought of as "biotechnology" took off in the international community is the object of this study.
[39] "Global" here signifies localized clusters of the industry rather than a single global division of labor.
[40] The OECD was an outgrowth of the Organization for European Economic Cooperation, established in 1948 to help administer aid through the Marshall Plan to Europe following WWII.

employment rate in member countries. Likewise, it hopes to facilitate the sound economic expansion of both member and non-member countries in recognition of the interconnectedness of nations within a global economy. It engages in policy analysis and gathers cross-national statistics in a variety of policy areas that ultimately expand well beyond economy. It also "produces internationally agreed instruments, decisions and recommendations to promote the rules of the game in areas where multilateral agreement is necessary" and to "help policy-makers adopt strategic orientations."[41] They possess only the power of deliberation, persuasion, surveillance and self-regulation in their attempt to govern transnational economic activity (Marcussen 2004b).

As early as 1982, the organization released its first report on the industry, entitled *Biotechnology: International Trends and Perspectives.* This was one year before Humalin, the first genetically engineered drug was released, a "blockbuster" that led to the success of Genentech, one of the largest U.S. biotech companies that served as a model for all firms in the industry worldwide. Later, in 1989, the OECD released a more comprehensive report on the industry, *Biotechnology: Economic and Wider Impacts* and has since (1993) initiated a bi-annual policy brief on biotechnology issued through the Internal Coordination Group for Biotechnology, formed to connect efforts in multiple Directorates. In 1999, the OECD joined efforts with other international non-governmental organizations to facilitate information exchange and coordinate on related projects. More recently, the OECD issued a preliminary report as part of its larger effort to gather and coordinate cross-national industry statistics on twenty-eight member and non-member nations (van Beuzekom

[41] See "About" section on OECD home page (http://www.oecd.org/about/).

2001)[42]. Overall, these reports indicate that the OECD not only supported biotechnology development, but that from a very early stage it assumed a leadership role in this policy arena both by alerting nations to obstacles to development and by recommending means to overcome them.

Until 2001, when the United Nation's Development Project (UNDP) released its Human Development Report *Making New Technologies Work for Human Development*, no other international organization or agency produced so important a report on the biotechnology industry for the international audience[43]. Moreover, the OECD produced *International Trends and Perspectives* many years before other important state of the industry data were initially collected, that is, before there were any established ways of understanding the progress or productivity of the industry[44]. Even before such success stories as Humalin were available, the OECD had already fixed upon biotechnology. Together, the timing and the foresight of the organization are striking.

The scientific precursors to the industry, prior to the OECD intervention, can be traced back to developments and connections among the scientists of Great Britain, France, the United States, Germany and Sweden. The historian Robert Bud traces the scientific origins of biotechnology, a lineage of the techniques and of the disciplinary boundaries within which the current techniques might be said to have

[42]van Beuzekom, Brigitte. *Biotechnology Statistics in OECD Member Countries: Compendium of Existing National Statistics*. STI Working Papers 2001/6. Organization of Economic Cooperation and Development. This initial report is part of an on-going effort and the report has been updated several times.

[43] Vandana Shiva, a physicist, philosopher of science and an activist responded to the UNDP report with an article entitled "The Seed and the Spinning Wheel: The UNDP as Biotech Salesman" (7/2001).

[44] Both consulting firms that have taken a special interest in the industry, Burrill & Co and Ernst & Young, Co. released their first annual report in 1985, and in 1986, respectively. The U.S. Congress's Office of Technology Assessment released *Biotechnology in a Global Economy* in 1991.

originated. The technical basis of the industry, part bio-chemistry, part engineering, and applied microbiology are the foundation of traditional production processes such as fermentation in beer and cheese making. The nations that historically hosted these crafts are those which developed a combination of academic biology with the infrastructure of industrial application that would have ultimately led to an early focus on the potential of biology. Though Bud describes these as the scientific origins of the industry, it is more likely that these proto scientific-industrial structures existed to a certain extent in several nations at that time. Early discussions on the uses of biology began in nations that currently have more developed biotech industries, and it was the reports of these member nations that captured the attention of the OECD.

The definition of biotechnology, the basis of the OECD frame that became part of their 1982 report, followed a series of national reports, a British (1980), a French (1980), an Australian (1981), a Canadian (1981), a Dutch (1981) and a U.S. (1981). These reports are referenced in the bibliography of the OECD report. Figure 3 of the Appendix below includes four definitions that are of particular importance: the German, which was the first national report (1974); an early attempt at a definition by the European Federation for Biotechnology which was a very small professional organization consisting of scientists from France, Germany and Great Britain; the British Royal Society definition; the OECD definition. A comparison of these definitions illustrate that the OECD definition was clearly related to the British definition. These reports share a common author, British scientist Alan Bull. Moreover, compared to the first "national" definition which was published in 1974 --

the German one[45]-- the OECD's is considerably less technical, more general and, with the addition of the section "…to provide goods and services" clearly transformed into an economic entity. It is the OECD's definition that has become so well known. Bud notes that "the best known definition is perhaps that spelled out by the Organization for Economic Cooperation and Development."

Clearly, the simplicity and compactness of the OECD definition communicates to a general audience in a way that previous definitions did not. Specifically because their recommendations are non-binding, a primary means of affecting change is through discourse. The OECD's effort to promote biotechnology was advanced because of the ambiguity of the term, which in part, they helped to create. While the terms "molecular biology" and "biotechnology" are now almost synonymous, the connection is hardly natural and, in Sweden for instance, biotechnology in the 1950s could even mean "ergonomics" (Bud 1994). In contrast, the term "biological engineering" was once preferred over the term biotechnology in the United States. Biotechnology's meaning has varied historically, with the geography and the social arena of use, and it remained open to re-definition. This quality of "interpretive flexibility" (Misa, 1992) allows a term to take on a range of meanings, each significant at various historical moments and for different social groups. Accordingly, in the case of biotechnology, a very tight technical definition derived from a strict construction of the science itself would have been appropriate for the scientific community given the coding that tied it to that group. Such a description would be

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[45] A 1974 definition from the Bundesministerium für Forshung und Technik (BMFT) "Biotechnology is concerned with the with the use of biological activities in the context of technical processes and industrial production. It involves the application of microbiology and biochemistry in conjunction with technical chemistry and process engineering."

unintelligible to a wider audience of non-specialists requiring a less technical definition. Thus, the OECD moved the concept of biotechnology from a technical to a general one.

Moreover, the organization engaged in a creative redrawing of boundaries in order to remove limitations on how policy makers would view biotechnology. To accomplish this, it highlighted the distinction of biotechnology as an input to many industries --enabling technology-- versus biotechnology as a mere industry. By foregrounding the techniques of molecular biology --in particular genetic engineering-- they showed how biotech could have broader industrial applications[46]. In the introduction to the 1982 report, after noting "…the importance of conventional molecular biology and genetic engineering", the authors asserted that "it would be *dangerous* to consider only that aspect of biotechnology" since there are "many other fields of value for agricultural, industrial and medical applications [that] receive far too little attention at present" (Bull 1982). The report's definition is preceded by a note that biotechnology "is not an industry, but a scientific activity" (1982, p.18), going on to define biotechnology as "the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services".

These discursive maneuvers placed biotechnology on a much more financially important side of two opposing categories, one whose scope of return is

[46] The report notes (p.25) two techniques, cell fusion and in vitro recombinant DNA methods. Cell fusion is a technique that allows the production of monoclonal antibodies which are valuable reagents for research and possible reagents for medical therapies. According to the report, both techniques, "are taking the experiments out of the laboratory and into the market place. They allow the 'species barrier' to be overcome and for new combinations of genes to be produced" (p.25). This emphasis suggests that basic research could be brought closer to application.

potentially limitless. That the OECD argued that it was dangerous to view biotechnology as just an industry illustrates the force with which they wanted to impose their particular notion of biotech. This view became the accepted wisdom, transforming the image of biotechnology into a panacea --an enabling technology-- whose importance, parallel to electricity or computing, was rooted in its capacity to generate a new, long term wave of economic growth in the economy as a whole (Freeman and Louçã 2001; Freeman 1994; Perez 1985)[47].

The new vision of biotechnology also offered national policy makers a level of generality to allow them to envision and promote their industry simply by accounting for and advertising what research facilities they already hosted. This level of generality is important where there is the burden of creating meaning across vast swathes of geographical space, that is, on the global level. It can unite heterogeneous actors across multiple social fields who might have similar enough ideas but, for instance, distinctive professional and organizational ways of thinking about problems and thus differing language and values which become an obstacle in the creation of unified meaning. Thus, by broadening the definition, the OECD permitted a wide range of development options for local (state and regional level) biotechnology developers and allowed for the development of niches of biotechnology within the broader framework.

In sum, prior to the discursive work of the OECD, biotechnology was viewed in its social aspects --population pressures and human health-- and technical

[47] Martin Kenney, one of the only scholars who challenges this view argues that it is an industry because it has created it's own economic space. Thackray, Arnold (Ed.). 1998. *Private Science: Biotechnology and the Rise of Molecular Sciences*. Philadelphia, PA: University of Pennsylvania Press..

aspects --how biological advances could be applied to certain industrial problems such as animal yields and large-scale fermentation. The OECD's innovative, expansive frame for biotech as an enabling technology was accomplished in a variety of ways: first, through a broad and general definition produced for the community of member nations rather than a scientific audience; second, through the articulation of a dichotomy and emphasis on input over industry and finally, through a set of specific recommendations –action items-- that intended to facilitate the use of biological techniques across multiple industrial sectors. The recommendations included, for example, expansion of publicly funded research into microbes more useful to industry and basic plant science intended for agricultural applications, the need for training and interdisciplinary skills development, government funding of national and international storage facilities for various biological materials as well as new patent laws to cover the specificities of biotech inventions. These recommendations were directed toward the state apparatus and were tasks that could be accomplished only through national policy initiatives. Moreover, to assist non-specialists in the task of digesting the report, authors included an extended glossary of biological terms and a checklist for strategic planning in biotechnology. The definition they offered was therefore a complex framework that was adaptable and generalizable.

In addition to the discursive innovations of the first OECD report, the OECD as an IGO had other symbolic means of diffusing ideas. Politically recognized by its member nations and respected within the wider community of nations, the OECD had the "jurisdiction" that other nations involved in biotechnology development (the

British) did not, i.e. a combination of geographic scope and technical expertise as an economic think-tank and, therefore, the authority to forecast a new opportunity that had had no substantive success at the time. Any nation that was considering the potential impact would not have had the same legitimacy to promote an industry that existed in such an elemental form. While the nations mentioned above had the basic infrastructure that would eventually come to be referred to as a "biotechnology industry", the vast majority of activity even in those nations was, essentially, still isolated within the realm of the scientific arena. It was only an international organization whose mission was economic forecasting that could have the legitimacy to consider such phenomena and circulate it widely (Fligstein and Mara-Drita 1996). With this authority the OECD was able to transform what was essentially a scientific definition into one instilled with economic purpose. In so doing, the OECD oriented biotechnology toward the economic ends of the state, that is, toward the creation of opportunities for economic growth[48].

Together, these factors suggest that the medium through which the OECD exercised their authority was a cultural one[49]. The power to create biotechnology as a meaningful opportunity was structured in the mission of the OECD as an intergovernmental agency. Marcussen (Marcussen 2004b) details how the OECD was originally conceived as an "ideational artist". The first Secretary General Thorkil Kristensen intended the OECD to expose national members to ideas that stood outside their standard policy realms. He imagined the organization's ability to maintain a particular intellectual independence in how it challenged members'

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[48] That the state is concerned with generating opportunities for economic growth is a point I will discuss presently.
[49] Note the term "institutional" is also appropriate here.

conventional policy orientations. As the field of IGO's became more crowded however, the OECD found itself in competition and, in the need to convince nations of the importance of its work, it became more of an "ideas agency", monitoring the policy landscape and reflecting back what seemed to be in demand among member states (Marcussen).

Thus, more than a "demand-pull" phenomenon, in the parlance of economics, the presentation of biotechnology can be better characterized as a "supply-push" of the most important member states of the OECD --those which contribute the majority of the budget of the organization-- in this instance, the United States, Japan and Germany (Marcussen 2004b). In fact, the flow of ideas within the established hierarchy of OECD member nations is from top to bottom, namely, from more powerful to less powerful members (Marcussen 1999: 93). In this view, the OECD becomes a tool of states at the top of the hierarchy for the creation of a global biotechnology market.

At the outset, this interpretation seems to be consistent with a traditional IR theory that reduces the power of IGOs to the most dominant member states.

As an "ideas agency" struggling to maintain itself in a crowded organizational field, it is the motivation of the agency to continue to present itself as relevant. "…(T)he acquisition and maintenance of power within organizational fields requires that dominant organizations continually enact strategies of control…" (Powell and DiMaggio 1991: 31).

The role of the OECD however should not be reduced as such. The counterfactual cannot be assumed that, in the absence of the OECD, powerful members would have acted alone or in concert to create a biotechnology market. The diffusion of ideas happens within the context of the bureaucratic process of the OECD. Both members and non-members that are on the receiving end of policy imperatives are socialized within the OECD process. Civil servants from member nations participate in on-going common procedures "…based on the collection, elaboration and diffusion of data, analyses, perspectives and ideas" (Reinalda and Verbeek 2004: 31). National civil servants come together for no less than sixty-nine monitoring and surveillance procedures per year which intends to improve national policy making, help nations adopt best practices and to comply with well-established standards and principles (Marcussen 2004b). Civil servants serve short terms of five years or less and move between home governments and IGO work, ensuring that any important developments that happen at the IGO level are brought to bear upon member government policies either through direct communications or during the course of civil servant careers. This process exerts a form of "soft" power that creates consensus among members. In sum, the OECD, even without capacity that legally binds nations, has a number of tools that structures national agendas along a common line.

In the promotion of specific agendas then, the OECD acts as a filtering agent that repackages policy initiatives and important economic trends and sets the stage for the development of markets across the OECD region, in service to powerful members. In this way, the OECD masks the power of dominant members within their own policy agendas. Reversing, the normal direction of legitimacy from member states to the organization, the organization in this case lends legitimacy to an agenda because it comes from an agency viewed as rational-voluntaristic (Boli and Thomas 1999); that is, it is legitimated through the expertise affiliated with credentialed professionals and with scientific research, offering the well-reasoned argument rather than the brute force of a state coercion. As such, the OECD was in a unique position to observe and legitimately articulate a potential opportunity, in a way that would have resonance in the international community.

The organization, having created and reinforced this national economic focus (1982, 1988, 1989) in the early phase of the industry, was then poised to make more careful recommendations and coordination efforts at the national level. In effect, this was a deepening of the constitutional work they'd already accomplished. OECD activities around biotech spanned several Directorates --the Directorate for Science, Technology and Industry (STI) and the Environment Directorate-- and areas --science, technology, industry, agriculture, environment and trade facilitated by the Internal Cooperation Group for Biotechnology established in 1993. The OECD activities cohered with the notion of broad-based applicability by aiming to advance application of the technology in multiple areas as well as activities to create the market for potential products.

Moreover, the OECD's statistical work on biotechnology is an important factor in the transnational constitution of the industry. Standard monitoring activities for which the OECD is well known, such as the creation of statistical reports, have a documented constitutive affect (Klotz 1995; Ruggie 1998 in Reinalda and Verbeek 2004). The OECD statistics project for biotechnology was initiated in 2001 by Brigittevan Beuzekom, an OECD staff member. Since that time, there have been ten reports on the topic, an average of more than one per year. The statistics report began as a way to create cross-country comparability for various measures of industry progress such as the amount of public R&D expenditure and number of firms. The report requires government representatives to gather industry data. For most nations the majority of these data were not specifically collected by their own government agencies prior to the first OECD report.

It is in the process of collecting such data that we can see industry constitution, institutionalization that is, at the regional and national level. In general, institutionalization is a process that can be thought of as occurring in both physical and symbolic space. As infrastructure begins to develop around, for instance, an industry, productivity can be then be examined through the use of industry data. Industry indicators -- the number of firms, the number of products, the number of employees-- are coupled to graphic representations that help observers assess the state of an industry in terms of its size and financial productivity relative to inputs. While this is a simplistic model of the analysis of industrial growth and its evaluation, it is sufficient to note that this is likely the order of things for a bottom-up development process. In the case of biotechnology, a top-down process with the notable exception of the original few nations including the U.S. and Japan, it seems that the process of industry evaluation is de-coupled from the actual development and inverted such that industry description actually precedes industry performance.

As such, the description of the industry in such early reports is symbolic, a representation of a future potential rather than a functioning industry. Indicators in the first report are dominated by U.S. statistics coming from the American National

Science Foundation while much of the rest of the report focuses on developments in individual areas of research that used molecular biology techniques such as Table 3 of the report which shows the number of acres in which genetically engineered crops are planted. When these indicators are coupled to the industry by adding the term “biotechnology” that is how they will likely be perceived and what they will be considered. The authority inherent in such data presentation, perhaps recognized by those well-versed in the art of constructing scientific arguments, is hardly so transparent to national decision makers and policy makers, who automatically rely upon the “facticity” (Latour and Woolgar 1979) of well-made presentations. The representation of the industry through data presentation is symbolic because it stands separate and apart from narrative which offers a more comprehensive understanding of the lack of income generating capacity of the industry. In this way, a report with figure upon figure of cross-national statistics, however poor the data may be, give the image of the existence of an industry: the biotechnology industry, in essence, becomes a fact.

In the specific case of biotechnology, the constitutional process is driven by the difficulty in unraveling basic university biology research from industry research and development. This difficulty is evident, for instance, in the North American Industry Coding System codes, used to identify categories of industrial activity. Such codes are used in the U.S. and abroad, both for the purpose of identifying industry for tax purposes and trade as well as for research. The codes to identify basic scientific research (541711) and to identify “biotechnology” (541712) are essentially identical except that the basic research coding has an amendment after each subcategory that says “except biotechnology research and development”. There are no other substantive rules to determine if one is doing basic scientific R&D or biotechnology R&D. This demonstrates the confusion and the essential ease with which local R&D institutions can simply be categorized or *re*-categorized as biotechnology even if they were engaged in basic research. This top-down industrial development through re-labeling is strongly suggested in the European Commission Report mentioned above where “…existing centres have mainly been labeled ‘biotech centres’ in order to focus them” (Enzing 1999: 20).

This scenario is not so unfamiliar. William Roy for example emphasizes that the idea that dominance by the large corporation was inevitable was itself an important causal factor in the actual rise of the corporation. Roy notes that “one of the primary ideological factors underlying the corporate revolution at the end of the century was the widespread assumption that large corporations were not only inevitable but an established fact, that is, the form was already institutionalized before its full blossoming” (Roy 1997).

While attempts to define the industry's activity more succinctly have preoccupied both the OECD and other industry developers, the view that biotechnology will contribute to national economic growth is an entrenched part of the OECD's approach, as illustrated in subsequent general industry reports from 1988 and 1989. This view has also structured the OECD's research and publications around the industry, concentrating on requirements for industrial growth in a variety of sectors under the umbrella of "biotechnology". While their position in a 1988 report held that statistical comparisons between nations were not possible, a report from 2004 used two definitions --a list based and another more compact definition-- in order to capture all possible instances of potential biotechnology for national comparison[50]. This switch suggests their all-encompassing view of the industry has advanced only further in that direction. That in their most recent statistics report (2009) thirty nations out of thirty-four surveyed are using the OECD definition to outline their industry demonstrates a powerful entrenchment of the OECD's institutional work over the last twenty-five years.

Systemic turbulence: Economic downturn of the 1970's

The economic conditions in the 1970's, along with the new way in which technology's role in national economic growth was understood at the time gave a particular resonance to the idea of biotechnology as enabling technology with national governments. Government attention to the centrality of technical innovation in economic growth came after the global economic slowdown of the 1970's. The downturn, a global level crisis, was marked by the peak of the expansion of U.S. corporations in European territory, world wide inflation, a massive flight of capital into off-shore markets and a steep rise in energy prices. (Arrighi 1994)

While these highly visible disruptions left many nations stagnating, Japan appeared to be a technological and financial powerhouse. This fact led to official recognition that there were particular national contexts that did indeed hold the conditions for economic growth (Nelson 1993; Sandholtz et al. 1989). Based on this

[50] This report was strongly criticized by Henry Miller (2006) on the grounds that anything could be considered biotechnology in the OECD's survey.

observation, an OECD report from 1982[51] provided a justification and a mission for national governments to create an innovation dynamic akin to Japan that had "…been continuously implementing innovation policies over a long period" (p. 6). During this time, government institutions were reconceived as National Innovation Systems (Lundvall 1999; Lundvall et al. 2002)[52]. As such, they were scrutinized for how they inspired the process of technological innovation and, in turn, their ability to generate national economic growth. Nations began to explicitly coordinate those conditions in an attempt to make them more precise and thus more efficient.

The global economic conditions in the 1970's and the international response that came in the formulation of the NIS reflects the rise of the Schumpeterian perspective in scholarly and policy circles. This view holds that technical innovation is the central source of economic growth and development[53]. The idea that some institutional conditions could be copied, at that time from Japan, and transplanted into other national contexts became widely accepted. The outcome was a commitment to creating the conditions for economic growth through concerted national policy, using institutions "borrowed" from other nations[54]. This faith

[51] OECD. *Innovation Policy: Trends and Perspectives*. Paris, 1982.

[52] On the national recognition of the importance of technological innovation and the NIS more generally, see RAND's most recent report *New Foundations for Growth: The U.S. Innovation System Today and Tomorrow*" Steven W. Popper and Caroline S. Wagner. RAND Publications, 2002. (http://www.rand.org/publications/MR/MR1338.0/MR1338.0.pdf)

[53] Nelson notes (1990) that basically all contemporary general accounts of the capitalist engine are based upon Joseph Schumpeter's work. Storper and Walker (1989:66) agree.

[54] In light of the Japanese system and in recognition that different styles of capitalism have been possible historically, i.e. the British free-market capitalism of the late 18th and 19th centuries, and American Fordist-Keynesian growth in the 20th century, it is clear that while success in the world capitalist system clearly depends upon some upgraded form of production that is viable across a wide array of national production systems, what is also highly relevant is the right mix of national institutions that will maximize growth without a more encompassing system change. Walker (2000:123) notes that "students of comparative development…have come to realize how much of the 'competitive advantage' of one country over another is not due to pre-given conditions, but to the way that labor-productivity, product quality, and business capability can be improved through innovation,

continues to hold sway among both government agencies and academics[55]. The framework of the national innovation system laid the crucial groundwork for understanding biotechnology as a potential resource for economic growth. Likewise, it gave a means through which biotechnology policy could be implemented at a national level.

The most compelling interpretation of the economic turbulence of the 1970's is outlined by a brand of World Systems Theory developed by Giovanni Arrighi (1994)[56]. Historical capitalism, in his approach, has been marked by cycles of material (trade and production) and financial expansion (pure capital accumulation) guided by a political hegemon that leads the global economy. Such expansion ultimately precipitates a crisis of over-accumulation, a period of chaos during which global competition dramatically increases in search of new ways to profit. During the downturn, there is created --reinvented or innovated-- a new way of producing or organizing capital that has the ability to galvanize the world economy again under the appropriate political guidance. But until a new hegemon arises, "…world capitalism tosses on rough international seas, as happened in the period between the wars as Britain faded and the United States refused to take up the mantle of

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education, state assistance, and industrial strategy." One of the students of comparative development to which Walker refers is an economist, Michael Porter who is hailed as an icon among actors in the biotechnology industry. More recently, the concept of national innovation systems has met some criticism Nelson, Richard R. (Ed.). 1993. *National Innovation Systems: A Comparative Analysis*. New York: Oxford University Press.. See also Chris Freeman. Freeman, C. 1995. "The'National System of Innovation'in historical perspective." *Cambridge Journal of economics* 19:5.. The national system of innovation in historical perspective. *Cambridge Journal of Economics*, 19, 5-24.

[55] World Bank Report---

[56] In *The Long Twentieth Century: Money, Power and the Origins of Our Times,* Arrighi emphasizes the *longue durée,* following Braudel, in the analysis of historical capitalist dynamics.

power (Storper and Walker 1989). With a new hegemon, the cycle of continuous change along a new path on enlarged foundations begins again[57].

Neo-Schumpeterian theorists of the Kondratiev long cycle (1998) posit that technological change is at the heart of cyclical dynamics. Perez (1985) and Freeman and Louçã (2001) see the economic system as changing through successive techno-economic paradigms consisting of a technological system with a complementary social-institutional system that nurtures it. The model is one of technological diffusion based on low and declining cost, unlimited supply, potential for pervasive influence and a generally recognized capacity to reduce the costs and change the quality of capital equipment. Each technological paradigm is marked by its key factor, such as steel or electronics, as well as an organizational scheme that exploits it such as the assembly line or flexible production. This combination diffuses through key sectors sweeping away old methods because of superior productivity. Following a period of diffusion and growth, decreasing returns on the innovation lead to a decline which sets in motion a new wave of innovation in search of competitive advantage. This innovation is frustrated, however, because existing institutions cannot accommodate the new key factor. The resulting crisis is resolved only when a new institutional structure is erected that is compatible with the new enabling technology.

[57] Arrighi, as well as other scholars of cyclical economic dynamics, consider the period beginning in the 1970's as a time of chaos triggered by the closing of the U.S. regime of capital accumulation. Many theorists and policy analysts in the 1980's saw this leadership passing to Japan based on its production system of flexible specialization (Piore and Sabel; Florida and Kenney) although this has yet to occur.

In their assertion that social and institutional factors play a role in the productive employment of technical innovations, Perez, Freeman and Louca improve upon more simplistic views of technological change. Despite this, their model is still marred by technological determinism. What is lacking in this explanation of economic change is the focus that leads to the investment at the beginning of each cycle. Their argument wrongly assumes that investors recognize inherent virtues of a particular technology and follow through with the massive infusion of capital necessary to nurture it, unprompted. This approach ignores the process whereby the relevant scientific techniques and literatures undergo a process of translation (Callon 1986) so that they become available conceptually to the actors required to invest in the opportunity. In the case of biotechnology, as with other highly specialized domains, the evaluative knowledge is available only to the affiliated experts. This reality requires a mechanism that can create the unanimity across diverse actors: scientists, investors and politicians.

This logic can be applied to the case at hand. I argue that the OECD played this important role in aligning national political actors around their vision. Their concept of biotech as an enabling technology meshed perfectly with the political tone and perceived economic and technological needs of that period. According to the OECD report, biotechnology was destined to impact virtually every industrial sector, including those that constituted the special domain of the nation-state, such as defense, public health and more recently environmental conservation. As the U.S. Department of Commerce portrays it, biotechnology would “Improve Human Health”, “End Hunger", “Meet Our Energy and Environmental Needs”, “Defend Our

Homeland”, “Catalyze New Innovations” and finally “Promote Economic Growth and Competitiveness” (U.S. Dept. of Commerce Technology Administration 2003: foreward). In this way, biotechnology became a cause par exemplar for a general social betterment --human nutrition and longevity, disease and poverty reduction, waste reduction, industrial sustainability, energy production, third-world development. Thus, from the notion of enabling technology a universalistic frame was created, depicting an industry that would be crucial to the reproduction of the interests of civil society.

Moreover, the economic currency gained through the discursive work of the OECD would be an important step in mobilizing institutional activity to create long-term economic growth. As such, any activity that seemed to relate to the industry could be reconceived as a potential resource for economic growth and could become particularly suitable for investment. In sum, the label “biotechnology”, as it was coupled to the concept of enabling technology, had a unique and expansive rhetorical power that made genetic engineering stand out against other technologies. The OECD portrayal of biotech had the force of an idea “whose time had come,” fitting into the conjuncture of events that made most governments anxious to embrace it as the development of the technological base of the next economic expansion.

In sum, the theory of techno-economic paradigms is inadequate to account for the diffusion of the biotechnology phenomenon. Arrighi’s framework for the mutual construction of states and capitalism remains the fundamental backdrop to the discussion. A cultural account such as the one provided here details how frames are constructed and employed in cognitively orienting many transnational actors. For the evolutionary economists (Perez 1985; Freeman and Perez 2004; Freeman 1993, 1994, 1999, 2001;Freeman and Louçã (2001), we need to reject technological determinism by paying attention to historical process and by delving into the deeper implications of social and institutional factors, most notably by addressing framing factors by actors who initially construct the technology as a solution. Viewing the symbolic dimensions of the development of a new cycle can address this inadequacy.

Conclusion: OECD and Policy Change

Star and Bowker (1999) note that "the creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting communities" (Star and Bowker 1999: 297). As I have argued, the OECD is in an ideal location relative to nation-states to create and maintain boundary objects. This process incorporates translation and diffusion functions that occur in the course of standard OECD practices of research, peer review, report writing, data gathering and national coordination. I would suggest further that the creation of umbrella concepts, such as biotechnology, although vague and difficult are necessary given the level of national coordination that they wish to achieve.

The OECD intervened at the point where molecular biology gained legitimacy within the scientific community and could be seen as commercially relevant. As a necessary step, biotechnology had first established a more clearly defined disciplinary foundation in molecular biology. The OECD had little to do with clarifying the debates among scientists about the import of new molecular techniques within science, but it powerfully inscribed the meaning of the new genetics within the setting of larger global economic problems and future directions for the international community. Biotechnology was thus made available in a discursively meaningful way to state actors. In this way, the OECD participated in institutionalization by laying a cognitive groundwork.

In the context of its statistics projects and definition making, the OECD can be viewed as providing a concrete framework that nations, through their representatives in the organization, could use to assess their own biotechnology industry. This project likely also had a shaming dimension, an entrenched aspect of the success of the peer-review process within the OECD.

The time it will take to achieve a growth effect is not due merely to the work involved in making technical advances. There is an important period of institution building that begins with the future vision of technology. It is a technical and social process that constructs the enabling capabilities where they do not exist to begin with. In the early development of the biotechnology industry, the idea of biotechnology as an enabling technology was the primary ideological factor, or “fact” as it was perceived, underlying this early institutional process. If biotechnology is *inherently* a general purpose technology, then its blossoming is merely a matter of fulfilling its promise, the influence of technological-push, while the international convergence around developing biotechnology activity, a demand-pull or economic system driven requirement. When the industry is already productive, what is the import of the difference between helping to fulfill its promise and the very creation of that promise? The answer lies in the way that we proceed as social scientists in extrapolating the outcome *post-facto* as a cause. Here, I show that there is a difference and that notions about what is economically possible and necessary play a role in how the future unfolds. Ultimately, whether a specific technology is the basis of a long wave is something that is only possible to assess *a posteriori*.

Regarding the role of IGOs in agenda setting and diffusion, I have argued that the OECD is an IGO well located to create and implement policy agendas. However, these policies may be more a reflection of what important members have already implemented or that would serve their interests. Such policies may not be in the best interest of other members, especially in the case of industrial policy, given the advantages of early entry and the extensive infrastructure and time to product in an industry such as biotechnology. While it is a seemingly harmless policy to promote when the result might be, for instance, more basic biology research funding, there are important opportunity costs to promoting policies in regions that won't benefit. This is especially the case in certain IGOs, such as the World Bank, where there is ample reason to expect that individual nations control the policy agenda. The U.S contributes twenty percent of the Bank's budget and appoints the president, who sets the overall agenda. And while Boli (1999) notes of INGOs and IGOs that "members stand on an equal footing with one another…and the one-member one-vote principle is followed religiously in both the selection of officers and the determination of policy…" (Boli and Thomas), this is of little consequence in the World Bank, where representation on their Executive Board consists of one member for each of eight developed nations while a single representative sits for 22 African nations. In this situation, it is unlikely that the interests of African nations are being served[58].

I now turn to a discussion of how this frame was used by transnational organizations. The cognitive aspects of the industry, the enabling frame and how it plays into local industrial development is belied by the constraints or the limits to how local firms and institutions, and on the aggregate, regional level production clusters, are created or reconfigured in fulfilling this vision in the hopes of attaining a more productive capacity. This is the next step in understanding not only the reach of transnational cultural processes, but also the globalization of an industry that has managed, despite many obstacles to somehow leave an imprint on industrial development.

[58] Devi Sridhar details how the World Bank implemented a nutrition program in Tamil Nadu, India that ran for years and for which the Indian government took out large loans. When it became apparent that the Bank's nutrition team refused to collect data for project evaluation purposes, the UK's Save the Children did a review showing that the Bank's program failed to improve rates of malnutrition in the region.

Chapter 3: Keywords and Frames: Biotechnology In the Global Setting

Introduction

This chapter examines culture in the context of a transnational level institutional process. In a statistical analysis, keywords (Ghaziani and Ventresca 2005; Williams 1976) are analyzed as cultural elements in how they acquire meanings over time. Research conferences provide such "cultural elements" (Mohr 1998) that suggest institutionalization[59]. Cultural elements are symbolic and embed technical work in a broader context. In biotechnology, these cultural elements can be found at conferences. Many conferences took place within the scientific community in concert with government agencies and other myriad organizations that took biotechnology in one aspect or another as its main topic of interest. Such conferences provided a key forum for negotiating the potential of biotechnology in its technical, discursive and economic facets during the phase of the biotechnology industry's evolution across borders. In a highly technical field, the development of a discourse should occur in an arena where professionals gather in person to discuss and concomitantly develop their own research in the field. Conferences "provide the opportunity to highlight trends and achievements, to redirect the course, and provide opportunities for

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[59] Mohr doesn't define elements but suggests that they are core constructions of the community in which they're found that reflect a cultural process. Powell and DiMaggio use the term cultural elements in a slightly different manner: the elements themselves are "taken for granted beliefs and widely held promulgated rules that serves as template for organizing" DiMaggio, Paul J. and Walter W. Powell. 1991. "The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organization Fields." in *The New Institutionalism in Organizational Analysis*, edited by Walter W. and Paul J. DiMaggio Powell. Chicago, IL: Chicago University Press.

communication among leaders..." (Barthel 1997). Proceedings embody the ethos, values and orientations of the meeting they summarize and the organizations that sponsor them.

This chapter describes an analysis of conference proceedings citations undertaken to examine the structure of the research community that built biotechnology, as well as the content of their discussion. I will describe the collection of an original data set comprised of biotechnology conference proceedings citations. Conferences took place between 1955 through 2005 all having the associated keyword *biotechnology*. I will present the actors that participated in the growing discussion on biotechnology as well as the regions within which conferences were held. Subsequently, I will present results of a statistical analysis, including those of a factor analysis of keywords that allows a view into the evolution of the industry as it formed.

Methodology

Data collection process

The conference database is an original analysis that uses conference proceedings citations to examine the long-term progression of actors and communities shaping a discourse. By capturing bibliographic items such as the title of a conference, the date and affiliated entitles, one can turn these elements into variables suitable for quantitative analysis. Such bibliographic data is normally used for citation analyses that examine the influence of a particular idea or scholar through a snowball of citations of a particular individual or group. In this study, they are used to examine a discursive frame development and institutionalization process.

The database was formed by searching for bibliographic sources using the keyword ‘biotechnology” contained in any field of the citation. More specifically the following terms were used:

Bioengineering
Biotechnologie
Biotechnology
Biotechnology industry/ies
Biotechnology and symposium
Biotechnology and congress/es

Catalogs searched included Worldcat, Proceedings First, Science Citation Index and the Directory of Published Proceedings

Endnote, a bibliographic software package, was programmed so that similar information that was entered differently in the catalog would be retrieved in the same Endnote citation field. For instance, conference organizers across a large number of citations were often listed in several different fields in the library catalog including "Author", "Editor" and "Notes" fields within Endnote. This issue occurs because there is no set standard for entering such information into the WorldCat database. In many cases, much of the conference information at the level of the Worldcat catalog was entered into the “Notes” field of the database and the data could only be extracted manually.

Through a series of successive searches, the resulting number of conferences was approximately 1400. Several searches were required to employ variations on the term “biotechnology” as noted above. The Endnote libraries were merged and subsequently saved as an Excel spreadsheet for an initial examination and reorganization. Data was cleaned and analyzed manually and subsequently using STATA version 9.0. and version 10.1.

I attempted to distinguish between the year of the conference and the year of the proceedings publication where possible. I do not expect to see any effect from this in the following analyses because potential lag times never exceed one year.

Duplicates in the form of several volumes of a single conference were eliminated. In cases where conferences were clearly part of a series, I attempted to retrieve remaining cases of a conference series that were not picked up in the initial rounds of data collection. In some instances, this allowed for an examination of the evolution of a concept in the title alone. For example, Alltech a firm that ran an annual symposium, changed the name of its conference over the course of a decade from “Biotechnology in the feed industry” to “Nutritional Biotechnology”. It is perhaps an indication of how biotechnology might have contributed to the reorganization of the sector (perhaps absorbed by a more generalized expansive industry).

Also regarding the issue of conference series, it is likely that the database *underestimates* the actual number of biotechnology conferences that took place, although it is uncertain the extent to which the count is underestimated. There are a number of series for which only several of the conferences of the series appear, for instance, the case of the *Biotechnology Symposium of the University of Leipzig*. The third and the fourth conferences from 2004 and 2005 are the only ones that were captured in the search. Presumably, there was a first and a second, however the conference may not have taken place in English or the proceedings may not have been published in English, or at all. Presently, I will address the issue of language in which the conferences were held.

Description of the database

The population is all conferences and symposia recorded in the Worldcat Library Catalog that have the keyword "biotech" in any Endnote citation field. The unit of analysis is the individual conference. Columns describe different aspects of the conference, such as title and organizers. The resulting number of conferences after removing duplicates was N=925[60]. The first conference that listed "biotechnology" as a keyword was in 1955. The final conference in the data occurred in 2005.

Most of the proceedings (96.5%) are in English. Instinctively, this would seem to present a problem of "missing" data, given that conferences held in other languages are not included. While I attempted to select for conferences in languages other than English (by using search terms such as "biotechnologie" or "biotec*), this issue is of arguably limited consequence. English is the international language of the scientific community. The vast majority of research

[60] In the tables for conference location and for conference sponsors, the n's are higher because the data were aggregated

journals are published in English. One of the earliest journals publishing work then considered biotechnology, *The Journal of Biotechnology and Bioengineering* (1962) was also published in English[61], suggesting that the process was initiated during a period where English had already been consolidated as the language of the international scientific community. Moreover, it is likely that the conference database captured both minor and major conferences, but when it did not, important ideas were carried to bigger conferences ultimately represented in this database. That is, institutional entrepreneurs from nations that would have participated in smaller conferences in their own language were likely to have met at one or more of the conferences contained here. As such, similarity of language is clearly part of the process of the formation of a global level discourse and the community that structures it.

Data Quality Issues

Cases were sorted and obvious duplicates were eliminated in Excel. The possibility for further duplicate conferences was examined later in Stata by reviewing conferences that took place in the same location and by cross-referencing the year and title of the conference.

Cases were reviewed individually and data in the final database was supplemented on a case-by-case reference back to the original endnote database or “library” to supplement any information that did not transfer through the original programming of Endnote.

[61] The journal was founded in 1959 as The Journal of Biochemical and Microbiological Technology and Engineering and changed its name in 1962.

Data Validity and Reliability

An internal control on reliability of these data is available in how previous findings on the biotechnology industry are in evidence here (Abbott and Hrycak 1990). Some of the results suggest that these data are reliable, in particular, the early participation of individual nations found below in Tables 5, confirmed by the year of national reports of several nations listed in the previous chapter.

Statistically, validity of the data is strongly suggested in how the measurement instruments vary over time, evident in the line plots of individual factors over time in the Results section of this chapter.

Variable creation

Basic data elements in string format (with the exception of conference year) were included in the data in their original form, such as title and organizers. Other variables were derived, such as the conference location and the sponsor categories. Below, I discuss individual variables creation in further detail.

NATION-STATE

I used the most specific level of available data that would be useful for an analysis. For example, if a conference was held in the United States in Iowa City, Iowa, the state was listed as "Iowa, U.S." If there was additional information available that indicated the conference was held by an international organization or that it had an international focus, the case was given an additional code (Iowa, U.S.; World). If there was no information on where the conference was, the cell was left empty.

Nations were grouped into regions. Regional groupings were based not only on geography, but also on social and political factors such as local sphere of influence and connection through supranational organizations such as ASEAN. Accordingly, the following regional groupings were created (note that for each group, the list contains only nations that were found in the data):

North America
Canada
Mexico
United States

Central America
Costa Rica
Guatemala

South America
Argentina
Brazil
Colombia
Venezuela

Northeast Asia
China
Hong Kong
Japan
Korea
Taiwan

South Asia
India
Indonesia
Malaysia
Pakistan

Singapore
Thailand

Middle East
Israel
Jordan
Saudi Arabia

Europe
Because these data cover the political reorganization of Europe after 1989, conferences were listed with political boundaries that have since changed. I listed each nation as it was for the year that the conference was held. In some cases (West Germany → Germany), the nation was recoded.

Austria
Belgium
Bulgaria
Croatia
Czechoslovakia
Czech Republic
Denmark
Finland
Hungary
Italy
France
Germany
Greece
Portugal
Slovakia
Slovenia
Spain
Sweden
Switzerland
Turkey
United Kingdom

Southern Europe
This variable is an attempt to solve the problem of categorization of Turkey. Turkey straddles both European and Middle Eastern geopolitical and cultural spheres, as is demonstrated by its membership in NATO and potential

accession to the European Union. In the regional variable **europe**, Turkish conferences were categorized (five cases) as European as they were mainly international and held in English. This variable is more culturally defined but the low N will make it less useful statistically than the aggregate variable **europe**.

Balkans
Bulgaria
Greece
Turkey

HDI

The United Nation's Development Program's Human Development Index ranks UN member nations by their level of development. According to the introduction of the 2008 Statistical Update, the ranking goes beyond a simple economic comparison. It is a composite measure of health, income and education that treats development as a concept. The index is a rank that is used to distinguish whether the country is a developed, a developing or an under-developed country (UNDP Human Development Indices 2008 Statistical Update).

Each conference was coded for its HDI rank based on where the conference was held. For instance, the conference that took place in Australia has an HDI rank of “4” while one in Nigeria has a rank of “154” and for Finland a “6”. The rank was assigned accordingly.

One problem with the use of this measure of development is that it ranks nations only for 2008 while conferences took place in individual nations over the course of several years in which the rank may have changed or before the rank was in use.

CONFERENCE LOCATION

The location of each conference was recorded manually based on information within each citation. From a substantive point of view, the location of a conference would seem to be irrelevant relative to the topic of the conference. That is not unlikely in the case where conferences are held in an exotic location intended to lure or lavish participants (as opposed to symposia which tend to be smaller gatherings of academics within a university setting). However, the conference location is relevant to the how conference activity may impact local industry development, either through the ideas created at the conference that are carried back to local settings, or through the participation of local institutions which learn and act based on conference ideas and action agendas. In a related way, the geographical region is relevant because conferences will tend to be held in those regions where research occurs. More often, conferences are held by institutions that have a geographic tie, i.e. Texas A&M University, the Singapore Society of Microbiology or the Israeli National Council for Research and Development. In general, it is in the interest of an entire research field when knowledge is advanced, but it is the special interest of these societies to strengthen career opportunities for membership within the territory that corresponds to their organization. So the American Society of Chemical Engineers will tend to have meetings within U.S. borders and those engineers will likely be employed within that area. To some degree, this will vary by the size of the nation where international conferences can provide local scholars an opportunity to present research and to network abroad, therefore learning and collaborating outside of their home organization.

SPONSOR

Each conference was reviewed through two databases (STATA and ENDNOTE) in order to derive all possible sponsors of a conference. This variable codes for each category of sponsor (international organization, university…) as follows:

1=Intergovernmental organization
2=Industry/private company
3=Government-military
4=Government-Department or Ministry
5=Professional Association (INTERNATIONAL)
6=Professional Association (LOCAL)
7=University (Public Research)
8=Private research (Research Institutes and Foundations)
9= NGO –misc (non of the above)

The coding scheme was obtained from patterns indicated by the data. In a number of cases where the nature or activities of the organization was unclear from the name of the association, I was able to locate the Association's website to determine a classification. In N=790 cases, there was only a single sponsor listed for the conference. The assumption of these data is that this was the only sponsor or the most important in terms of structuring participation and discourse. There is no way of testing this assumption using these data, but there is reason to believe that it is the case given the general coherence between the conference title and the organizing body.

SECTOR/ACTIVITY

This variable is intended to track the sectors in which biotechnology was being discussed. With its use, one could attempt to capture the evolution of conceptions of biotechnology based on shifting emphasis on different sectors.

Strict sectoral coding of these data however is inappropriate for several reasons. Categorization of some conferences was difficult due to the lack of information in the citation. In particular, further research was required to understand more in regard to either the conference or the subject itself. “Lignocellulosics”, for example, is a type of biomass that can be used for energy production or industrial and agricultural waste processing. One would first have to define the topic and then it should be further specified in the title or by the organization holding the conference in order to know the proper category (agriculture or energy). In a number of cases, no choice was possible. I will address this problem further in this chapter’s “Discussion” section.

Another consideration is the term “sector” itself. It is a broad term, perhaps too broad for many of the conferences captured here. It is tempting to try to make many conferences “fit” into a specific broad category, such as microbiology, but there are a number of complicating factors. Because many of the conferences are academic, the topics are more “basic science” in nature and a biotechnology application was envisioned only for some later point in time. Such conferences could only be categorized into academic disciplines or sub-disciplines. Trying to capture both disciplinary and industrial boundaries within the same variable is likely to obscure patterns that would otherwise be visible.

On the other hand, contained here are also titles that refer to more clear-cut industrial activities that fit more succinctly into a sector like “medicine”. However, these cases are relatively infrequent. For those where the downstream application was either included in the title or was obvious, categorization is simplified. For example, the conference *Biotechnology of plasma proteins: hemostasis, thrombosis and iron proteins: Proceedings of the International Symposium on Biotechnology of Plasma Proteins, Florence, April 9-11, 1990* can be coded under “Medicine”.

Ultimately, it is futile to attempt a sectoral classification of such titles as the *First Annual Conference of the Indian Society for Plant and Animal Biotechnology* or *High pressure food science, bioscience and chemistry* as there is no means by which to make a judgment. The dataset contains such a varied array of activities, because biotechnology has been used so loosely, but also because it captures the rise of the industry and the full array of “pure” and “applied” topics of research in which it was explored. It is in the difficulty of categorizing biotechnology conferences by sector that the seeds of cross-sectoral diffusion can be seen. This is likely what the early planners saw in a biotechnology.

A solution to this problem lies in the alternative of classification of conference subjects using keywords. A keyword, as defined by Ghaziani and Ventresca (2005) is “…a word or phrase, often mobilized by different groups of social actors for different purposes, whose meanings are contested during unsettled times” (Ghaziani and Ventresca 2005). They use keywords to study cultural change around the term *business model* using a data set of 500 journal abstracts over a 25-year period. Keywords in these data are activities or subjects that can be found in the title data and transformed into a series of binary variables. Keywords, as opposed to sectors, allow an examination of the importance of particular subjects or activities while avoiding the confusion of sectors in transition.

Classification by means of keywords is simpler, more accurate and truer to the data and the discursive trends. Moreover, this solves the issue of cross-classification by only focusing on a single word, thereby eliminating the problem of multicollinearity that would result from cases that could very easily belong in two separate categories.

Selection of Method

A factor analysis is an ideal method for studying cultural change over time. It is a statistical procedure the goal of which is to uncover a smaller number of latent (hidden) variables by studying the covariation among a set of observed variables (Beckfield). It is a method that reduces a large amount of textual data that would otherwise be ill-suited for statistical analysis. John Mohr, in his call to approach the analysis of meaning with a formalist approach describes what he sees as the core principles for a structural analysis of meaning: "(a) basic elements within a cultural system are identified, (b) the pattern of relations between these elements is recorded, (c) a structural organization is identified by applying a pattern-preserving set of reductive principles…and (d) the resulting structure (which can now be used as a representation for the meaning embedded in the cultural system) is reconnected to the institutional context…" (Mohr 1998:352).

The factor analysis of keywords accomplishes precisely the type of structural analysis of meaning that for which Mohr calls.

Description of the organizations

Universities

Universities were very often the conference venue. As places of learning, university research centers sponsored or held workshops or symposia. They play a central role as both the labor source for the industry, in the production of highly skilled labor, and as the origin of the research that is ultimately commercialized. They have an interest in the industry as they seek to patent research to benefit financially from basic research (Kenney 1988) and in the expansion of opportunities for research faculty that are increasingly motivated to seek financial opportunities outside the university setting (Kenney 1986 ; Powell 1998)

Non-profit research

This category includes non-profit research institutes such as the Electric Power Research Institute. These were coded as "private research" and are aspect of civil society organization. Institutes that were listed as part of a university were coded as "university". Likewise, private research foundations, whose goal is primarily to fund research, were counted as "private research".

Journals

In several instances, scholarly journals were the organizers of conferences. The journal of Biotechnology and Bioengineering organized a conference series under the leadership of Elmer Gaden, a biochemical engineer that has championed the industry for decades (Bud 1994). As organizers, journals were coded under “private research.”

U.S. Congressional Hearings

Biotechnology was often a topic within U.S. Congress. N=135 cases were congressional hearings. These hearings were excluded from the conference analyses because they are fundamentally different from conferences in that they are not open forums for discussion of research but rather presentations made at the request of policy makers.

Professional Societies

Professional associations or societies were in large part organizations of academics working within a particular field such as microbiology or engineering. Many of the associations were international and were coded as such. Organizations qualified as international if they contained the word “international” in their name or if further research indicated their international nature. Local organizations were those of a delimited region and were qualified either by the name of a particular nation (American Chemical Society) or a region (African

Policy Studies Network; European Brewery Convention[62]). International unions and federations that were organized around a professional activity such as bioengineering were also coded as professional society. Membership in a professional society such as *Societas Biochemica, Biophysica et Microbiologica Fenniae*, a Finnish organization, connects members to several international professional associations such as the Federation for European Microbiological Societies. However, the main activities of the organization are local and so it was coded as such. Similarly an organization such as The Society for General Microbiology, which is based in the U.K. is somewhat difficult to classify because is a local organization and its membership, according to the website is 75% based in the U.K. but it aspires to international membership and has the prestige of an older, more established organization and therefore the potential to attract international membership.

The local or international nature of these associations is important in that it allows an understanding of the potential scope of the diffusion of particular ideas associated with the industry as well as the scope of the organizations that were most closely working with some vision of the industry.

Intergovernmental Organizations

Intergovernmental organizations such as the Organization for Economic Cooperation and Development (OECD) or the United Nations Development Program (UNDP) are organizations that represent the interest of the state in the international setting. As demonstrated in another chapter of this dissertation, the

[62] "Because European professional associations can easily be argued to be "international", I recoded these data as such. The change did not make a substantive difference in any analysis.

OECD took an early interest in the industry, with other IGOs soon following suit. While some activities might be geared toward civil society, the members are nations rather than other entities. Following Inoue and Drori (2006) It is expected that IGO's will represent a smaller proportion of organizations here than INGO's.

Government

The role of the national governments in helping to build biotechnology has been well documented (Kenney 1986; Wiegele 1991). In general, if not with direct financial assistance to the industry, governments participate through funding of basic research that has application potential. This has been the tendency of the U.S. government even before biotechnology but more so following World War II (Noble 1977),. Governments have also participated through regulation or an intentional lack regulation to allow lines of research to develop. Policies may be coherent and centralized through a single department as in the case Germany (EU Report) or they may be haphazard, distributed through several government departments or ministries. They have also played a role in encouraging universities to patent research,

Keyword analysis

Conference titles were examined and searched for n=112 words with which biotechnology was associated. The analysis included both theoretically relevant terms such as "medicine" and "environment" as well as those that appear with relative frequency, such as "polymer", "waste" or "tissue". The result of the initial search, with keywords in order of the frequency of appearance, is displayed in Table 13. (A second table with keywords in alphabetical order appears in the Appendix). In general, keywords with n≥20 single mentions over the course of the 50 years (1955-2005) were retained for the analysis with an exception made for those with particular theoretical relevance (where the criterion was 15≤ n ≤20). Keywords were indicated in the data as keyword=1 if present and keyword=0 if absent for each conference. Data were aggregated by year for all keywords so that a mean, in this case a proportion, of conferences that took the keyword as its theme, became the cell entry. The keywords were correlated and the correlation matrix factor analyzed as described below.

I performed an exploratory analysis to try to re-assemble or aggregate keywords into sectors, for both quantitative and qualitative reasons. Quantitatively, working with variables that have a higher frequency of occurrence would allow individual factor analyses for each decade. This might have provided a differently detailed understanding of the evolution of the discourse. However, when I factor analyzed the data separately for each decade, the result, for each decade except for the last (1995-2005) was a Heywood case[63]. It also might have allowed theoretically relevant keywords into the final analysis that didn't qualify due to mentions of n<20. Qualitatively, aggregating some of the more obvious words makes sense when the low-n keywords were added to words that have a naturally broader coverage than others, as in the case of medicine,

[63] A Heywood case is a statistical anomaly where the communality of the factor model exceeds 1. The communality of the model will always lie between 0 and 1 unless there is a problem. In the case of the factor model of keywords by decade, the problem is the lack of sufficient data to provide stable estimates.

microbiology or plant biology (see Keywords Table 13). This method requires more substantive knowledge of conference topics to ensure all possible cases are captured. For example, a search for "enzymes", one of the more prevalent words in the title data would not return "amylases" and "proteases". Both of these are enzymes and conferences were held in honor of them. Ultimately, eigenvalues for factors using aggregated variables were often $\psi \leq 1$ and they were therefore not the final results presented. Further, individual keywords are cleaner to use in that they avoid the problem of multicollinearity as previously mentioned. Finally, the point of a discourse analysis of keywords would not be to bury particular keywords under larger headings as this obscures the symbolic muscle that keywords seem to exert. Capturing sectoral change with a keyword analysis such as this would likely require a keyword search for individual sectors from a comparative approach. Sectors are likely to change most often at the margins and how truly transformative any new technical or organizational development would be in a sector would require a more in-depth comparative analysis of sectors than is proposed here.

For similar reasons, as well as for clarity and parsimony, I opted to remove a small number of the variables that have greater than 20 mentions. Their presence was either nonsensical, overlapped too closely with another word (biotechnology and technology) or could signify concepts that weren't technical such that their interpretation was difficult (*develop* and *control*).

Model selection

I performed a factor analysis using Stata to determine co-occurrence of keywords over time within the set of biotechnology related conferences. Stata's default setting is the principal-factor method, which analyzes the correlation matrix of input variables. The factor loadings are computed using the squared multiple correlations as estimates of the communality.

Given that all models were X^2 significant, the final model was selected based on a number of issues. A model with more factors rather than less, was chosen based on the need to balance the amount of variance explained by each factor against the substantive interpretability of individual factors. Exploratory analyses showed that factor loadings for defining variables were higher (≥.70) in models that did not restrict the number of factors by default. When the number of factors was restricted to $f<5$, factor loadings for defining variables were normally lower, in the range of $x \leq .5$. However, restricted models grouped a greater number of variables, between three and five per factor with loadings of $x \geq .5$, the standard value at which defining variables are selected. Unrestricted models on the other hand tended toward two defining variables per factor. Restricted models explained a greater proportion of variance per individual factor than did unrestricted models, which required at least double the number of factors to explain a similar proportion of variance. Unsurprisingly, eigenvalues were also higher for models with fewer factors. After testing several models to find the optimal number of factors, it is clear that the smaller models group elements that may not be related substantively, but merely mathematically because of the constraints of the procedure. Thus, while the models restricted to three to four factors are X^2 significant, yield an acceptable proportion of variance explained, have acceptable factor loadings and are by definition more parsimonious, factors within the unrestricted or less restricted model are interpretable within the context of historical events. The more elaborate model ultimately reveals more of the subtleties of such a complex phenomenon. On the other hand, models with more than 8 factors seemed to be diluted, as eigenvalues of several factors dipped below one. Testing a variety of models also revealed that certain groupings are very stable and common, more so than others, which varied when the number of factors were altered. A model with 8 factors retains most of these groups and it is therefore the model retained.

Factors were rotated using the orthogonal varimax rotation option. This maximizes the variance of the squared loadings within factors. Factor loadings were evaluated based on $x \geq \pm.40$. All evaluation of results is based upon rotated factors.

Given that only n=38 or 4% of conferences occurred before 1975, I will present the same model both for the full data as well as for the data for the 30 years spanning forward. The tables for the full model are presented in the Appendix for comparison. Eigenvalues in the 30 years model were higher for individual factors and remained >1 for each factor. This was not the case for the full data and was the deciding factor in using a subset of data for the analysis.

Results

Descriptive tables

Table 2: Conferences Over Time (1955 To 2005)

	Freq.	%
1950's	2	0.2
1960's	15	1.6
1970's	55	6.0
1980's	300	32.4
1990's	413	44.7
2000's	140	15.1
Total	925	100.0 [64]

Table 3: Conferences Over Time (5 Year Increments 1955-2005)

	Freq.	%
1955-1959	2	0.2
1960-1964	6	0.7
1965-1969	9	1.0
1970-1974	21	2.3
1975-1979	34	3.7
1980-1984	72	7.8
1985-1989	228	24.7
1990-1994	242	26.2
1995-1999	171	18.5
2000-2005	140	15.1
Total	925	100.0

[64] For all tables, percentages may not add up to 100 due to round-off error.

Figure 5: Number of Biotechnology Conferences per Year 1955-2005

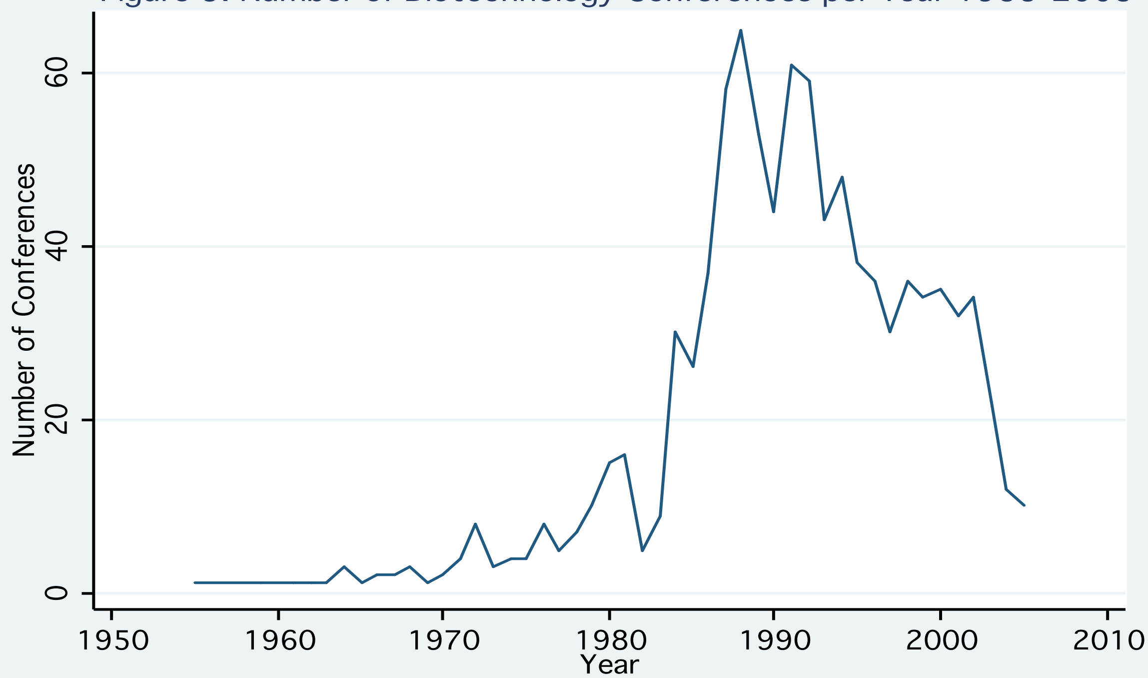


Table 2 and Table 3 give the frequency of conferences over time, from 1955 through 1975. For the initial 15 years in which biotechnology was used as a conference keyword, it increased in a slow trickle until 1970 when the number of conferences doubled from the previous five years. The most significant jump is shown in Table 3, between the late 1970s and the early 1980s where the number of conferences more than tripled. The proportion remains stable over the following five years, in the early 1990s and then begins a slow decline over the next ten years. The peak period for conferences was from 1985 to 1995.

Table 4 and Table 5 display the regional concentration of conferences related to biotechnology, Table 4 giving the distribution over time. There are two noteworthy items. First, North America and Europe (bold type) held over 75% of the conferences, that is, they controlled that margin of the discussion on biotechnology. Second, both tables show the virtually equal overall contribution of Europe and North America to the conference activity. Table 5 indicates an approximate difference of 13 percentage points with North America having the higher proportion in the 1960s. This gradually decreases until the 1990s when the proportion of conferences are equivalent and then after 2000, Europe shows a 10 percentage point increase. Japan builds and maintains a presence from the 80s onward, as does India.

Table 4: Regional Focus Of The Conference

	Freq.	%
Africa	13	1.3
Australia/New Zealand	22	2.3
Cent/South America	17	1.8
Europe	364	37.5
Middle East	11	1.1
Northeast Asia	67	6.9
North America	371	38.3
Russia	12	1.2
South Asia (India)	81	8.4
Other region	12	1.2
Total	970*	100.00

*N is higher for this table because a number of conferences were national collaborations

Table 5: Regional Focus of Conference by Decade*

	Decades						
	50s	60s	70s	80s	90s	2000s	Total
Sponsor							
Africa	0 (0.0)	1 (6.7)	0 (0.0)	0 (0.0)	7 (1.6)	5 (3.3)	13 (1.3)
Australia/NZ	0 (0.0)	0 (0.0)	3 (5.3)	8 (2.6)	8 (1.8)	3 (1.2)	22 (2.3)
Central/S. America	0 (0.0)	1 (6.7)	0 (0.0)	5 (1.6)	9 (2.1)	2 (1.3)	17(1.8)
Europe	**1 (50.0)**	**5 (33.3)**	**23 (40.4)**	**115 (37.1)**	**159 (36.6)**	**61 (40.1)**	**364 (37.5)**
Northeast Asia**	0 (0.0)	1 (6.7)	1 (1.8)	25 (8.1)	37 (8.5)	15 (9.9)	79 (8.1)
North America	**1 (50.0)**	**7 (46.7)**	**30 (52.6)**	**128 (41.3)**	**157 (36.2)**	**48 (31.6)**	**371 (38.3)**
South Asia (India)**	0 (0.0)	0 (0.0)	0 (0.0)	24 (7.7)	50 (11.5)	18 (11.5)	92 (0.77)
Other region	0 (0.0)	0 (0.0)	0 (0.0)	5 (1.6)	7 (1.6)	0 (0.0)	12 (1.2)
Total	2 (100.0)	15 (100.0)	57 (100.0)	310 (100.0)	434 (100.0)	152 (100.0)	970 (100.0)

*Due to small n's, regions were aggregated as well as decades. Northeast Asia was combined with Russia. South Asia was combined with Middle East.

Europe and North America break down as follows:

Table 6: European Nations Having Biotechnology Related Conferences

	Freq.	%
Austria	11	3.0
Belgium	11	3.0
Czech Republic	11	3.0
Finland	24	6.6
France	18	5.0
Germany	44	12.1
Great Britain	62	17.0
Italy	25	6.9
Netherlands	44	12.1
Sweden	12	3.3
All Others	102	28.0
Total	364*	100.0

*Nations listed here comprised at least 3% of European total.

Table 7: North American Nations Having Biotechnology Related Conferences

	Freq.	%
Canada	33	8.9
Mexico	11	3.0
United States	327	88.1
Total	371	100.0

A closer examination of the 1950s and 60s reveals that Sweden and the U.S. were the first two nations to have a biotechnology related conference. The 1960s breakdown indicates that Great Britain, Sweden and the Czech Republic had conferences, but so did Ethiopia, a landmark conference in the developing world entitled *Global Impacts of Applied Microbiology* well documented in the literature (Bud 1994). Venezuela and Russia also had conferences in this period. Of North America, the U.S. and Canada were also part of the early biotech discussion. Also notable of the developing regions is that while a small handful of nations were present in the early discussion, their participation stalled and never grew substantially beyond those initial conferences, except in the case of India. These items are indicative of the reliability of these data, as they have been documented in Robert Bud's work although never measured quantitatively.

Table 8. Nations that Held the Most Biotechnology Conferences

Nation	Freq.	%
U.S.	322	26.1
Great Britain	62	5.0
India	49	4.0
Germany	44	4.0
Netherlands	44	4.0
Japan	42	3.4
Canada	33	2.7
Italy	25	2.0
Finland	24	1.9
China	18	1.5

Table 8 lists the top ten nations holding conferences in descending order. The U.S. is a striking leader, where it held just over 25% of all conferences. The following nine top conference holders equal together just over the U.S. total. India is an important presence, shown to be the only top conference holder in the developing world, but Table 5 above (Regions by Decade) demonstrates that its participation only began to increase in the 80's and did not increase in earnest until the 90s. Japan has been the leading Asian nation in biotechnology and a presence from the very beginning (Kenney 1986). According to other sources (European Commission report; Bud 1994), all of the nations presented here are known sources of research development on biotechnology. The only exception is Italy. An examination of conference titles and other data reveals that only about a third (8/25) of sponsoring organizations for Italian conferences were actually Italian. The rest were European, IO or unknown. This suggests that Italy is present here more as an enticing conference location rather than a contributing force in the biotechnology discussion documented here.

Table 9: Biotechnology Conference Sponsors

	Freq.	%
Intergovernmental Organization	53	4.5
Industry	77	6.6
Government: military	8	0.7
Government: Dept/Ministry	213	18.2
Professional Association: int'l	153	13.0
Professional Association local	329	28.1
University Research/public	178	15.2
Private research & Foundations	153	13.0
NGO: nota	9	0.8
Total	1173*	100.0

*N represents aggregate data because 135 conferences had between two and five sponsors listed.

Table 10: Biotechnology Conference Sponsors by Decade

	Decades						
	50s	60s	70s	80s	90s	2000s	Total
Sponsor							
IGO	0 (0.0)	0 (0.0)	7 (9.9)	16 (4.1)	23 (4.5)	7 (3.9)	53 (4.5)
Industry	0 (0.0)	1 (5.8)	0 (0.0)	39 (10.0)	29 (5.7)	8 (4.4)	77 (6.6)
Government*	0 (0.0)	4 (23.5)	13 (18.3)	80 (20.5)	88 (17.3)	36 (19.8)	221(18.5)
Prof. Assoc*	2 (66.7)	10 (58.8)	36 (50.7)	134 (34.3)	212 (41.7)	88 (48.4)	482 (41.1)
University	1 (33.3)	0 (0.0)	10 (14.1)	63 (16.1)	77 (15.1)	27 (14.8)	178 (15.2)
Private Research	0 (0.0)	2 (11.8)	5 (7.0)	54 (13.8)	76 (14.9)	16 (8.8)	153 (13.0)
NGO: nota	0 (0.0)	0 (0.0)	0 (0.0)	5 (1.3)	4 (0.79)	0 (0.0)	9 (0.77)
Total	3 (100.0)	17 (100.0)	71 (100.0)	391 (100.0)	509 (100.0)	182 (100.0)	1173 (100.0)

*Professional Associations and Government categories were each collapsed for this table.

Of conference sponsors, Tables 9 and 10, display the rich variety of organizations that have taken part in the discussion of biotechnology at conferences. Professional associations comprise the majority of organizations. In agreement with Inoue and Drori (2006), these data show that IGOs are part of the landscape but they represent a smaller proportion of the total presence than do professional associations. Governments participated through IGOs but they also played a direct role in sponsoring biotech discussion at conferences at a rate of close to one-fifth of the total (18.5%).

In light of the general trends present in the later time periods, according to these data, the 50s and 60s indicate the incipient phase of a larger process. However the low cell sizes for those two decades make a refined interpretation difficult. Given that, the 60s suggest the early entrance of government, and professional associations. Relative to other groups, once government and university are part of the discussion, they remain so, rather steadily over time. By the 1990's however, the proportional role of professional societies in the biotech discussion begins to overwhelm the presence of government. The generally dominant presence of professional associations might be viewed as a more general trend of the growth of the NGO sector internationally. (Boli and Thomas 1999). IGO's began taking part in conferences in the 1970s, suggesting a model where IGOs pick up on activities in member nations, document and legitimize them and then become a force for diffusion (a process I suggested in the first chapter of this dissertation). NGO presence was largely a strong and stable force in the conference scene over the course of fifty years.

At the same time however, industry, university research and private research participation increased. Industry and university would be the main beneficiaries of a new patent law, resulting from the *Diamond v. Chakrabarty* case that allowed the patenting of genetic materials and therefore, potential economic returns for genetic experimentation. This is the moment when ideals and visions came together with legal backing and scientific technique to move the industry forward. From that period onward (the 80s), Universities and IGO's became a very stable presence in the conference venue.

These conferences point to a world-polity structure around biotechnology (Drori et al. 2003). They show which organizations in the broadest sense were interested in developing biotechnology at different time points. They point to the structuration of the international biotechnology community by permitting an examination of the full range of organizations that constitute the community.

Across the various organizational categories there is the tendency to maintain a relatively stable presence once entry occurred. Fluctuations over time, for instance from the 1970s to the 1980s represent the organizational field becoming more crowded.

Moreover, these data illustrate a culture-structure (Kane 1991, Mohr 1998) or an ongoing site for the exploration and, perhaps, sedimentation of meaning toward institutionalization.

Table 11: Level of Development of Nations Holding Biotechnology Conferences*

	Freq	%
Low	6	0.7
Medium	99	11.1
High	785	88.2
Total	890	100.00

*Level of Development measured by UNDP HDI, 2008
*N is aggregated individual level country data available.

Table 12. Development Level of Host Country by Decade

	Level of Development		
	HDCs	LDCs	Total
Decade			
50's	2 (100.3)	0 (0.0)	2 (100.0)
60's	13 (92.9)	1 (7.1)	14 (100.0)
70's	52 (100.0)	0 (0.0)	52 (100.0)
80's	266 (92.7)	21 (7.3)	287 (100.0)
90's	340 (85.0)	60 (15.0)	400 (100.0)
2000's	112 (83.0)	23 (17.0)	135 (100.0)
	785 (88.2)	105 (11.8)	890 (100.0)

Pearson X^2 (5) = 20.5546 Pr = 0.001

The development level of the nation-state that holds the conference is described in Tables 11 and 12. It is remarkable that overall, 88% of biotechnology conferences have taken place in the developed world. It is unsurprising given that this pattern corresponds to the region of the world where the scientific infrastructure at the basis of the industry is most advanced and where the political will to promote industrial biotechnology seems to have been greatest. However, it is clear that the initiatives did not for the most part come from the poorest regions despite that much of the discourse is geared toward how genetic advances could benefit the most pressing problems in poor regions of the world. The sudden increase between the 80s and 90s of the proportion of conferences held by low/med countries is likely a key moment in diffusion.

Table 13: Keywords from Title Data, by Frequency of Mention

Word	N	%
Technolog(y)	542	(58.6)
Biotech	488	(52.8)
Gene(tic)	85	(9.2)
Plant	76	(8.22)
Environmental	71	(7.67)
Microb(Sklair)	70	(7.57)
Chemical	62	(6.70)
Product(ion)	61	(6.59)
Food	54	(5.84)
Industr(y)	50	(5.41)
Engin(eering)	48	(5.19)
Process	48	(5.19)
Develop(ment)	47	(5.08)
Molecul(ar)	42	(4.54)
Cell(ular)	41	(4.43)
Medi(cal)	35	(3.78)
Agricult(ure)	34	(3.68)
Paper	32	(3.46)
Animal	29	(3.14)
Material	26	(2.81)
Biochem(istry)	23	(2.49)
Fuel	22	(2.38)
Control	21	(2.27)
Mechanic(al)	21	(2.27)
Oil	19	(2.05)
Tissue	19	(2.05)
Gas	18	(1.95)
Protein	18	(1.95)
Improv(ing)	18	(1.98)
Nutrition	17	(1.84)
Safe	17	(1.84)
Pharma(aceutical)	16	(1.73)
Natur(al)	15	(1.62)
Breed(ing)	14	(1.51)
Enzyme	14	(1.51)
Health	14	(1.51)
Biocat(alysis)	13	(1.41)
Bioeng(ineering)	13	(1.41)
Organism	13	(1.41)
Diseas(e)	12	(1.30)
Horticulture	12	(1.30)
Human	12	(1.30)
Therap(eutic)	12	(1.30)
Bacteria	11	(1.19)
Biomed(ical)	11	(1.19)
Energy	11	(1.19)
Fermentation	11	(1.1
Waste	11	(1.19)
Policy	10	(1.08)
Protect	10	(1.08)
Comput	9	(0.97)
Heat	9	(0.97)
Nitrogen	9	(0.97)
Polymer	9	(0.97)
Quality	9	(0.97)
Remediat(ion)	9	(0.97)
Resource	9	(0.97)
Treatment	9	(0.97)
Cellulose	9	(1.01)
Blood	8	(0.86)
Conserv(ation)	8	(0.86)
Marine	8	(0.86)
Clinic(al)	7	(0.76)
Coal	7	(0.76)
Diagnos(tic)	7	(0.76)
Economic	7	(0.76)
Forest	7	(0.76)
Informat(ion)	7	(0.76)
Strateg(y)	7	(0.76)
Aqua	6	(0.65)
DNA	6	(0.65)
Ethics	6	(0.65)
Global	6	(0.65)
Nucle(ar)	6	(0.65)
Recombinant	6	(0.65)
Tropic	6	(0.65)
Water	6	(0.65)
Cancer	5	(0.54)
Genom(ic)	5	(0.54)
Ligno(cellulosic)	5	(0.54)
Membrane	5	(0.54)
Physic(al)	5	(0.54)
Aerospace	4	(0.43)
Biophysic(s)	4	(0.43)
Drug	4	(0.43)
Ecolog(y)	4	(0.43)
Evolut(ion)	4	(0.43)
Fung(i)	4	(0.43)
Innovation	4	(0.43)
Mycology	4	(0.43)
Seed	4	(0.43)
Tool	4	(0.43)
Wood	4	(0.43)
Automat(ion)	3	(0.32)
Electro(nic)	3	(0.32)
Ethylene	3	(0.32)
Hydrolys(is)	3	(0.32)
Immuno	3	(0.32)
Pollut(ion)	3	(0.32)
Risk	3	(0.32)
Thermal	3	(0.32)
Tree	3	(0.32)
Virus	3	(0.32)
Yeast	3	(0.32)
Legal	3	(0.32)
Bioinfo(rmatics)	2	(0.22)
Hazard	2	(0.22)
Mineral	2	(0.22)
Political	2	(0.22)
Pulp	2	(0.22)
Hormon(e)	2	(0.22)
Reclam(ation)	2	(0.22)
Fiber	1	(0.11)
Vaccin(e)	1	(0.11)
Biomass	0	(0.00)

Table 14: Correlation Matrix of Selected Keyterms (as Dummy Variables), Conference Proceedings Data 1975-2005*

	year	agri	animal	bioche	biotec	chem	engine	food	gas	gene	improv	industr	materi	medi	microb	molec	nutritio	oil	pharm	plant	proces	prduct	protein	safe	tissue
year	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
agriculture	-0.031	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
animal	-0.166	0.097	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
biochem	0.144	0.006	-0.029	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
biotech	0.225	0.035	-0.029	-0.016	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
chemical	-0.259	-0.029	-0.023	0.263	0.003	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
engineering	0.241	-0.040	-0.012	0.147	-0.121	0.192	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
food	0.032	0.049	-0.045	0.020	0.005	-0.011	-0.045	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
gas	-0.023	-0.028	0.020	-0.023	0.039	0.056	-0.016	-0.035	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
gene	-0.198	-0.005	0.089	-0.005	-0.080	-0.058	0.132	-0.066	-0.046	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
improv	0.356	0.014	0.154	-0.023	0.024	-0.038	0.012	-0.002	-0.020	0.113	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—
industry	-0.121	0.004	0.012	0.054	0.054	0.051	-0.006	0.063	0.001	-0.046	-0.034	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—
material	0.359	0.002	0.007	-0.027	-0.101	-0.019	-0.030	-0.014	-0.024	-0.033	0.023	0.017	1.000	—	—	—	—	—	—	—	—	—	—	—	—
medi	0.166	-0.021	0.013	-0.038	-0.047	-0.044	-0.039	-0.059	0.037	-0.061	-0.033	0.029	0.018	1.000	—	—	—	—	—	—	—	—	—	—	—
microbiology	-0.705	-0.034	-0.052	0.007	-0.204	0.005	-0.016	-0.019	-0.040	0.128	-0.040	-0.032	-0.024	0.042	1.000	—	—	—	—	—	—	—	—	—	—
molecular	0.318	-0.043	-0.039	-0.035	-0.054	-0.059	-0.068	-0.032	-0.031	0.140	0.082	-0.052	-0.037	-0.052	0.075	1.000	—	—	—	—	—	—	—	—	—
nutrition	0.368	0.059	0.114	-0.022	-0.032	-0.037	-0.042	0.206	-0.019	-0.017	0.039	0.039	-0.023	0.004	-0.039	-0.030	1.000	—	—	—	—	—	—	—	—
oil	0.067	0.012	-0.026	-0.023	0.030	0.022	-0.018	-0.036	0.752	-0.047	-0.020	-0.001	-0.025	0.068	-0.013	-0.032	-0.020	1.000	—	—	—	—	—	—	—
pharm	0.062	-0.028	-0.026	-0.023	0.030	-0.008	0.009	0.029	-0.020	-0.047	-0.020	-0.001	0.022	0.068	-0.041	-0.032	-0.020	-0.021	1.000	—	—	—	—	—	—
plant	0.181	0.070	0.065	0.017	0.032	-0.002	-0.026	-0.052	0.032	0.124	0.110	-0.064	0.009	0.018	0.001	0.205	-0.019	0.028	-0.023	1.000	—	—	—	—	—
process	-0.099	-0.046	-0.014	-0.037	-0.062	-0.004	0.066	0.046	0.038	-0.060	-0.033	0.009	0.108	-0.034	-0.012	-0.004	-0.032	0.035	-0.034	-0.078	1.000	—	—	—	—
product	-0.075	-0.006	0.177	0.014	0.007	-0.071	-0.067	0.027	-0.037	-0.042	-0.006	0.014	-0.019	-0.024	0.006	-0.058	-0.036	-0.039	0.146	-0.059	0.056	1.000	—	—	—
protein	-0.300	-0.028	-0.025	-0.023	-0.024	-0.007	0.039	-0.035	-0.020	0.034	-0.020	0.001	-0.024	0.002	-0.011	0.007	-0.019	-0.020	-0.020	-0.047	0.002	0.026	1.000	—	—
safe	0.154	-0.027	-0.025	-0.022	0.033	-0.037	0.043	0.172	-0.019	0.037	-0.019	-0.033	-0.023	0.004	-0.009	-0.030	0.041	-0.020	-0.020	-0.019	0.041	-0.004	-0.019	1.000	—
tissue	0.508	-0.028	-0.026	-0.023	-0.092	-0.039	0.171	-0.004	-0.020	-0.021	-0.020	-0.035	0.068	0.034	-0.041	0.042	-0.020	-0.021	0.033	0.181	-0.034	-0.008	-0.020	-0.020	1.000

Table 15: Correlation Matrix of Selected Keyterms, Proportion of Conferences/Year with Specified Keyterm, Conference Proceedings Data 1975-2005

	year	agri	animal	bioche	biotec	chem	engine	food	gas	gene	improv	industr	materi	medi	microb	molec	nutritio	oil	pharm	plant	proces	prduct	protein	safe	tissue
year	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
agriculture	-0.031	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
animal	-0.166	0.149	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
biochem	0.144	0.166	-0.088	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
biotech	0.225	0.199	-0.081	0.085	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
chemical	-0.259	-0.292	-0.017	0.216	-0.138	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
engineering	0.241	0.086	-0.137	0.104	0.071	-0.225	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
food	0.032	0.184	-0.251	-0.068	0.273	-0.368	0.317	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
gas	-0.023	-0.098	0.141	0.259	-0.021	0.360	0.129	-0.147	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
gene	-0.198	-0.096	0.336	-0.350	0.161	-0.108	-0.238	-0.327	0.071	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
improv	0.356	0.137	0.297	-0.087	-0.028	0.006	0.053	-0.107	0.044	0.110	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—
industry	-0.121	-0.158	-0.035	0.550	0.169	0.242	0.077	0.279	0.397	-0.408	-0.186	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—
material	0.359	0.100	0.117	-0.210	-0.258	-0.216	-0.064	0.026	-0.060	-0.025	0.390	-0.350	1.000	—	—	—	—	—	—	—	—	—	—	—	—
medi	0.166	0.308	0.029	-0.169	-0.106	-0.411	-0.069	0.112	-0.062	-0.206	0.201	-0.172	0.491	1.000	—	—	—	—	—	—	—	—	—	—	—
microbiology	-0.705	0.060	0.000	-0.238	-0.561	0.283	-0.001	-0.033	-0.138	-0.182	-0.249	-0.186	-0.024	0.067	1.000	—	—	—	—	—	—	—	—	—	—
molecular	0.318	0.387	0.034	0.221	0.175	-0.089	0.080	-0.034	-0.141	-0.180	0.201	0.099	-0.239	0.074	-0.290	1.000	—	—	—	—	—	—	—	—	—
nutrition	0.368	0.188	-0.004	0.046	0.240	-0.211	0.034	0.133	0.086	-0.130	0.042	-0.053	-0.181	0.319	-0.325	0.311	1.000	—	—	—	—	—	—	—	—
oil	0.067	-0.163	-0.087	0.263	-0.136	0.208	0.078	-0.178	0.873	-0.056	0.025	0.323	-0.162	0.089	-0.144	-0.024	0.262	1.000	—	—	—	—	—	—	—
pharm	0.062	-0.032	-0.183	-0.104	0.247	-0.321	0.341	0.730	-0.085	-0.229	-0.024	0.268	-0.197	-0.002	-0.162	0.076	0.240	-0.020	1.000	—	—	—	—	—	—
plant	0.181	0.316	0.028	0.304	0.314	0.228	0.131	-0.008	0.354	0.112	0.006	0.060	-0.165	-0.181	-0.323	0.244	0.225	0.215	-0.021	1.000	—	—	—	—	—
process	-0.099	0.015	-0.116	0.267	0.181	0.215	-0.038	-0.172	0.466	-0.087	0.042	0.412	-0.155	0.042	-0.115	0.219	-0.118	0.452	-0.184	0.148	1.000	—	—	—	—
product	-0.075	-0.286	0.438	-0.005	0.101	-0.196	-0.036	-0.432	0.155	0.550	-0.175	0.005	-0.053	-0.181	-0.185	-0.215	-0.194	0.035	-0.375	-0.158	0.126	1.000	—	—	—
protein	-0.300	-0.253	-0.157	-0.224	-0.022	0.072	-0.315	-0.279	-0.051	0.662	-0.176	-0.297	-0.222	-0.177	-0.020	-0.123	-0.156	0.007	-0.177	0.135	0.002	0.188	1.000	—	—
safe	0.154	0.023	-0.043	-0.148	0.167	-0.148	0.162	0.013	0.364	0.160	-0.158	-0.058	0.026	0.054	-0.262	0.076	0.046	0.314	0.040	0.383	0.311	0.080	0.030	1.000	—
tissue	0.508	0.102	-0.322	0.062	0.260	-0.182	0.592	0.353	-0.057	-0.141	0.005	-0.025	0.067	-0.025	-0.278	0.098	0.172	-0.131	0.187	0.353	-0.051	-0.130	-0.158	0.214	1.000

Table 16: Factor Loadings, Keyword Data 1975-2005, Rotated Factors*

		Factors							
		Energy	Rise of Genetics	Molecular Bio weds Agriculture	Biotech Replaces Microbiology	Decline of Chemistry Pharma	Tissue Engineering	Materials in Medicine	Animal Modification
Eigenvalues	unrotated	3.584	3.239	2.805	2.299	2.014	1.597	1.286	1.174
	rotated	2.819	2.542	2.333	2.193	2.129	2.088	2.058	1.836
Variable									
agriculture		-0.193	-0.235	0.626	-0.066	0.112	0.045	0.169	0.061
animal		-0.045	-0.051	0.131	-0.023	-0.058	-0.159	0.153	0.845
biochem		0.207	-0.401	0.254	0.357	-0.346	0.122	-0.243	0.022
biotech		-0.027	0.150	0.338	0.505	0.227	0.346	-0.189	-0.009
chemical		0.178	-0.018	-0.141	-0.043	-0.854	-0.100	-0.186	-0.127
engineering		0.064	-0.321	-0.079	-0.164	0.187	0.711	-0.048	0.030
environment		0.252	-0.069	0.108	-0.849	-0.063	0.182	-0.018	-0.103
food		-0.168	-0.363	-0.024	0.117	0.516	0.315	-0.073	-0.402
gas		0.899	-0.056	-0.066	0.001	-0.169	0.113	-0.025	0.159
gene		-0.036	0.824	-0.042	0.076	0.097	0.030	-0.006	0.406
improv		-0.016	0.014	0.226	0.132	-0.106	0.015	0.667	0.124
industry		0.352	-0.536	-0.091	0.554	-0.067	-0.004	-0.393	-0.043
material		-0.094	-0.070	-0.195	-0.053	0.071	0.024	0.869	0.029
medi		0.155	-0.167	0.418	-0.142	0.346	-0.107	0.554	-0.180
microbiology		-0.210	-0.253	-0.351	-0.581	-0.190	-0.359	-0.099	-0.086
molecular		-0.035	-0.093	0.758	0.122	-0.049	0.018	-0.061	-0.034
nutrition		0.188	-0.019	0.596	-0.175	0.294	0.065	-0.099	-0.080
oil		0.948	-0.039	0.054	-0.100	-0.027	-0.076	-0.065	-0.055
pharm		-0.079	0.383	-0.144	0.182	0.608	0.107	-0.306	-0.144
plant		0.206	0.133	0.496	0.071	-0.374	0.530	-0.101	-0.097
process		0.581	-0.078	0.062	0.454	-0.209	-0.100	0.046	-0.078
product		0.147	0.282	-0.282	0.189	0.128	0.004	-0.145	0.757
protein		-0.013	0.822	-0.109	0.076	-0.068	-0.174	-0.196	-0.139
safe		0.500	0.242	0.079	-0.102	0.137	0.372	0.095	-0.010
tissue		-0.078	-0.042	0.068	0.006	0.103	0.802	0.060	-0.207

*Red highlighting indicates defining variables where |.4|≤r≤|1.0|. Blue highlighting: |.3|≤r<|.4|. n(obs) = 31; X^2 (300) = 552.85 Prob> X^2 = 0.000; Model R^2 =0.78.

Table 17: Factor Scores for Keyword Data 1975-2005, 3-Year Running Average*

*Red Highlighting represents peak year for each factor

YEAR	Energy	Rise of Genetics	Molecular Bio weds Agriculture	Biotech Replaces Microbiology	Decline of Chemistry Pharma	Tissue Engineering	Medical Materials	Animal Production
1975	-0.757	-0.945	-0.861	-2.335	-0.453	-1.058	0.267	-1.032
1976	-0.832	0.142	-0.663	-1.608	-1.051	-0.869	-0.005	-1.231
1977	-0.812	-0.195	-0.825	-0.395	0.364	-0.547	-0.148	-1.372
1978	-0.778	0.252	-1.099	-0.266	0.215	-0.163	-0.874	-0.156
1979	-0.450	-0.584	-1.096	-0.022	1.072	-0.463	-0.795	0.649
1980	-0.333	-0.099	-0.626	-0.285	-0.138	-0.179	-0.233	2.069
1981	-0.288	1.080	-0.535	0.521	0.183	-0.431	-0.365	1.381
1982	0.681	0.620	-0.908	0.936	-0.495	-0.084	-0.584	1.095
1983	0.580	0.203	-1.029	1.190	-0.262	-0.530	-1.049	0.444
1984	0.499	-1.133	0.223	0.974	-0.683	-0.592	-0.916	0.622
1985	-0.585	-0.678	0.779	0.923	-0.209	-0.796	-0.201	0.351
1986	-0.473	-0.230	1.225	0.868	-0.066	-0.678	-0.049	0.091
1987	-0.034	0.104	0.329	0.805	-0.249	-0.222	0.419	-0.219
1988	0.127	0.165	0.308	0.303	0.033	0.091	-0.093	0.087
1989	0.466	0.352	0.000	0.326	-0.042	0.171	0.205	-0.037
1990	0.626	0.525	0.169	0.268	0.087	0.089	0.091	0.014
1991	0.953	0.564	0.320	-0.094	0.028	-0.125	0.171	0.103
1992	0.553	0.259	0.823	-0.118	0.404	-0.418	0.191	0.088
1993	0.939	0.103	0.733	-0.364	0.430	-0.552	0.361	-0.260
1994	1.065	0.384	1.049	-0.420	0.516	-0.325	0.537	-0.473
1995	1.813	0.328	0.636	-1.049	0.575	-0.069	0.118	-0.262
1996	0.945	0.203	0.616	-0.707	0.562	0.083	-0.218	-0.205
1997	0.206	-0.236	0.106	-0.092	0.480	0.521	-0.314	-0.307
1998	-0.288	-0.067	-0.278	0.197	0.428	1.672	0.052	-0.430
1999	-0.360	-0.205	-0.236	0.235	0.134	1.910	-0.058	-0.526
2000	-0.392	-0.348	0.260	-0.043	-0.328	1.655	-0.363	-0.260
2001	-0.675	-0.460	0.964	-0.021	-0.325	0.890	-0.528	-0.428
2002	-0.726	-0.426	0.954	-0.044	-0.429	1.096	0.041	-0.206
2003	-0.622	-0.019	0.162	-0.040	-0.112	0.736	0.453	-0.328
2004	-0.588	0.026	-0.515	0.201	-0.308	0.060	1.717	0.188
2005	-0.482	0.194	-0.869	0.202	0.078	-0.768	2.012	0.364

Figure 6: Scatterplots of Factors for Keyword Factor Analysis, Individual Factors over Time, in Order of Initiation

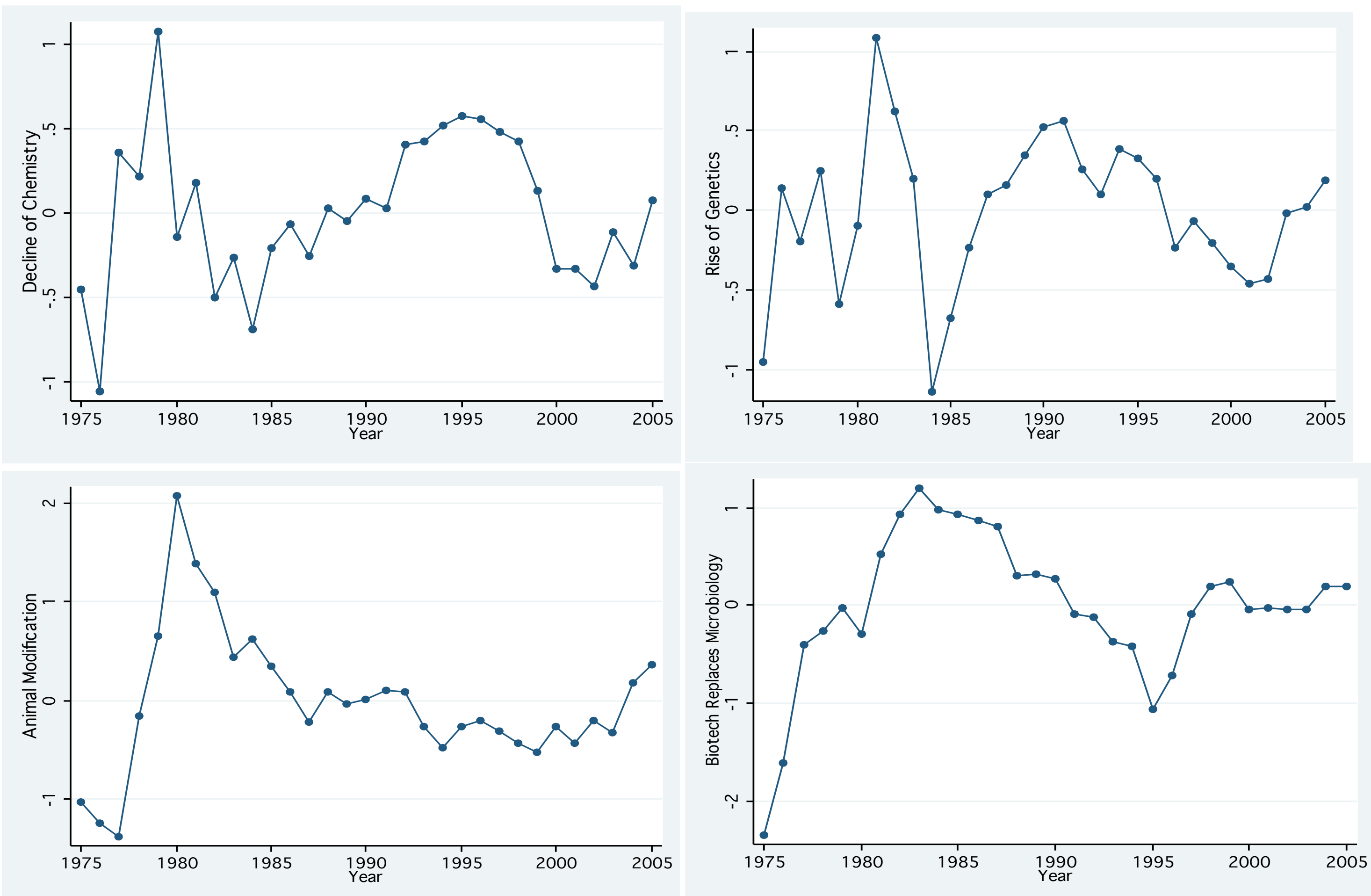
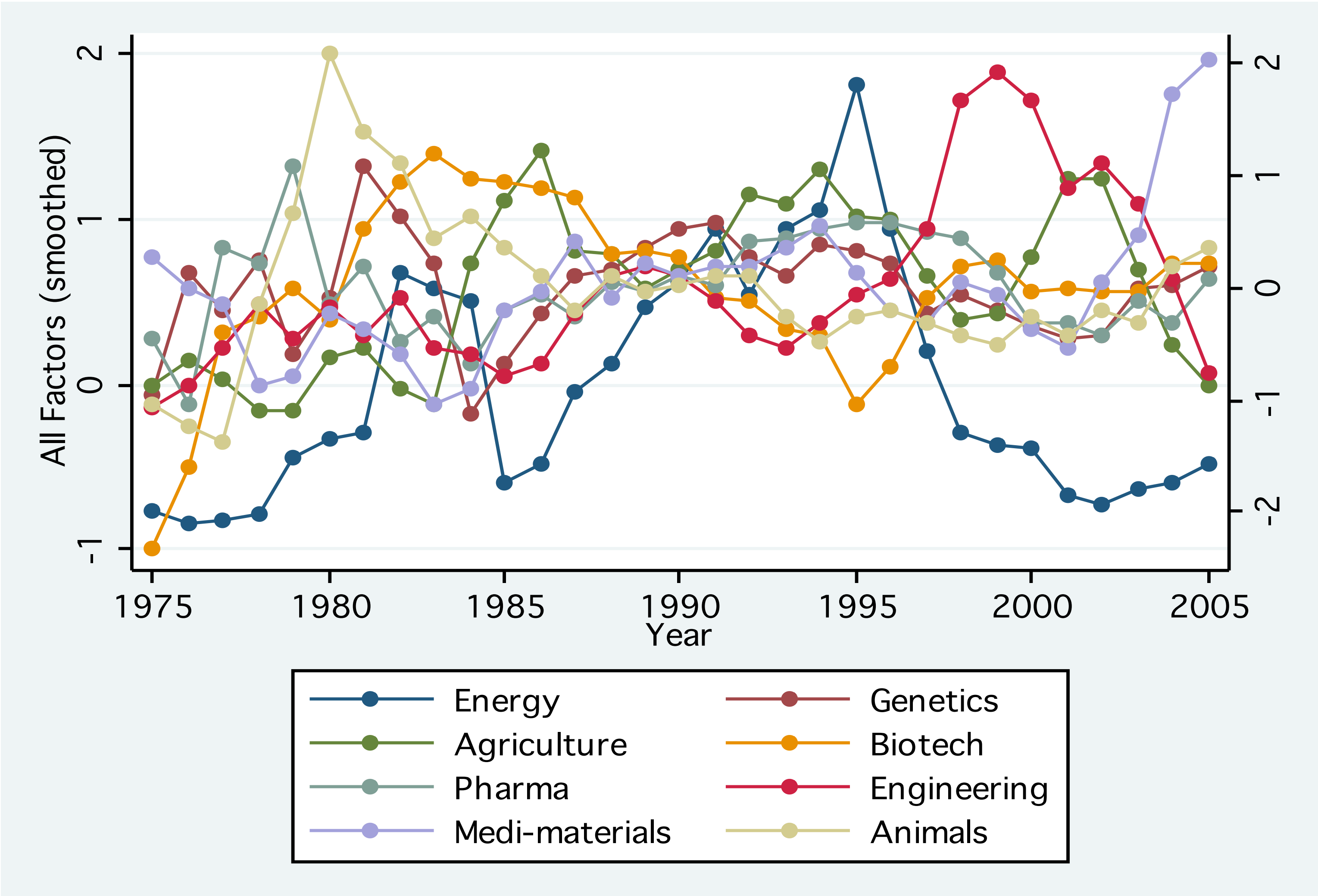


Figure 6 cont'd: (Scatterplots of Factors for Keyword Factor Analysis)

Figure 7: Factor Scores for Keyword Factor Model over Time, All Factors, 1975-2005



Factor Analysis

Results of a factor analysis of keywords associated with biotechnology conferences are presented here. The factor analysis model describes discursive trends over the course of 30 years of conferences (those that took *biotechnology* as a keyword). I have included relevant tables from this analysis.

Table 14 is the correlation matrix of keywords in the original data set where each keyword is a binary variable. These correlations are very low, with the exception of keyword-year associations, an early suggestion that there is a time-varying nature to keywords. Table 15 is the correlation matrix used for the factor analysis. It displays correlations of the proportion of conferences each year that took the keyword as its theme. The proportions provide much better correlations, with the necessary variation required for a factor analysis. Rather than review and interpret pairwise correlations here, I will proceed to the model discussion where their values will be placed in context.

Table 16 provides the selected model to describe various keyword trends. The model is significant at P> 0.000. The model explains R^2 =0.78 of the variance in the data. Rotated eigenvalues indicate that there is no single dominant factor where many keywords strongly cluster together. Rather, there are a number of different patterns of importance whose explanatory value goes slightly down for each successive factor. Eigenvalues for all factors are >1. Each of the factors has been named according to the dominant pattern of the factor.

Factor scores, or estimates for each case based on the model, were calculated by Stata, using a variation on the multiple regression procedure. Factor scores were then smoothed with a three-year running average. The smoothed scores are plotted to visualize the variation of the keyword over time. The table of factor scores (Table 17) highlights in red the peak year of chatter for that keyword. That peak is visible in the time plots.

Together, the factors can be viewed as describing a number of important trends in the reorganization of the discipline of biology with important scientific advances in materials, techniques or knowledge. What is notable among the factors is the mix of both discursive and substantive events as will be detailed below. Factors are ordered chronologically by their peak year of chatter. Figure 7, the graph of all factors is perhaps too crowded for a refined interpretation, but what is evident there is the stability focused around the 90s and the relative instability around keywords for the time points before and thereafter.

For the term *biotechnology* itself, conference data suggest that a more focused discussion began in the 1950s, about twenty years before the term gained momentum and about forty before hitting a peak, although one account indicates the term “biotechnology” has been in use with a variety of meanings since 1917 (Bud 1993). There is a relatively steady increase in biotechnology conferences over time, peaking between 1985 and 1995 and thereafter they began to decline. Viewing biotechnology as an industry, this suggests an increasing interest in the industry and then a relative decline in interest. Alternatively, viewing biotechnology as a keyword, I would argue that this is a discursive phenomenon where the word "biotechnology" became increasingly of interest and gained a momentum in the 80's and 90's. Thereafter, as the industry developed, the term becomes too unspecified to be of technical use and therefore sustains a decline.

Factors Interpretation

Decline of chemistry *Peak Year: 1979*

Primary variables[65]:
- Chemical (-)[66]
- Food
- Pharma

Secondary variables:
- Biochem (-)
- Medicine
- Plant (-)

Discussion: The changing boundaries between the chemical and the pharmaceutical industries is in evidence here. During this early period of the industry, chemical companies restructured in order to take advantage of opportunities in biotechnology but they didn't do so nearly as quickly as did pharmaceutical companies. The general decline of chemistry as an academic discipline, evident in both the closing of chemistry departments (U.K.) or the merging with biochemistry departments, may also be part of what the factor captures. One indicator of this is that Noble prizes in chemistry are mostly awarded to biochemists in recent years. Chemistry as an academic discipline today leans heavily toward biology and as applied, biotechnology.

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[65] Primary or defining variables on each factor are $|.4| \leq r \leq |1.0|$. Secondary are: $|.3| \leq r < |.4|$.

[66] Indicates a negative association with the factor

Animal Modification *Peak Year 1980*

Primary variables:
- Animal
- Gene
- Product

Secondary variables:
- Food (-)

Discussion: Biotechnology offered a number of opportunities for farmers raising livestock to streamline the process and maximize profit through vaccinations, reproductive technologies and synthetic hormones. The negative association with the keyword food here may indicate that food in these data refer more to the food processing industry than with agricultural innovations or practices.

Rise of Genetics *Peak Year: 1981*

Primary variables:
- Gene
- Industry (-)
- Protein

Secondary variables:
- Engineering (-)
- Food (-)
- Pharma

Discussion: Before the realization that genes encode protein in the 1950s, with the sequencing of DNA, genes were thought of as characteristics or traits of an organism. Although formal genetics studied traits or phenotypes and their quantification before DNA, scientists did not work with the assumption that traits were encoded by DNA. A series of DNA studies during the 1940s and 1950s led to the realization that DNA is the physical carrier of genetic information, leading to a convergence between genetics and biochemistry, under whose scope fell the study of proteins. Genetic traits or genes, hitherto exclusively defined as phenotypes, began to be associated with a sequence of DNA. The relationship of these events to the pharmaceutical sector is that it was one of the first industries to recognize the potential for the industry. (Kenney 1986: 198-199)

Biotechnology replaces Microbiology *Peak Year: 1983*

Primary variables:
- Biotechnology
- Industry
- Microbiology (-)
- Process
- Environment (-)

Secondary variables:
- Biochemistry

Discussion: The title of this factor does not intend that microbiology was actually replaced by biotechnology. This is viewed as a discursive phenomenon. The keyword decline accompanies two parallel events: the rise of the use of the word biotechnology, but also, the rise of new area of research, molecular biology based on manipulation of DNA. Microbiology during this period did not so much decline as become incorporated into molecular biology. This occurred for two reasons: first, new techniques such as PCR came to make the discovery of DNA an increasingly powerful medium for basic biology; second, the study of bacteria was transformed from the goal of research in itself to a tool for exploiting other potential areas of application. Within the locus of areas affiliated with the growth of a biotechnology discussion, we can therefore also witness the flexibility of disciplinary boundaries around biotechnology developments. The presence of the keyword biochemistry reflects the changes chemistry underwent relative to these developments (Kay 1993).

Molecular Biology weds Agriculture *Peak Year: 1986*

Primary variables:

Agriculture
Medicine
Molecular
Nutrition
Plant

Secondary variables:

Biotechnology
Microbiology (-)

Discussion: *Agriculture* and *molecular* are the two central keywords for this factor. All of the keywords here converge around that relationship. Agriculture was transformed by biotechnology, essentially through engineering plants that have genes transferred into them so that they will behave in a particular way. The creation of new varieties of pest resistant crops has transformed the way food is grown in the United States and much of the world. This process enrolled plant biology and medicine as well and "Nutrition" as a keyword is central to the problem of malnutrition in the developing world, a prominent target of the science and industry's effort in the 50s and 60s. A number of IGOs and NGOs are currently devoted to this problem.

Energy *Peak Year: 1995*

Primary variables:

Oil
Industry
Process
Safe

Discussion: Defining keywords for this factor are *gas, oil industry, process* and *safe*. Together they point to the discussion on the potential of biotechnology for energy and as a new source of energy and for remediation of industrial problems and processes. The keyword *safe* is an interesting association here. Of all the social (as opposed to technical) keywords that were searched in the data, this was the only one that had enough mentions to include in the factor analysis. Its use suggests perhaps an attempt to actively promote the notion of safety of this industry or an exploration of the safety of new techniques or processes.

Tissue Engineering *Peak Year: 1999*

Primary variables:
- Engineering
- Plant
- Tissue

Secondary variables:
- Biotech
- Microbiology (-)
- Food
- Safe

Discussion: This factor refers to a more recent phenomenon and as such, a fair interpretation of the associations here is a development in biomedicine called tissue engineering. This includes methods of creating or "engineering" human compatible transplant materials. Alternatively, this factor may also be viewed as a plant tissue engineering or "tissue culture", techniques in plant biology that speed up the process of creating better plant varieties. According to the UN's Food and Agriculture Organization website, "Tissue culture has produced plants that are increasing crop yields by providing farmers with healthier planting material." Given the presence of the keyword *food*, it is likely the latter. This factor also registers the defining keywords with the rise of biotechnology, and again, the "decline" of microbiology. Regarding the food industry's relation to biotechnology, it is a sector that has been transformed over the last few decades due to processing, pharmaceutical agents and genetic advances that protect livestock from disease and make animals grow faster and larger.

Materials in Medicine *Peak Year: 2005*

Primary variables:

- Material
- Medicine
- Improv[67]

Secondary variables:

- Industry (-)

Discussion: Materials in medicine research examines the "…science and technology of biomedical materials and their applications as medical or dental implants, prostheses and devices and of biological materials (Bonfield, et al, 1990). The first editorial (1990) of a journal called *Materials in Medicine* indicated that it is a multi-disciplinary area and that the relevant sciences are medicine and engineering. The founding of the journal predates the factor by fifteen years

Discussion

An examination of biotechnology as a discursive or cultural element, --a keyword (Williams 1976)-- allows a view into the way the world polity worked with a broad and general frame that depicted it as an enabling technology. To accomplish this task, keywords were extracted from their social setting, the system of conferences in which biotechnology was discussed, in order to examine their structure. Using original data, the results have described a number of previously well-documented facts in the history of the industry. This is

[67] This keyword was shortened to capture variations on the word "improve"

important for establishing the robust nature of an analysis using conference proceedings citations data for examining institutional evolution, in this case, frame evolution. However, what is notable and original about the results is that they exhibit how new keywords, and ultimately new activities may be introduced into an industrial sector, biotechnology, over time. Keywords represent what biotechnology means overtime. Biotechnology was a broad enough frame that it added eight new meanings, here, factors, over the course of 25 years. In continuous interpretation by transnational actors, the frame was able to accommodate the incorporation of new activities, and new meanings, over time. This quality indicates a "cultural power", one that "…depends partly on the ability to elicit relative consensus of meaning while sustaining a divergence of more specific interpretations" (Ghaziani and Ventresca 2005). Likewise, it demonstrates what Barthel (1997) refers to as *robustness* in the analysis of discourses in that the frame enabled a variety of potential directions for action. The sponsors of meetings are ultimately the actors with the power to augment the biotechnology frame over time.

Ghaziani and Ventresca (2005) used data collected from business journals, analyzing frames associated with the keyword "business model" from 1975-2000. They are interested in the "global-local" tension in the creation of meaning. That is, during times of social or economic upheaval, keywords are recast where at once they can have more specific, locally-tailored meanings while remaining general enough to engage a collective global audience. They seek to resolve this tension in the creation of meaning (Wuthnow 1989), seeing frames as competing, and in doing so, they identify the co-existence of frames as a conflict. In their analysis however, competing frames are not wholly incommensurable. Frames, oriented like various spokes that gravitate around the central axis of a wheel, can be explained by location –-social, geographical, organizational-- and how location makes relevant one frame for certain actors versus others without any one frame necessarily representing a substantive departure of meaning, and therefore consensus, from the others. In this way, not all communities need to come to an overall consensus, as their research suggests, because the unique intersection of a variety of factors (geographical, social, organizational, professional) indicates that each community requires a particular frame within which problems experienced more widely can be addressed.

Biotechnology as a meta-frame created a substantive generality that provided for the proliferation of various meanings under the biotech heading. This is important where there is the burden of creating meaning on the transnational level. A plurality of (related) frames, while potentially leading to confusion among users and audiences, allows the creation of meaning for multiple actors in times of economic or social upheaval. However, this plurality can be also be paramount in uniting heterogeneous actors across multiple social fields who might have similar enough ideas but, for instance, different professional backgrounds and thus differing language and values which become an obstacle in the creation of consensus or institutional change. The mechanism by which these communities come to some consensus during "unsettled times" is by working within a meta-framework which can incorporate a variety of frames as well as distinctive professional and organizational ways of thinking about problems. Seemingly broad and confusing, described by list based definitions, biotech as an enabling-technology was a more thoroughgoing way of creating consensus, as opposed to promoting it as simply agriculture *or* pharmaceuticals *or* energy. This meta-frame, permits a wide range of development options for local (state and regional level) biotechnology developers and allows for the development of multiple meanings within the broader framework. And, while this conceptualization was distinctive in its own right, it could incorporate other frames already in existence or those that would emerge as a result of new scientific discoveries or industrial advances as these data illustrate.

The effect of this flexibility has not only been on the boundaries of the industry itself, that is, on the more obvious components such as the new start ups that are initiated specifically as "biotechnology" firms; it also "softens" the boundaries of other types of organizations and institutions, enabling their reinterpretation into this new industrial paradigm. An EU report from 1999 that examined the major initiatives to develop a biotech industry undertaken by seventeen European nations notes that although "a few countries actually have created *ex nihilo* biotech public research institutes…in most cases, councils, funding organizations or public institutes have mainly labeled existing centres 'biotech centres' in order to focus them." (Enzing 1999: 20). Institutionalization happens then not only by creating new practices within an "open" social/industrial/economic space (Kenney 1999); it also happens when a powerful line of discourse gives actors a handle in making entrepreneurs and other local development players reinterpret their own and other's practices to recontextualize them in moments of change. This takes Ghaziani and Ventresca's analysis of the global-local tension one step further: assuming that consensus is the ultimate end-point, they seek to demonstrate that several frames can exist at once, a "global" or a dominant frame at the same time as local frames. The response of the research presented here is that more than possible, in the case of biotechnology it has been a necessary part of creating meaning on the transnational level and by suggestion the likely means by which local development agencies are able to begin to demarcate biotechnology regions in their territory.

Conclusion

A keyword analysis using conference proceedings data is shown to be a reliable and exciting statistical method for tracking discourse for a large number of documents. These data confirm a number of well-described events in the recent history of the biotechnology industry, yet they also add nuance with regard to a cultural interpretation of biotechnology history.

While this method does not supplant a more detailed textual analysis, it enables the review of an amount of textual data that would otherwise be prohibitive. This is another assertion, among Mohr (Mohr) –following Bourdieu-- (Griswold 1992; Kane 1991, 1997, Ghaziani and Ventresca 2005) of the viability of approaching cultural analysis in formalist way, that is, with quantitative methodology.

Further, this approach is perhaps a new way for world-society theorists to add texture to the documentation of world-polity structure around new themes that become subject to international diffusion processes. While it can track organizations that have marshaled around a new focus, like the Yearbook of International Organizations, it can illustrate in a more detailed way the process around the selection of frames that are diffused and how the frame developed.

This chapter has examined culture in the context of a global level institutional process. Keywords have a cultural power that work in an arc to garner institutional energies around particular projects. They will have this effect based on several factors: first, how they mesh with existing cognitive frameworks –described in the OECD chapter for how biotechnology became a medium for development of national innovation strategies; and second, how they couple to "real life" activity. They acquire their own power as they add more and more meanings over time but this ultimately leads to their demise as they become more vague and in that sense, decoupled. In the case of transnational level activity however, a flexibility in meaning is useful to unite actors across geographic, institutional and professional boundaries as it allows adaptability to various social groups. This suggests an original way of thinking about discursive processes on the transnational level where large organizations are implementing projects across geographic borders.

Chapter 4: Conclusion

Taken together, nations, regions and entrepreneurs want to be identified with biotech despite the general risk of such investments. A recent article in the business section of The New York Times (Despite Odds, Cities Race to Bet on Biotech: June, 11, 2009) drives this home: The article states that "Schreveport, Louisiana and Huntsville, Alabama are gambling millions in taxpayer dollars on if-we-build-it-they-will-come research parks and wet laboratories which hold the promise of low-pollution workplaces and high salaries." What such regions ultimately want out of investments in expensive scientific facilities is industrial development that will support their economic growth. To understand why they believe this is possible, I've drawn upon theoretical developments within the sociology of culture.

In an interpretive, textual analysis of the published reports of the Organization of Economic Cooperation and Development, I have demonstrated the underlying meanings of the organization's aggressive biotechnology promotion, finding that the broad general frame that they created for biotechnology, that of an enabling-technology, allowed for a proliferation of meanings on the transnational level. An analysis of the relation of the bureaucratic structure of the OECD to the procedures by which national civil servants interact within the organization suggests a diffusion mechanism. The hierarchical structure of the organization suggests that powerful members such as the United States may work through the OECD to establish a transnational biotechnology market. The OECD is a unique IGO as an economic think tank, devoted to economic development. It seems to function both like a “ready made” epistemic community in the development and application of economic research, yet it has a fixed structure that embeds broader power arrangements of the larger state system. Interestingly, the OECD describes its on-going working groups, where civil servants and national experts regularly meet, as a permanent intergovernmental conference (Marcussen 1998a: 12). These diverse views of the type of organization that is the OECD suggest a rather open exchange of ideas by describing itself as a research conference. Yet this statement masks the fact that the flow of policy ideas, according to Marcussen, is a top-down structure within the OECD, where larger nations that contribute a higher portion of the budget tend to have a bigger say. One mechanism of this influence is that the OECD reflects back to the larger transnational community what influential contributors want to see in terms of policy and market development. While there may be alternative definitions that continue to circulate, the OECD had the authority to speak on such matters in comparison to potential challengers. In the long run, the organization all but ensured the longevity of their framework because their statistics project is the largest of its kind and will be the only way for a state to assess its own industry against another’s.

Culturally, if as suggested in the first chapter, we view biotechnology as a keyword, that is, as a discursive phenomenon, then I have documented a cultural structure around the development of biotechnology, a structure through which cultural elements can be isolated and the cultural meanings explored. This culture-structure consists of the set of conferences populated by transnational actors who engaged and experimented with the biotechnology frame over time. The culture-structure may be considered a place of cultural experimentation where professional societies and other organizations played with the frame of biotechnology by adding new meanings. This process, the attempt to couple new activities to the frame, is institutional or boundary work. In this sense, the structure is also a site of frame enactment (Friedland and Alford 1991; Snow et al. 1986). Kane (1991). following Levi Strauss (1966) indicates that symbolic classifications are based on binary opposition. Classifications create action potential through demarcation of a binary. The definition of biotechnology as an input rather than an industry allowed for such widespread action potential.

Following the direction of a number of cultural theorists in the analysis of the discourse (Sewell, Swidler, Kane, Mohr, Schudson, Barthel) the results here demonstrate that biotechnology was a perfect frame or “fiction”. Frames are lent credibility and objectivity when, based on the position of the speaker (Bourdieu 1991) – they are offered in a scientific setting, or by a scientist or an economist, granted the authority of science. A persuasive account, a reasoned argument, is bolstered in this way. This is cultural power. The frame of biotechnology linked both to current understanding about the role of technology and it had a practical, ready-made action framework within which it could be implemented, the national innovation system, that characterized national level institutions as pliable to set the right institutional conditions for industrial development for economic growth.

Thus, good frames also *translate*: they make discursively available a complex situation and translate it in a way that creates meaning for various users.

The keyword analysis of the term *biotechnology* was applied to an original data source, conference citations data available through the World Library Catalog. Keywords associated with the biotechnology were factor analyzed. Keywords analyses have most often used journal articles as data. The data source in this study is unique in that it captures a broader range of organizations in the transnational community than do world society analyses, even though some organizations in addition to NGOs are available in the Yearbook of International Organizations.

The factor analysis of biotechnology as a keyword demonstrates an arc of use of the term and, having mobilized a number of associated meanings and organizations over time, it begins to fall out of use. This may result from two possibilities: the first is that after close to three decades of scientific development, the term biotechnology became so vague that it lost any technical utility it may have had. Where once it had mobilizing potential, there may have been other terms that came into use, such as the "life science industries". Second, the frame reached its limit in the exploration of meaning that happened in the course of experimentation with the frame.

Using these data, I've gathered evidence of, primarily, the cultural supply-side at the transnational level. However, I have suggested, using European Commission data, how this meta-frame constructed at the OECD is used on the local level as the basis to build biotech regions. Biotech is often "built" by re-labeling as biotechnology existing local resources –universities, R&D firms, think tanks. This top-down process was permitted by at least twenty-five years of boundary work done by NGOs, industry, foundations, journals and universities, that coupled biotechnology to the general frame. The same New York Times article mentioned above adds further evidence in this direction. The Vice President of the Biotechnology Industry Organization, Patrick Kelly, says "A good strategy capitalizes on a city's existing strength, whether it is the presence of the Centers for Disease Control and Prevention in Atlanta, a highly educated work force in Huntsville, or experience running clinical trials in the Research Triangle". The diffusion of an all-encompassing biotechnology frame explains how cities can simply "choose" their focus based on what pre-exists in their region. Theoretically, this suggests a process of local level coupling. Together, the research on the OECD's frame, along with the structural analysis of biotechnology as a keyword, demonstrates the discourse's structuring potential. It indicates the power of the organization, at least in the 1980s to have the ability to expand a "biotechnology for a growing population" frame in the 1960s (Bud 1993) to a "biotechnology as the new basis of your nation's economic growth" during the early 1980s. It did this by aligning biotechnology with economic theory that defined the moment for the transnational community, the end of a techno-economic paradigm, and created a solution, "build biotech". This also coincided with a new articulation of national level institutions –tax policies, patent law, scientific regulation—within the context of national innovation systems and how they could be set to create the conditions for economic growth.

I have suggested that a search process was set in motion by a global economic downturn, the transition from one global political-economic hegemony to another, whose effects began to be broadly experienced as early as the 1970s. Among the many interpretations of these events, I have examined two competing theories, a world-systems theory (Arrighi 1994) and evolutionary economic theory that places technological change at the heart of macro-economic shifts.

Relatedly, I have also provided a critique of the notion of a techno-economic paradigm that lies at the heart of the biotechnology framework. Evolutionary economists have theorized and documented an important relationship between technology and economic growth, in particular Rosenberg's account (1994) with, for instance, the historical example of steel as an enabling technology. I show, using biotechnology as a keyword, that biotech did not begin its journey with all of the meanings that it eventually acquired by the turn of the millennium. These meanings were constructed over time by a vast array of transnational organizations. This is demonstrated by the different peak times for each factor in the keyword analysis. I conclude that enabling technologies cannot be predicted a priori because, while genetic engineering is a widely applicable resource, it will require a level of imagination, adjustment, accommodation and financing within target sectors to understand how to implement its use. This is not the case with previous examples such as steel. In this way, the growth of biotechnology has not been a system-driven requirement as has been predicted by Perez (1985) and Freeman (1989). Rather, these capacities are built up over time, in the gradual creation of opportunities across sectors. Without understanding the historical sequence and the struggle to create this industry from the top down, it could be easy to view the industry as a natural development of the global economic system.

Moreover, this research also challenges the even more entrenched view that technology has a substantive core that fully determines how it will be used in a social context. This is a very different depiction of technology-based growth than has been described by Nelson and Winter (1982). Sydney Winter, whose research almost single-handedly revived the work of Joseph Schumpeter and his concept of business cycles, later indicated that planning or predicting technological use in advance is close to impossible. He notes that

> the most formidable obstacle of all derives from the direct clash between the future-oriented character of a dynamic optimization and the fact that selection and adaptation processes reflect the experience of the past. If firms cannot 'see' the path that technological opportunity will follow in the future, if their decisions can only reflect past experience and inferences drawn there from, then in general they cannot position themselves optimally for the future. They might conceivably do so if the development of technological opportunity were simple enough to validate simple inference schemes. Such simplicity does not seem descriptively plausible… (Winter 1987)

Winter reveals the predicament of firms in his theory. In the search for innovations that can ensure the firm's long-term survival, they are more or less left to chance because information about what worked in the past, what brought the firm to that point, cannot be a guide to action because it is impossible to know in advance what will be valuable in the long-run. He goes on to say that “this obstacle is not featured prominently in the simulations reported by Nelson and Winter, which are largely confined to very tame and stylized technological regimes in which opportunity is summarized by a single exponentially increasing variable (Winter 1987).

Winter here, in a striking admission that unmasks the process of social construction of technological opportunity in his paper from 1982, indicates that technology’s effect looks much more central and more stable as a growth factor, not because of the scientific validity of his work, but because of his and Nelson’s craft in portraying as a statistical reality, something that was not true.

Overall, this statement reveals the role of economists, of science more broadly, of economic theory and economic think tanks like the OECD and the authority they are granted by other social groups in leading policy development regarding the economy.

Practically speaking, there are either vast sums of money being spent on real-estate for science parks, for lab facilities and equipment and in these acts, the state makes a choice that the development of biotechnology is more important than other programs to which money can be better spent. When there is no money to commit to the industry, local resources are re-labeled. Where does this leave developing nations, who may have few or no resources to create an industry? While the outcome of this process seems that, in the worst case, it can only advance scientific infrastructure because of the level the investment, clearly, there have been and there will be costs in promoting such a difficult to build, and a difficult to define, industry.

Limitations of this research

While the OECD is viewed here as the most dominant transnational organization promoting the biotechnology industry, it is not unlikely that there were other organizations that contributed to the promotion of the biotechnology industry. Other efforts would most likely have been country specific efforts. Specific organizations that might be investigated for a role in the process are the World Bank, The Rockefeller Foundation and U.S. AID.

Additionally, interviews with key players during the early period of biotechnology promotion would be important for understanding actors' motives within the context of the larger justifications that were provided by IGOs such as the OECD and used by governments. Interviews may reveal nuances of the process that are not visible using transnational conference level data.

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Appendix

Figure 1. Nations included in the European Commission Inventory of Public Biotechnology Programs

Austria
Belgium
Denmark
Finland
France
Germany
Greece
Iceland
Ireland
Italy
Netherlands
Norway
Portugal
Spain
Sweden
Switzerland
United Kingdom

Figure 2: OECD Member Countries

Australia
Austria
Belgium
Canada
Czech Republic*
Denmark
Finland
France
Germany
Greece
Hungary*
Iceland
Ireland
Italy
Japan
Korea*
Luxembourg
Mexico*
Netherlands
New Zealand
Norway
Poland*
Portugal
Slovak Republic*
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

*Nations added as members after 1982

Figure 3: Definitions of biotechnology 1974-1982

Year *Agency*

Definition

1974 *Bundesministerium für Forshung und Technik (BMFT)*

"Biotechnology is concerned with the with the use of biological activities in the context of technical processes and industrial production. It involves the application of microbiology and biochemistry in conjunction with technical chemistry and process engineering."

1981 *European Federation of Biotechnology (EFB)*

"Biotechnology is the integrated use of biochemistry, microbiology and engineering sciences in order to achieve the technological application of the capacities of microorganisms, cultured tissue cells and parts thereof."

1979 *United Kingdom Advisory Council for Applied Research and Development and the Royal Society* ("Spinks Report")

"Biotechnology is the application of biological organisms, systems manufacturing and service industries"

1982 *Organization of Economic Cooperation and Development*

"the application of scientific and engineering principles to the processing of materials and biological agents to provide goods and services."

Figure 4: Example 1 of Biotechnology Industry Graph from OECD Statistical Report 2001

DSTI/DOC(2001)6

BIOTECHNOLOGY AND ALLIANCES

Table 1. **International strategic biotechnology technology alliances with at least one partner based in the United States, 1980–98**

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Total US alliances	139	126	200	177	234	235	292	318	367	357	312	287	394	444	497	639	578	497	477
US-Europe	5	6	9	7	14	22	24	28	21	16	11	18	40	42	62	59	75	49	47
US-Japan	6	8	12	7	7	16	14	11	6	6	4	1	5	10	7	6	13	14	6
US-other	3	2	1	0	2	3	0	3	4	5	4	1	5	7	6	6	7	6	2
Intra US	10	12	23	13	28	27	39	36	36	23	13	16	33	57	58	60	53	93	53
Total biotech alliances	24	28	45	27	51	68	77	78	67	50	32	36	83	116	133	131	148	162	108
of which international	14	16	22	14	23	41	38	42	31	27	19	20	50	59	75	71	95	69	55

Source: OECD, NSF: Special tabulations of the CATI database at MERIT, 1999.

Figure 8: Aggregate Keywords and Components*

Agriculture = agricult + nitrogen (fixation) + food + feed + animal

Energy = gas + fuel + oil + energy + coal

Social= ethics + legal + economic + hazard + safe + risk + strategy

Plant = plant + tree + ethylene + horticulture

Medical = medi + clinical + blood + biomedical + therapy + cancer

Pharmaceutical= pharma + drug

Environment = environ + ecology + pollution + remediation + reclamation +waste + conservation

Biochemistry = biochem + enzyme + hydrolys

Physical science = aerospace + biophysical + electro + heat + materials + physical

Microbiology = microbiology + yeast

*Aggregate Keywords were tested but not used in final factor analysis

Table 18: Correlation Matrix of Selected Keyterms, Proportion of Conferences/Year with Specified Keyterm, Conference Proceedings Data 1955-2005

	year	agri	animal	biochem	biotech	chem	engine	food	gas	gene	improv	indus	mater	medi	microb	molec	nutrit	oil	pharm	plant	proces	prduct	protein	safe	tissue
year	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
agriculture	0.356	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
animal	0.254	0.305	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
biochem	0.408	0.321	0.095	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
biotech	0.582	0.337	0.206	0.273	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
chemical	0.183	-0.061	0.100	0.251	0.074	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
engineering	-0.053	-0.080	-0.148	-0.064	-0.095	-0.160	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
food	0.420	0.366	0.002	0.150	0.387	-0.091	-0.012	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
gas	0.268	0.071	0.259	0.362	0.190	0.332	-0.035	0.048	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
gene	0.313	0.131	0.425	-0.072	0.383	0.034	-0.142	-0.009	0.203	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
improv	0.456	0.268	0.393	0.066	0.186	0.097	-0.063	0.080	0.155	0.232	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—
industry	0.262	0.038	0.104	0.489	0.342	0.168	0.006	0.327	0.374	0.158	-0.020	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—
material	0.496	0.259	0.258	-0.014	0.128	-0.033	-0.118	0.214	0.081	0.155	0.471	-0.110	1.000	—	—	—	—	—	—	—	—	—	—	—	—
medi	0.512	0.473	0.240	0.091	0.273	-0.100	-0.153	0.346	0.132	0.097	0.341	0.061	0.591	1.000	—	—	—	—	—	—	—	—	—	—	—
microbiology	-0.661	-0.235	-0.229	-0.303	-0.655	-0.101	-0.179	-0.286	-0.233	-0.338	-0.267	-0.282	-0.227	-0.281	1.000	—	—	—	—	—	—	—	—	—	—
molecular	0.520	0.511	0.212	0.366	0.328	0.067	-0.082	0.196	0.035	0.071	0.322	0.204	-0.020	0.296	-0.338	1.000	—	—	—	—	—	—	—	—	—
nutrition	0.480	0.321	0.145	0.189	0.306	-0.039	-0.076	0.288	0.199	0.064	0.161	0.078	-0.012	0.446	-0.303	0.423	1.000	—	—	—	—	—	—	—	—
oil	0.274	-0.007	0.044	0.350	0.116	0.220	-0.042	-0.003	0.884	0.086	0.122	0.313	-0.028	0.229	-0.209	0.112	0.340	1.000	—	—	—	—	—	—	—
pharm	0.296	0.118	-0.026	0.043	0.286	-0.127	0.048	0.760	0.034	-0.031	0.088	0.282	-0.045	0.171	-0.231	0.209	0.329	0.076	1.000	—	—	—	—	—	—
plant	0.564	0.495	0.263	0.468	0.452	0.291	-0.103	0.288	0.469	0.334	0.206	0.219	0.111	0.194	-0.418	0.443	0.385	0.339	0.175	1.000	—	—	—	—	—
process	0.296	0.200	0.075	0.394	0.312	0.252	-0.115	0.071	0.540	0.121	0.178	0.399	0.034	0.255	-0.268	0.366	0.053	0.515	-0.024	0.356	1.000	—	—	—	—
product	0.496	0.093	0.569	0.262	0.406	0.069	-0.167	0.029	0.330	0.620	0.091	0.202	0.214	0.225	-0.406	0.142	0.095	0.214	-0.066	0.283	0.356	1.000	—	—	—
protein	0.080	-0.089	-0.022	-0.079	0.156	0.126	-0.187	-0.093	0.050	0.631	-0.063	-0.117	-0.085	0.007	-0.165	0.022	-0.036	0.089	-0.070	0.272	0.120	0.320	1.000	—	—
safe	0.357	0.173	0.103	0.015	0.265	-0.005	-0.024	0.180	0.438	0.271	-0.023	0.067	0.156	0.225	-0.272	0.218	0.165	0.383	0.146	0.493	0.408	0.277	0.124	1.000	—
tissue	0.487	0.214	-0.168	0.169	0.267	-0.047	0.154	0.432	0.043	0.015	0.099	0.069	0.169	0.129	-0.244	0.210	0.256	-0.038	0.260	0.439	0.073	0.083	-0.067	0.288	1.000

Table 19: Frequency of Collaborative Conferences by Decade*

Decade	Freq.	%
1950’s-70's	19	6.9
1980's	98	35.6
1990's	117	42.5
2000's	41	14.9
Total	275	100.0

*Collaborations are conference held or sponsored by two or more nation

Table 20: Collaborations by Location (Relative to U.S.)

	Outside U.S.	Inside U.S.	Total
	Freq (%)		
Collaborative Conference	178 (64.7)	97 (35.3)	243 (100.0)

Table 21: Keywords Mentioned in Title Data, Alphabetical Order

Word	Freq	(%)	Word	Freq	(%)	Word	Freq	(%)
Aerospace	4	(0.43)	Fuel	22	(2.38)	Polymer	9	(0.97)
Aqua	6	(0.65)	Fiber	1	(0.11)	Pollut(ion)	3	(0.32)
Agricult(ure)	34	(3.68)	Forest	7	(0.76)	Process	48	(5.19)
Animal	29	(3.14)	Fung(i)	4	(0.43)	Product(ion)	61	(6.59)
Automat(ion)	3	(0.32)	Gas	18	(1.95)	Protect	10	(1.08)
Bacteria	11	(1.19)	Gene(tic)	85	(9.19)	Protein	18	(1.95)
Biocat(alysis)	13	(1.41)	Genom(ic)	5	(0.54)	Pulp	2	(0.22)
Biochem(istry)	23	(2.49)	Global	6	(0.65)	Paper	32	(3.46)
Bioeng(ineering)	13	(1.41)	Hazard	2	(0.22)	Quality	9	(0.97)
Bioinfo(rmatics)	2	(0.22)	Health	14	(1.51)	Reclam(ation)	2	(0.22)
Biomass	0	(0.00)	Heat	9	(0.97)	Recombinant	6	(0.65)
Biomed(ical)	11	(1.19)	Hormon(e)	2	(0.22)	Remediat(ion)	9	(0.97)
Biophysic(s)	4	(0.43)	Horticulture	12	(1.30)	Resource	9	(0.97)
Biotech	488	(52.76)	Human	12	(1.30)	Risk	3	(0.32)
Blood	8	(0.86)	Hydrolys(is)	3	(0.32)	Safe	17	(1.84)
Breed(ing)	14	(1.51)	Immuno	3	(0.32)	Seed	4	(0.43)
Cancer	5	(0.54)	Improv(ing)	18	(1.98)	Strateg(y)	7	(0.76)
Cell(ular)	41	(4.43)	Industr(y)	50	(5.41)	Technolog(y)	542	(58.59)
Cellulose	9	(1.01)	Informat(ion)	7	(0.76)	Therap(eutic)	12	(1.30)
Chemical	62	(6.70)	Innovation	4	(0.43)	Thermal	3	(0.32)
Clinic(al)	7	(0.76)	Legal	3	0.32)	Tissue	19	(2.05)
Coal	7	(0.76)	Ligno(cellulosic)	5	(0.54)	Tool	4	(0.43)
Comput	9	(0.97)	Marine	8	(0.86)	Treatment	9	(0.97)
Conserv(ation)	8	(0.86)	Material	26	(2.81)	Tree	3	(0.32)
Control	21	(2.27)	Mechanic(al)	21	(2.27)	Tropic	6	(0.65)
Develop(ment)	47	(5.08)	Medi(cal)	35	(3.78)	Vaccin(e)	1	(0.11)
Diagnos(tic)	7	(0.76)	Membrane	5	(0.54)	Virus	3	(0.32)
Diseas(e)	12	(1.30)	Molecul(ar)	42	(4.54)	Waste	11	(1.19)
DNA	6	(0.65)	Organism	13	(1.41)	Water	6	(0.65)
Drug	4	(0.43)	Microb(Sklair)	70	(7.57)	Wood	4	(0.43)
Ecolog(y)	4	(0.43)	Mineral	2	(0.22)	Yeast	3	(0.32)
Economic	7	(0.76)	Mycology	4	(0.43)			
Electro(nic)	3	(0.32)	Natur(al)	15	(1.62)			
Energy	11	(1.19)	Nitrogen	9	(0.97)			
Engin(eering)	48	(5.19)	Nucle(ar)	6	(0.65)			
Environmental	71	(7.67)	Nutrition	17	(1.84)			
Enzyme	14	(1.51)	Oil	19	(2.05)			
Ethics	6	(0.65)	Plant	76	(8.22)			
Ethylene	3	(0.32)	Pharma(aceutical)	16	(1.73)			
Evolut(ion)	4	(0.43)	Physic(al)	5	(0.54)			
Fermentation	11	(1.19)	Policy	10	(1.08)			
Food	54	(5.84)	Political	2	(0.22)			

Table 22: Factor Loadings, Keyword Data 1955-2005, Rotated Factors*

		Factors							
		Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8
Eigenvalues	unrotated	5.549	2.452	2.114	1.541	1.191	1.065	0.840	0.703
	rotated	2.750	2.247	2.235	2.122	1.833	1.624	1.427	1.215
Variable									
agriculture		-0.059	-0.017	0.676	0.118	0.335	0.094	0.139	0.129
animal		0.095	0.207	0.162	-0.052	0.185	0.055	0.792	-0.084
biochem		0.261	-0.102	0.393	-0.013	-0.053	0.624	0.045	0.099
biotech		0.067	0.362	0.269	0.365	0.124	0.337	0.163	0.233
chemical		0.255	0.061	0.098	-0.228	-0.095	0.264	0.037	0.018
engineering		-0.039	-0.220	-0.163	0.089	-0.166	-0.059	0.039	0.304
food		-0.034	-0.029	0.136	0.790	0.234	0.174	-0.073	0.177
gas		0.923	0.066	-0.003	-0.017	0.038	0.168	0.165	0.130
gene		0.067	0.830	-0.002	0.030	0.068	0.003	0.354	0.087
improv		0.077	-0.045	0.248	-0.014	0.430	-0.022	0.454	0.052
industry		0.278	0.008	-0.022	0.345	-0.116	0.695	0.098	-0.044
material		-0.016	0.015	-0.056	-0.013	0.826	-0.024	0.189	0.180
medi		0.164	0.066	0.324	0.270	0.740	-0.036	0.032	-0.148
microbiology		-0.142	-0.285	-0.201	-0.297	-0.133	-0.272	-0.258	-0.340
molecular		0.047	0.042	0.720	0.137	0.050	0.190	0.095	0.044
nutrition		0.263	0.003	0.537	0.417	0.022	-0.189	0.122	-0.040
oil		0.952	0.030	0.085	0.056	0.011	0.058	-0.023	-0.085
pharm		0.039	-0.045	0.087	0.826	-0.033	0.016	-0.008	0.037
plant		0.350	0.285	0.573	0.091	0.012	0.144	0.073	0.458
process		0.511	0.168	0.223	-0.089	0.195	0.468	-0.134	0.046
product		0.199	0.594	-0.006	-0.020	0.184	0.294	0.392	0.087
protein		0.037	0.826	0.068	-0.095	-0.086	-0.085	-0.196	-0.065
safe		0.454	0.281	0.119	0.124	0.174	-0.096	-0.112	0.404
tissue		-0.015	-0.024	0.206	0.297	0.108	0.024	-0.139	0.637