Political Decentralization and Technological Change: Hypotheses From Comparative Case Studies in Blood and Electricity

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I. Introduction

This paper will examine the linkages between government decentralization and long-run technological progress. This emphasis on decentralization is motivated by recent studies of comparative institutions which tie decentralization to various policy variables and outcomes, and by research performed by "national innovation systems" scholars who describe numerous causal links between policy variables and comparative innovation rates. The focal question asked here is: *if variations in government decentralization can explain differences in policy, and if differences in policy can explain differing rates of technological innovation, then can variation in decentralization explain comparative rates of innovation?* The existence of such a relationship has been suggested to varying degrees by political economists who argue that the competitive aspects of decentralized systems and their ability to access superior information about local conditions help to create environments generally conducive to economic development, and hence technological innovation. However a decentralization-innovation correlation has failed to found in statistical tests of such a relationship.[1] Therefore, below I report on two case studies which compare the development of two technologies (electricity and blood products) in five countries (US, Germany, Great Britain, France, and Japan). The weakness of statistical analysis is such that its failure may be the result of model misspecification, measurement error, or endogeneity, rather than absence of a statistically significant causal relationships; thus prompting the case studies reported here. The case studies confirm the statistical analysis, in neither of the sectors studied did political decentralization seem to matter for the pace of technological innovation. The case studies do confirm that innovation should be considered separately from diffusion, and that decentralization may have a positive effect on diffusion but may have no relationship with innovation. The case studies also generate various new hypotheses about how political decentralization may affect technological change. Specifically, decentralization appears to aid technological progress by allowing its supporters to "venue-shop" around political resistance, by changing the incentives of local governments, and by allowing political deals over policy design to be conducted more efficiently at lower levels of interest group aggregation.

[1] Taylor, Mark Z. 2007a. "Political Decentralization and Technological Innovation: Testing The Innovative Advantages of Decentralized States" *Review of Policy Research* 24(3):231-257

Defintions

For the purposes of this paper, the following working definitions are proposed.[2] "Technology" is defined here as a physical product or process of handling physical materials which is used as an aid in problem solving. More precisely, technology is a product or process which allows social agents to perform entirely new activities or to perform established activities with increased efficiency. "Innovation" is the introduction, discovery and/or development of new technology, or the adaptation of established technology to a new use or to a new physical or social environment. "Diffusion" is the process by which an innovation is propagated over time among members of a social system. "Technological progress" is the combined activities of innovation and diffusion.

"Decentralization" is defined here as an increase in both the number and equality of centers of political power and policy-making. Decentralization can be vertical or horizontal. In vertically decentralized states, authority has been shifted away from the central government and towards local governments, the classic example being federalism.[3] In horizontally decentralized states, authority is shared between an executive, legislature, judiciary, and in some cases even a powerful bureaucracy or autonomous military. In practice, many states decentralize further, with power formally divided between different houses of the legislature, competing bureaucracies, and/or branches of the armed forces. Although decentralization can be informal, we are concerned here only with formal government structure, that captured by law or constitution. In line with this interpretation, the term "executive branch" will hereafter refer to the elected heads of state, their cabinet members, and the bureaucracy. It is also important to distinguish between the decentralization-centralization and strong state-weak state typologies. These concepts mainly overlap in their consideration of the role of the executive, namely the bureaucracy. The bureaucracy of a "strong state" is relatively immune to pressures from the general public or even elected officials; while in a "centralized state" the bureaucracy is united under one roof such that each ministry is

[2] For further discussion see Jasanoff, Sheila , Gerald E. Markle, and James C. Petersen (eds.) *Handbook of Science and Technology Studies* (Sage 1995).
[3] Rodden, Jonathon "The Promise and Peril" unpublished mimeo (2001).

relatively immune to pressure from other ministries, and often from elected officials outside the executive branch.[4]

II. Literature Review

Why might decentralized states foster long-run technological progress? A brief survey of the relevant literature finds multiple causal paths for such a relationship. Friedrich Hayek argued that local governments, due to their superior information about local conditions and preferences, can make better policy decisions than national governments and thereby create better environments for investment and industry.[5] Charles Tiebout contended that competition between sub-national units can allow individual citizens and firms to match their preferences with a specific menu of public goods.[6] Competition of this type has since become known as the "Delaware Effect" whereby sub-national political units compete for corporate investment, resulting in races-to-the-bottom in local tax rates and regulatory barriers.[7] According to Barry Weingast, the result of this type of competition is "market preserving federalism": a national environment which not only favors business, but which also provides incentives for government officials to commit to preserving free markets rather than allowing expropriation by the state, lest they lose or destroy the economic engines of national wealth.[8]

Scholars of technological innovation take different theoretical routes but reach the same general conclusion about the benefits of decentralization. Drawing on models of evolutionary biology, many economists focus on the random nature of technological progress, stressing the importance to innovation of diversity in the face of randomly changing shocks and opportunities over time.[9] They recognize that

[4] Drezner, Daniel "State Structure, Technological Leadership and the Maintenance of Hegemony" *Review of International Studies* 27(1) (January, 2001), fn 10.
[5] Hayek, Friedrich A. "The Use of Knowledge in Society" *American Economic Review* 35 (1945).
[6] Tiebout, Charles "A Pure Theory of Local Expenditures" *Journal of Political Economy* 64 (1956).
[7] Cary, William L. "Federalism and Corporate Law: Reflections Upon Delaware" *Yale Law Journal*, 83(4) (March 1974).
[8] Weingast, Barry R. "The Economic Role of Political Institutions: Market-Preserving Federalism and Economic Development" *Journal of Law, Economics, and Organization* 11 (1995); Qian, Yingyi and Barry R. Weingast "Federalism as a Commitment to Preserving Market Incentives" *Journal of Economic Perspectives* 11(4) (Fall 1997); Rodden, Jonathan and Susan Rose-Ackerman "Does Federalism Preserve Markets?" *Virginia Law Review* 83(1), (Oct. 1997).
[9] Freeman, Chris and Francisco Luca *As Time Goes By* (Oxford Univ. Press, 2001); Mokyr, Joel "Induced Technical Innovation and Medical History: An Evolutionary Approach" *Journal of Evolutionary Economics* 8(2) (1998); Saviotti, Paolo *Technological Evolution, Variety, and the Economy* (Edgar Elgar, 1996); Metcalfe, J. S. "Technological Systems and Technology Policy in an Evolutionary Framework" *Cambridge Journal of Economics* 19 (1995); Hodgson, Geoffrey *Economics and Evolution: Bringing Life Back into Economics* (Univ. Michigan, 1993); Freeman, Christopher "Schumpeter's Business Cycles Revisited" in Heertje, Arnold and Mark Perlman *Evolving Technology and Market Structure* (Univ. Michigan, 1990); Nelson, Richard R. *Understanding Technical Change as an Evolutionary Process* (Elsevier Science, 1987); Nelson, Richard R. and Sidney G. Winter *An Evolutionary*

innovation is empirically unpredictable in both form and direction, often resembling a trial-and-error search in which the market or social environment ultimately selects which technology will survive in the long-run. The implication of the evolutionary approach is that a variety of political-economic environments will multiply the chances that any one of them will provide the best circumstances for successful innovation. Another school of thought highlights the importance of "trialability" and "heterophilous communication" in speeding the invention and adoption of new technologies.[10] "Trialability" means the ability to try a new technology on a small-scale before adopting it on a wider level. Decentralization aids "trialability" in that it provides an environment where new innovations can be tried first in some small sub-unit of the society.[11] Decentralization also allows for easier separation of populations into different socio-economic and even cultural sub-units. Diffusion scholars argue that the separation of, and communication between, these heterophilous sub-units is essential to innovation and diffusion, and that the absence of heterophily can act as an invisible barrier to diffusion.[12] This notion of heterophily is supported by several case studies, the core argument of which tends to be that some segments of society face (or choose to respond to) certain social problems before others, and hence become early adopters of new innovative policies or technical solutions.[13]

Since technological innovation is a sparsely studied question in political science much of the above is necessarily based on extensions of well-established theory to new problems. And while this approach is widely prescribed for scientific research, it can often seem uncompelling given the complexity of phenomena in the social sciences.[14] In other words, the question of technological progress may simply look

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Theory of Economic Change (Belknap Press, 1982); Alchain, A.A. "Uncertainty, Evolution, and Economic Theory" *Journal of Political Economy* 58 (1950); Hayek, F. A. "Competition as a Discovery Procedure" in *New Studies in Philosophy, Politics, Economics and the History of Ideas* (University of Chicago Press, 1978) ; Hall, Peter *Innovation, Economics and Evolution : Theoretical Perspectives on Changing Technology in Economic Systems* (Harvester Wheatsheaf, 1994). For a general critique, see Krugman, Paul "What Economists Can Learn From Evolutionary Theorists" talk given at the European Association for Evolutionary Political Economy (November 1996).

[10] Rogers, Everett *Diffusion of Innovations* Fourth Edition (Free Press, 1995); Magill, Kathleen P. and Everett M. Rogers "Federally Sponsored Demonstrations of Technological Innovation" *Knowledge* 3(1) (1981); Klonglan, Gerald Edward "Role of a Free Sample Offer in the Adoption of Technological Innovation" PhD Thesis (Iowa State University, 1963).

[11] Rogers (1995).

[12] Rogers (1995); see also Granovetter, Mark S. "The Strength of Weak Ties" *American Journal of Sociology* 78 (1973); "The Strength of Weak Ties Revisited" in Peter Marsden (ed.) *Social Structure and Network Analysis*(Sage, 1982).

[13] Geertz, Clifford *Peddlers and Princes: Social Change and Economic Modernization in Two Indonesian Towns* (Univ. Chicago Press, 1963); Walker, Jack "Innovation in State Policies" in Jacob, Herbert and Kenneth N. Vines *Politics in the American States: A Comparative Analysis* (Little & Brown, 1971).

[14] King, Gary, Robert Keohane, and Sidney Verba *Designing Social Inquiry : Scientific Inference in Qualitative Research* (Princeton Univ. Press, 1994).

like a nail to holders of the theoretical hammers described above. Therefore it is important to go further and suggest that perhaps the most convincing argument for a structure-innovation relationship comes not so much from extrapolations on older theory, but from tying together two chains of evidence recently established in disparate stands of comparative politics. The first chain comes from social scientists who study linkages between government policy and technological progress. Often using a case study approach, scholars such as Richard Nelson, Michael Porter, Bengt-Ake Lundvall, Charles Edquist, for example, examine the effects of different science policies, trade regimes, or financial environments.[15] This "national innovation systems" literature brings to light the complexity of the innovation process and the diversity of factors involved in it, however it has also resulted in some fairly complex models of national innovation and suggests some 20-30 major independent variables (policies and meso-institutions), each of which may play a role in technological innovation depending on its configuration vis-à-vis the other variables. While this approach has been useful in identifying many of the regulatory and resource issues surrounding innovation and in establishing some important causal linkages between policy and innovation on a country by country basis, it has yet to yield a more general theory of innovation at the national level. The second chain of evidence comes from scholars who link national institutions to policies and policy outcomes. Here Kenneth Shepsle, Stephan Haggard, Matthew McCubbins and other researchers who study policy differences between nations, increasingly point to differences in government structure and electoral systems as causal explanations for a myriad of policy phenomena, including budget deficits, corruption, government and policy stability.[16] This paper attempts to join these two lines of research and investigate the possibility of a causal relationship between government structure and rates of technological progress.

IV. Case Studies

Given the failure of the statistical regressions to confirm the decentralization-innovation hypothesis (Taylor 2007), we turn now to the case studies in order to generate further variables and hypotheses for

[15] Nelson, Richard R. *National Innovation Systems: A Comparative Analysis* (Oxford Univ. Press, 1993); Lundvall, Bengt-Ake *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning* (St. Martin's Press, 1992); Edquist, Charles *Systems of Innovation : Technologies, Institutions, and Organizations* (Pinter, 1997).
[16] Haggard, Stephan and Matthew McCubbins, *Presidents, Parliaments, and Policy* (Cambridge Univ. Press, 2001); Shepsle, Kenneth A. and Mark S. Bonchek *Analyzing Politics: Rationality, Behavior, and Institutions* (W.W. Norton, 1997); Graham, B. D. *Representation and Party Politics* (Blackwell, 1993); Francis, John G. *The Politics of Regulation: A Comparative Perspective* (Blackwell, 1993); Ramseyer, Mark and Frances Rosenbluth *Japan's Political Marketplace* (Harvard Univ. Press, 1993); Wilson (1990); Hall, Peter *Governing the Economy: The Politics of State Intervention in Britain and France* (Polity, 1986).

consideration. Two technological case studies (electric power and blood products) were performed across five countries (United States, Great Britain, Germany, France, Japan) in separate time periods. In both cases the following phenomena were observed: 1) government structure had no apparent correlation with innovation; 2) government structure did appear to correlate with the diffusion of new technology, with decentralized states diffusing faster than centralized states; 3) technological progress appeared to create "winners" and "losers", and the losers act politically to defend themselves; 4) decentralization provided the supporters of technological progress with the ability to "venue-shop" around political resistance, which increased both the costs of political resistance to new technology, as well as the likelihood of finding a favorable political environment for technological progress; 5) decentralization appeared to aide diffusion by creating incentives for subnational governments to support it, and by allowing political deals over policy design to occur at the subnational level where there was less obstructive interference from non-local interests. The rest of this section will provide more in-depth discussion of these observations and the cases which produced them.

Case Selection

Of the over forty different technologies considered for the case studies, the two innovations selected were electric power and blood products. Since the goal of the case studies is to generate theory and testable hypotheses, and not to perform tests, selection on the dependent variable is not an issue. Rather I was more concerned with selecting cases that have an abundance of data with which to work in order to provide the widest possible range of potential variables. Electric power was selected for its tremendous impact on all aspects of society, as well as the large amount of existing comparative research on the invention and early diffusion of electric power technologies (central stations, incandescent lighting, electric transportation, stationary motors). The time period (1879-1914) also predates the modern industrial laboratory system, the military-industrial complex, and the formalization of a permanent role for government as a promoter of technological development, each of which is sometimes credited as a source of technological advantage. The selection of blood technology is antithetical to electricity in several respects. First, electricity is a large technical system (or network) often requiring enormous capital outlays and having large network effects over vast geographic areas; in comparison, blood technology is

inexpensive, portable, limited, and individualistic. Second, innovation in electricity is more focused on products (generators, motors, lamps), while blood technology finds its most significant innovation in processes (transfusion, testing, heat treatment). Third, electric power was a "revolutionary" innovation which produced major changes throughout society, while the blood technologies investigated here were small "evolutionary" or "adaptive" innovations which caused only minimal changes in social life and the economy.[17] Fourth, electricity and blood products are based in part on distinctly different scientific fields and solve problems in different industries and different aspects of social life. Fifth, unlike electricity, most blood technology was developed in the context of well-established modern research institutions, amidst popular belief in the benefits of technological progress, and after considerable observation of the potential advantages of government participation. Finally, the case data on electricity and blood products overlap significantly in cross-sectional terms, allowing me to at least partially control for geography, culture, and other long-term national characteristics.

The countries chosen for the case studies were the United States, Germany, Great Britain, France, and Japan. The two relatively decentralized states in both time periods are the United States and Germany, both of which formally divided power vertically between the national, state, and municipal governments and horizontally between the executive, legislative, and judicial branches.[18] Opposite them in both time periods sit Great Britain, France, and Japan, each a relatively centralized unitary state with policymaking power concentrated on a single branch of government, and little formal autonomy or significant power to "check" or "balance" given to the other branches or the sub-national governments.[19] These countries were

[17] For more on this distinction see Rosenberg, Nathan "A General Purpose Technology at Work: The Corliss Steam-engine in the Late 19th Century U.S. Series: Working Paper #8485 (National Bureau of Economic Research, 2001); Helpman, Elhanan *General Purpose Technologies and Economic Growth* (MIT Press, 1998); Bresnahan, Timothy F. "General Purpose Technologies: Engines of Growth?" Working Paper #4148 (National Bureau of Economic Research, 1992); Mokyr, Joel *The Lever of Riches: Technological Creativity and Economic Progress* (Oxford Univ. Press, 1990).

[18] Anton, Thomas J. *American Federalism and Public Policy: How the System Works* (Temple Univ. Press, 1989); Woll, Peter and Robert H. Binstock *America's Political System* (McGraw-Hill, 1991) Fifth Edition; Feuchtwanger, Edgar *Imperial Germany: 1850-1918* (Routledge, 2001); Pulzer, Peter *Germany 1870-1945: Politics, State Formation, and War* (Oxford Univ. Press, 1997); Hancock, M. Donald *West Germany: The Politics of Democratic Corporatism* (Chatham House, 1989).

[19] Lee, Stephen J. *Aspects of British Political History 1815-1914* (Routledge, 1994) ;McCord, Norman *British History 1815-1906* (Oxford Univ. Press, 1991); Peele, Gillian *Governing the UK* (Blackwell, 1996) Third Edition.; Anderson, R.D. *France 1870-1914: Politics and Society* (Routledge & Kegan, 1977); Gildea, Robert *France: 1870-1914* (Addison Wesley Longman, 1996); Sowerwine, Charles *France Since 1870: Culture, Politics, and Society* (Palgrave, 2001); Hayward, Jack *The One and Indivisible French Republic* (WW Norton, 1973); Hayward, Jack *The State and the Market Economy* (NYU Press, 1986); Loughlin, John and Sonia Mazey (eds.) *The End of the French Unitary State?: Ten Years of Regionalization in France (1982-1992)* (Frank Cass, 1995); Suleiman, Ezra N. *Politics, Power, and Bureaucracy in France: The Administrative Elite* (Princeton Univ. Press, 1974). Suleiman, Ezra N. *Elites in French Society* (Princeton Univ. Press, 1978); Suleiman, Ezra "From Right to Left: Bureaucracy and

chosen to maximize variation in the independent variable (decentralization) while controlling as much as possible for major conditional variables such as level of development, size, culture, ideology, etc. Note that where potentially significant differences do exist between nations they tend to cut across the decentralization-centralization divide thus enhancing the comparison. For example, within the group, the US and Great Britain share similar levels of economic development, technical sophistication, economic ideology, language, religious tradition, and cultural heritage, yet the two nations are opposites in terms of government structure. Conversely, where the degree of government decentralization is similar, the nations tend to vary significantly on most other axes.

There are two potential objections to the classifications of government structure above. First, one might be tempted to discount the French electricity case because, unlike the other cases of centralized government where power is concentrated on the Prime Minister and his/her cabinet, France during its Third Republic (1870-1940) possessed a government structure which concentrated power on its legislature's lower house (Chamber of Deputies). Note however that this does not violate the definitions or assumptions posited in this study, which are silent regarding the location within government of concentrated political power and require only that it be concentrated on a single branch of government. Future research might investigate the relevance of the location of centralized power to policy outcomes; but for now, given the French Chamber of Deputies' relatively unbalanced and unchecked control of budgets, legislation, and other branches and levels of government, France during this period is coded as a centralized state.[20]

Second, Japan during the late 19th and early 20th centuries, though centralized, was far less democratic than the other nations in the studies. Democracy is an important control variable because it enables interest groups to influence technological progress in ways not always available in non-democratic states, and vice-versa; moreover experience shows that non-democratic states tend to consistently under-

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Politics in France" in Suleiman, Ezra (ed.); Duus, Peter "The Era of Party Rule, Japan 1905-1932" in Crowley, James B. ed. *Modern East Asia: Essays in Interpretation* (Harcourt Brace, 1970); Teidemann, Arthur E. "Big Business and Politics in Pre-war Japan" in Morely, James W. *Dilemmas Of Growth In Prewar Japan* (Princeton Univ. Press, 1971); Ishii, Ryosuke *A History of Political Institutions in Japan* (Univ. of Tokyo Press, 1980); Ito, Takatoshi *The Japanese Economy* (MIT Press, 1992); Nakamura, Kichisaburo *The Formation of Modern Japan* (East-West Center, 1962); Pyle, Kenneth B *The Making of Modern Japan* (DC Heath, 1996) Second Edition.

[20] Sowerwine (2001); Gildea (1996); Loughlin & Mazey (1995); Hayward (1986); Suleiman (1978); Anderson, R.D. (1977); Suleiman (1974); Hayward (1973).

perform democratic states in long-run technological progress.[21] Democracy in Japan during this period was uneven, but slowly strengthening overall. Having just emerged from feudalism during the mid-1800s, the Japanese did not initiate major structural changes until the 1860s and failed to achieve full democracy until after the phases of electrification considered in our case studies. More specifically, at all levels, the government of Japan was generally made up of former *samurai* headed by a handful of elites who operated within a poorly defined and constantly changing institutional structure from 1868 through 1889. A formal Constitution was promulgated in 1889 and a bicameral Parliament convened soon afterwards. Yet Japan's new institutional structure still placed most substantive power in the hands of a "clique" of collegial elites who designed and implemented policy without substantive checks or balances to their power, or even clearly defined ministerial portfolios. Moreover, these political elites strongly supported technological progress and modernization, judging them to be essential to the protection of Japan from the foreign colonization and general upheaval taking place in the rest of Asia. Hence, at the national level, power was concentrated on pro-technology "cliques", while subnational governments served at best as administrative units in the service of the center. Due in large part to generational change and the ability of the elected members of Parliament to use their few institutional powers to leverage concessions from the cliques, we begin to see after 1905 the advent of viable political parties and their growing participation in national government. However, it is not until the 1920s that democracy is widely considered to have been achieved. This does not necessarily eliminate Japan from consideration, but provides a warning that it not be lumped in casually with the other cases and should instead provide a contrast with the more democratic states.[22]

Electric Power Overview

Before discussing the case study findings, brief summaries of the two case studies are provided in the following two sections. The electricity case studies examined innovation and diffusion of electric power technologies during the decades following the invention of the incandescent lighting (1878-79).[23] Although scientific experiments with electricity date back centuries before this time, and useful applications began to

[21] One need only observe the experiences with both technological progress in the Soviet Union, the People's Republic of China, and the much shorter regime of Nazi Germany to see that innovation and diffusion proceeded differently there than in democratic states. See also Mokyr (1990); Rosenbern (1985)
[22] Pyle (1996); Ito (1992); Ishii (1980); Teidemann (1971); Duus (1970); Nakamura (1962).

appear during the first half of the 1800's, it was not until the development of incandescent lighting and, more importantly, Edison's centralized large-scale power generators which ran it (1879), that electric power began to have its transformative effects on social life, urban transport, industrial production, and mass consumption. Thereafter, modern electric power technology advanced and diffused in three successive waves, each of which drove demand for more power generation and distribution, and in turn provided the basis for subsequent technological development. The first wave was driven by incandescent illumination (1879-1890), the second by electric trams and trolleys (1890-1900), the third by electrification of factories and mass-transport systems (1900-1914). In each of these waves the decentralized states (United States, Germany) were more technologically progressive than the centralized states (Great Britain, France, Japan) despite a growing general awareness of the overall economic and social benefits of electrification (see Chart 7). Japan, a potential outlier, was a slow diffuser on an absolute scale, but a rapid diffuser on a relative scale, starting later but often diffusing more quickly than the other states, especially in proportion to other existing forms of power. By World War I, despite their prompt entry into the electricity industry in 1882-84, the technological backwardness of Britain and France was popular knowledge, and each of the centralized states was generating far lower quantities of electricity per capita, at higher prices per kilowatt-hour, and (with the exception of Japan) using a far lower percentage of their electricity for manufacturing or transportation than was done in the United States or Germany.

Chart 7: Appearance and Diffusion of Various Electric Power Technologies

	First central power station	Incandescent lighting, 1887 (US=100)	First electric tram	Miles of electric trams, 1900	First AC power[24]	Generating Capacity, 1912-15 (kWh)
United States	1882	100	1887	20,000	1893	5,165,000 (1912)
Germany	1884	37.5	1890	1,800	1891	2,075,000 (1913)
Great Britain	1882	25	1896	572	1899	1,135,000 (1914)
France	1883	8	1895	292	1895	1,800,000 (1913)
Japan	1887	--	1895	--	1896	569,000 (1915)

Source: Levy-LeBoyer & Morsel (1994), Minami (1987), Todd (1994), Hughes (1983), Milliard (1981)

[23] Weak current technologies such as the telegraph, teleprinter, electric clock, and stock ticker may have been technically revolutionary, but electric power in this form had only limited social or economic impact.
[24] modern, 3-phase electric power

What do the electricity cases suggest about non-structural variables and alternative explanations for the variation in rates of technological change? The case studies fail to support several of the more intuitive alternative explanations for the observed variation in technological progress in electricity. For example, one obvious candidate is the nation's base-level of technological advance. However, differences in technological base or scientific sophistication did not correlate well with differences in electrification rates: Britain and France were leading innovators in the field yet also laggards in diffusion, while Japan compensated for its scientific backwardness by luring several top Western electricity researchers during the 1870s-1880s to instruct in newly established university programs and help set up research facilities. A second possibility, lack of national interest in electricity, does not appear to have been determining factor since technology transfer was aggressively pursued by all of the countries in this study, and actively promoted by the major producers of electrical machinery and equipment who sought footholds in the British, French, and Japanese markets. Resistance to the spread of electricity was likewise relatively similar across nations, with opposition arising for several common reasons, including concerns over safety, the aesthetics of power lines, price, availability, monopoly abuse, and the existence of vested interests in competing forms of power, especially gas. Nor, in any of these societies, was the labor force in traditional industries supportive of the job-destroying aspects of factory electrification, though such opposition was generally balanced by the job creation experienced in the electrical industry itself, the expanding public transport sector, and the evolving mass-production system made possible by electricity. Level of economic development might also be discarded as a determining factor since the most developed country, Great Britain, was also the slowest to diffuse, while the least developed country, Japan, diffused with relative speed. Capital scarcity shows similar behavior, with capital rich Great Britain versus capital poor Germany and Japan, though these latter countries did benefit from significant war indemnities at the time. Economic openness does not appear to vary with diffusion rates since Great Britain pursued free trade at the time, while the United States, France, Germany and Japan were protectionist. Finally, given electricity's economies of scale and network effects, population or land area may have been factor in its diffusion and we do find that the United States and Germany were larger than the centralized states; however, anecdotal

evidence suggests that electricity diffusion in small but decentralized Switzerland was comparable to that of America and Germany.[25]

Two alternative explanations which cannot be so easily dismissed are 1) differences in domestic economic ideology and 2) Gerschenkronian development. In the United States, Germany, and Japan, economic thought of the time period was favorable towards, or at least relatively uncritical of, monopolies; whereas British and French policymakers perceived economic monopolies as antithetical to the public interest, a source of dynamic and static inefficiencies, and a threat to government power. This factor is important because the technology of electricity turned out to have large economies of scale which heavily favored monopoly, or at least oligopoly, production. Schumpeter has even argued that the activities of research and development themselves have economies of scale, and are therefore promoted best by monopolies, although the empirical evidence for this thesis is conflicting.[26] However, at least in the early electric power industry, some tolerance for economic concentration was necessary for technological advance beyond the initial stages of DC power. And both contemporary and historical analyses of British and French technological backwardness in electricity repeatedly blame domestic contempt for, and hence lack of, economic concentration on both the supply side (electric power and machinery manufacturers) and the demand side (industrial customers) of the electric power industry. The problem with this explanation is that ideology is inseparable from interests in this case, and there existed strong pro- and anti- monopoly interests in each of the countries studied. Hence we are brought back to government structure and how it may have affected the ability of these competing interests to achieve their policy goals.

Another non-trivial alternative explanation is the Gerschenkronian thesis, which contends that late-developers will industrialize in rapid spurts and, despite capital scarcity, acquire the most advanced technology in order to compensate for a lack of skilled labor.[27] This dovetails with the spurt-like electrification of the late-developers of U.S. and Germany, and the relatively slower development of Great Britain, which was rich in capital, skilled labor, and had led the first industrial revolution. It would also seem to apply to the Japan case, which was both the latest developer and fastest diffuser of electricity in

[25] Population in 1900/1901: US (76 million), Germany (56 million), Japan (44 million), France (38 million), UK (37 million, Swtizerland (1.9 million).
[26] Schumpeter, *Capitalism, Socialism, and Democracy* (Harper & Row,1950)

relative terms. However, France was also identified by Gerschenkron as a late-developer, but the case study reveals that France diffused electricity no faster, if not more slowly, than Britain. Also the application of Gerschenkron's model to the US, Germany, and Japan breaks down at more specific levels of detail. For example, the US and Germany were lead innovators and exporters of electricity technology, while Gerschenkron implies that significant copying and importation of new technology should take place, at least initially. And although this description closely fits the Japan case, Japan violates other major tenets of the model such as Gerschenkron's insistence on a heavy participation of government in states with scarce capital. Rather, the case study shows that Japan's electricity industry has always been private, as has much of the capital which founded it, and that the industry suffered relatively little intervention by government until the 1930s.[28] Also, Japan's industrialization was founded on the poorly electrified textiles industry, not on the most technologically advanced industries as Gershenkron predicts.[29]

The general summary above is not intended to categorically dispel alternative explanations for differences in electrification. However, it should eliminate some of the initial hesitations about attributing a causal role to government decentralization and allow us to approach the case study observations with somewhat greater confidence in the independent variable. These observations will be discussed below, after a general overview of the blood technology cases.

Blood Technology Overview

The blood cases examined the innovation and diffusion of two technologies devised to protect the blood supply against contamination by HIV, the virus which causes AIDS. The AIDS epidemic surfaced in the industrialized world in June 1981. As a blood born disease, AIDS posed a deadly threat to all transfusion recipients, especially the hundreds of thousands of hemophiliacs whose lives depended on sometimes weekly transfusions of blood derivatives known as anti-hemophilic factor (AHF).[30] The technological solution to this problem ultimately consisted of an enzyme-linked immunosorbent assay

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[27] Gerschenkron, Alexander *Economic Backwardness in Historical Perspective* (Belknap Press, 1962)
[28] Samuels, Richard J. *The Business of the Japanese State: Energy Markets in Comparative and Historical Perspective* (Cornell Univ. Press, 1987);
[29] Minami, Ryoshin *Power Revolution in the Industrialization of Japan, 1885-1940* (Kinokuniya, 1987); Ito, Takatoshi *The Japanese Economy* (MIT Press, 1992).
[30] Transfusion of blood factor is required in hemophiliacs anywhere from once every six months in mild cases to 2-3 times per week in more severe cases. Phone interview Nava Rahmanim, Information Specialist, National Hemophilia Foundation (July 25, 2002).

(ELISA) adapted to identify the presence of HIV virus in blood and blood derivatives, and a heat-treatment process designed to kill HIV virus in transfused blood and blood products. The first HIV ELISA tests were developed and applied in French research laboratories in July-August 1983, and the first successful heat-treatment process was licensed to its German industrial developer, Behringwerke A.G., in 1981.[31] However, these innovations took years, until 1985-86, to diffuse into usage wide enough to effect a solution to the problem posed by HIV. More interestingly, these technologies generally progressed faster in the decentralized United States and Germany than in centralized Great Britain, France, and Japan. In the

Chart 8: Innovation and Diffusion of Basic Blood (HIV) Safety Technologies

	First domestic AIDS identif'd	First domestic transfusion AIDS	ELISA innovated	Heat innovated	ELISA diffused	Heat Diffused
US	June 1981	July 1982	Apr. 1984	1983	Mar. 1985	Mar. 1983
Germany	1982	Oct 1983	--	May 1981	Apr. 1985	Feb. 1985
UK	Dec 1981	Spring 1983	autumn 1984	1984	Oct. 1985	Oct. 1985
France	June 1981	July 1982	July/Aug 1983	--	Aug. 1985	Sept/ Oct. 1985
Japan	July 1983	July 1983	--	late-1985	Nov. 1986	late-1985

Source: Montagnier (2000), Feldman & Bayer (1999), Starr (1998), Institute of Medicine (1995), Kirp & Bayer (1992), Grmek (1990), Centers for Disease Control (June 5, 1981; July 16, 1982).

Chart 9: Time Elapsed From…

	First knwldge AIDS to ELISA diffusion[32]	First knwldge transfusion - AIDS to heat diffusion[33]	First domestic AIDS case to ELISA diffusion	First domestic transfusion AIDS case to heat diffusion	First domestic AIDS case to ELISA innovation	First domestic transfusion AIDS case to heat innovation
US	45 months	8 months	45 months	8 months	34 months	~6 months
Germany	46 months	29 months	~40 months	16 months	--	0 months
UK	52 months	39 months	46 months	~31 months	34 months	~12 months
France	50 months	~38 months	50 months	~38 months	~25 months	--
Japan	65 months	~40 months	40 months	~30 months	--	~30 months

Based on Chart 8

[31] Montagnier, Luc *Virus: The Co-Discoverer of HIV Tracks Its Rampage and Charts the Future* (W.W. Norton, 2000); Institute of Medicine, *HIV and the Blood Supply: An Analysis of Crisis Decisionmaking* (National Academy Press 1995).
[32] Dated from the first international recognition of the disease, June 1981.
[33] Dated from the first international recognition of the possibility of transmission via transfusion, July 1982.

meantime, tens of thousands of people contracted transfusion AIDS and died, sometimes not before unknowingly passing the virus on to others. Given the widespread and lethal nature of the threat, and the relative simplicity of the technological fixes,[34] it is puzzling that the technological solutions took so long in coming, and that months, if not years, passed between the lead and late adopters (see Charts 8 & 9).

Again, the case studies fail to support some of the more obvious alternative, non-structural explanations for the observed variation in technological response times in blood products. Several of these non-structural variables are suspect because they did not differ across countries. These variables include: the uncertainty regarding the nature of the disease and its transmission, competing demands to solve other and clearer national problems such as the ongoing Soviet threat and domestic economic troubles, a desire to tighten budgets and reduce taxes, and in no country was homosexuality fully socially accepted. Also, many of those interest groups most affected by the AIDS threat (blood banks, gays, hemophiliacs) ironically sought to impede a technological solution in each of the five countries studied.[35] Many politically active gays perceived testing as a tool for discrimination. Hemophiliacs, only recently granted "normal lives" by the invention and diffusion of AHF, were initially wary of any technological changes which might affect its quality, availability, or cost.[36] The blood industry saw HIV-tests and heat-treatment as technologies with questionable effectiveness but certain to drive up the costs of doing business. HIV-tests, it was argued, would drive away gay donors, highly valued in some regions, while attracting potential AIDS sufferers seeking free and anonymous diagnoses. And since heat-treatment increased the price of blood products by upwards of 60%, neither the blood banks, their customers, nor the medical insurers were enthusiastic about the effect on their bottom lines, especially since the etiology of the disease was open to debate.[37] Each of these groups took advantage of the uncertainty about the science of AIDS, and the uncertainties

[34] Most, if not all, of the component technologies which formed the foundations of the HIV ELISA and heat-treatment had existed for at least a decade.
[35] Griggs, John (ed.) *AIDS: Public Policy Dimensions* (United Hospital Fund of New York, 1987); Fee, Elizabeth and Daniel M. Fox *AIDS: The Making of a Chronic Disease* (Univ. of California Press, 1992); Berridge, Virginia and Philip Strong (eds.) *AIDS and Contemporary History* (Cambridge University Press, 1993).
[36] Cryoprecipitate, essentially frozen AHF, was invented at Stanford University in 1965 and eliminated hospital visits for most hemophiliacs. Powdered AHF concentrate, which both eliminated the need for frozen storage facilities and enabled injection by non-medical personnel, was perfected in the late 1960s by a University of North Carolina—Hyland team. These technologies are credited with adding 20+ years to the average life expectancy of hemophiliacs. See Starr (1998) p. 220-222.
[37] Office of Technology Assessment *Blood Policy and Technology* (U.S. Congress, January 1995) p. 69.

surrounding the HIV anti-body tests and the heat-treatment process, to defend their political and economic interests.

Those variables which did differ between the five countries, but which did not correlate with the different rates of innovation and diffusion, also suggest factors which might be eliminated as alternative explanatory variables. First, seroprevalance does not appear to have been a factor. The US and France were the earliest to be hit by AIDS and suffered amongst the highest infection rates outside of Africa; however the US was a leader in the diffusion of HIV tests and heat-treatment processes, while France was a late-adopter. Nor does scientific capability appear to be significant since the US and France were both at the frontiers of the science and technology of AIDS, while neither Japan nor Germany appear as major scientific contributors prior to the late-1980s. Culture, admittedly a poorly understood variable in political economy, does not seem to have played a role here, since both lead and late innovators fell within similar cultural groupings. For example, Germany and France were heavily catholic, US and the UK protestant, and Japan a mixture of Shinto, Buddhism, and Confucianism.[38] Nor do popular attitudes towards homosexuality or its relationship to AIDS correlate well with the diffusion of technological solutions to what was often perceived, even amongst hemophiliacs, to be a homosexual affliction.[39] For example, the French scientific establishment tended to see sexuality as incidental to AIDS and generally avoided this red herring which for years dogged American researchers, who at first perceived of AIDS as a strictly "gay disease".[40] Meanwhile, in Japan, hemophiliac sufferers far outnumbered either gay or intravenous drug-related victims of AIDS making it less of a "moral" issue.[41] Nor did the broad structure of the national health care system seem to matter, since every country but the United States had near total national health

[38] If anything, one might argue that Japanese culture should have been the most gay tolerant of the countries. Unlike much of the Western nations, neither homosexuality nor sodomy was illegal in Japan, and gay relationships were historically semi-accepted within the samurai ethic, Buddhist priesthood, performing arts, even to the point of allowing a substantial male prostitution industry. See the 18th century classic on samurai ethics Tsunetomo, Yamamoto *Hagakure: The Book of the Samurai* translated by Willaim Scott Wilson (Kodansha International, 1979) or the popular 17th century collection of short stories about gay samurai Saikaku, Ihara *The Great Mirror of Male Love* translated by Paul G. Schalow (Stanford Univ. Press, 1990); also McLelland, Mark J., *Male Homosexuality in Modern Japan: Cultural Myths and Social Realities* (Curzon Press, 2000); Pflugfelder, Gregory M. *Cartographies of Desire: Male-Male Sexuality in Japanese Discourse, 1600-1950* (Univ. of California Press, 2000); Leupp, Gary P. *Male Colors: The Construction of Homosexuality in Tokugawa Japan* (Univ. of California Press, 1997); Feldman (1999).
[39] Homosexuality is coded as both a common and variable factor in recognition that, while in no society was homosexuality accepted as mainstream social practice, its legal, cultural, and social permissibility varied considerably between countries.
[40] Shilts, Randy *And The Band Played On : Politics, People, and the AIDS Epidemic* (St. Martin's Press, 1987).
[41] Feldman, Eric A. and Shohei Yonemoto "Japan: AIDS as a 'Non-Issue'" in Kirp, David L. and Ronald Bayer (eds.) *AIDS in the Industrialized Democracies: Passions, Politics, and Policies* (Rutgers Univ. Press, 1992).

coverage, and each with significant but varying degrees of government participation.[42] Finally, the neither political ideology of the ruling party nor changes of government appear to have mattered: during this period the conservative LDP maintained its decades long dominance in Japan, in France the conservatives lost to the first Socialist-Communist coalition in fifty years, while the Thatcher, Kohl, and Reagan eras began on either side of the Atlantic.

Furthermore, unlike electricity, in order for technological progress in blood safety to occur AIDS first had to be identified as a problem in need of a technological solution, a process which by some measures took decades. However, there appears to be no correlation between government structure and problem identification. Thanks to the monitoring activities of the US Centers for Disease Control (CDC),[43] and the relatively high rate of infection in the United States, many of the epidemiological "first's" occurred there, however such was the reputation of the CDC that its pronouncements were rapidly communicated throughout the international medical community. Hence, none of the governments or medical communities in France, Japan, West Germany, or the UK can credibly claim to have been relatively less aware of the AIDS threat than the others. And although AIDS may have arrived at different times in these countries, none of the governments appear to have experienced a significant delay in identification of domestic AIDS cases once the virus did cross their borders.

Again, the brief surveys above do not completely eliminate the importance of non-structural variables, nor are they intended to do so; rather they should serve to discharge some prevalent and initial hesitations, and allow us to proceed for now to a consideration of government structure. The following section will summarize the observations made in the case studies regarding decentralization and its possible relationship with technological progress.

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[42] Sapolsky, Harvey "Empire and the Business of Health Insurance" *Journal of Health Politics, Policy, and Law* 16 (1991); Giamo, Susan "Adapting the Welfare State: The Case of Health Care Reform in Britain, Germany, and the United States" *Comparative Political Studies* (32)8 (December 1999); Henke, Klaus-Dirk, Ade, Claudia; Murray, Margaret A. "The German Health Care System: Structure and Changes" *Journal of Clinical Anesthesiology* 6 (May/June, 1994); Wilsford, David *Doctors and the State: The Politics of Health Care in France and the United States* (Duke Univ. Press, 1991); Okimoto, Daniel I. and Aki Yoshikawa *Japan's Health System : Efficiency and Effectiveness in Universal Care* (Faulkner & Gray, Inc, 1993).

[43] As part of the U.S. Public Health Service, the CDC was fell under the jurisdiction of the federal executive branch and was controlled by the Department of Health and Human Welfare. The reason for its appearance is that, amongst other duties, the CDC acts as a health monitoring institution and keeps watch on new diseases and potential epidemics through the world. See also Etheridge, Elizabeth W. *Sentinel for Health : A History of the Centers for Disease Control* (Univ. of California Press, 1992). Shilts (1987), Montagnier (2000).

Findings from the Case Studies

The first hypothesis suggested by the case studies is that government structure has no correlation with innovation. In the electricity case, major scientific advances and technological innovations occurred in each of countries under study, with the possible exception of Japan.[44] These innovations included major advances in generator technologies, direct current distribution systems, central power stations, incandescent lighting, alternating-current, long-distance transmission systems, electric motors and machinery, trams, railways, batteries, etc.[45] Two exceptions to this observation stand out. First, that the Japanese made no major contributions in this period has already been mentioned, but it is important to recognize that does *not* mean that the Japanese did not innovate. Few technologies are simple turnkey operations which can be seamlessly transferred and implemented from one society to another; rather, significant innovation is often required to adapt imported technological systems to local physical and social conditions. In Japan, for example, the lighting and electricity industry set up laboratories to pursue both adaptive technologies and basic research for domestic production. And where adaptive innovation did not occur, failure was often the result. Such was the case with Great Britain's first central power station, which involved the simple transfer and installation of American generators, and which were not adapted to fit the local infrastructure and institutional environment, and therefore resulted in failure and abandonment.[46] A second exception to the observed lack of correlation between decentralization and innovation involves what might be termed "late" innovation. That is, if we look at the longer history of electric power technology, earlier innovations, such as the first incandescent bulbs and power station components, were distributed relatively evenly across countries; however, anecdotal evidence suggests that as the technology progressed, "late" innovations, such as advanced AC motors and machinery, may have come disproportionally from the decentralized states. The reason for this phenomena may be tied to diffusion and will be discussed later alongside the second hypothesis below.

[44] Scientists and engineers in Belgium, Russia, Switzerland, Italy, and Denmark also played pivtoal roles in the development of electric power technology and the science of electromagnetism upon which it is based.
[45] It should also be mentioned that scientists and engineers in Belgium, Russia, Switzerland, Italy, and Denmark also played pivotal roles in the development of the science and technology of electric power. Hughes (1983).
[46] Holborn Viaduct station of 1882, Hughes (1983); Hannah, Leslie *Electrification before Nationalisation: A Study of the Development of the Electricity Supply Industry in Britain to 1948* (Johns Hopkins Univ. Press, 1979); This was also true outside of electricity, such as the relatively poor performance of the Tomioka Silk Filature technology transfer project in Japan, see McCallion, Stephen W. "Silk Reeling in Meiji Japan: The Limits to Change" Ph.D. Dissertation (Ohio State Univ., 1983).

A lack of correlation between government structure and innovation was also observed in the blood case, with neither centralized nor decentralized states demonstrating consistent lead times in innovation. Researchers in France and Great Britain independently isolated the HIV virus in April 1983 and December 1983 respectively, with the French team perfecting an ELISA test for HIV antibodies several months later and the British producing a laboratory version of an HIV-antibody for use in research by autumn 1984. [47] However, in both Britain and France, the transition from the laboratory to the production line was not as timely, and it was the American pharmaceuticals firm Abbot Laboratories which perfected the first commercial ELISA test for HIV by March 1985. Meanwhile, the first successful heat-treatment process for blood products was licensed to its German industrial developer, Behringwerke A.G., in 1981, and American pharmaceuticals companies were producing FDA approved heat-treated blood products by March 1983, only two months after being warned by the Centers for Disease Control of the dangers of transfusion AIDS. [48] In England, the main producer of blood products at the time was the state-run Blood Products Laboratory (BPL), which initiated heat-treatment research as early as 1981, though not in response to AIDS but to a hepatitis-B outbreak at a school for hemophiliac children. Regardless, due to inadequate financing the BPL did not manage to produce experimental runs of heat-treated AHF until 1984 and were unable to make the transition to mass production. BPL eventually marketed heat-treated AHF in the spring of 1985, but did not complete the full conversion of its facility until the end of the year.[49]

The second hypothesis suggested by the case studies is that decentralization correlates positively with the diffusion of new technology. Data on the global diffusion of electric power during the turn of the century is somewhat uneven and must be derived from disparate sources; however, regardless of the source

[47] Which had been isolated by Montagnier two months before; Berridge, Virginia *AIDS in the UK: The Making of Policy, 1981-1994* (Oxford Univ. Press, 1996) p. 46, 51

[48] Montagnier, Luc *Virus: The Co-Discoverer of HIV Tracks Its Rampage and Charts the Future* (W.W. Norton, 2000); Institute of Medicine, *HIV and the Blood Supply: An Analysis of Crisis Decisionmaking* (National Academy Press 1995). This quick response by the makers of blood derivatives relative to that of the blood bankers, who dealt in whole blood, was likely due to differences in their competitive market structure. Blood derivatives such as AHF were considered pharmaceuticals and were produced in a competitive market by manufacturers who paid their donors and competed for customers. Conversely, whole-blood was produced by non-profit organizations which acted as local monopolies and depended on volunteer donors to provide their products. Furthermore, whole-blood was legally deemed part of a service during the 1950s-60s and was therefore relatively immune from consumer law suits, a luxury not available to the makers of blood derivatives. Sapolsky, Harvey M. and Stephen L. Boswell "The History of Transfusion AIDS: Practice and Policy Alternatives" in Fee and Fox (1992); Feldman (2000).

[49] Starr (1998).

or type, the data consistently show electric power technology diffusing faster in the decentralized states than in the centralized states. Furthermore, the quantitative data is uniformly backed up by qualitative assessments (both current and historical) from equally diverse sources. Although each of the Western countries initiated incandescent lighting and the construction of central power stations within a year of each other, the United States and Germany quickly took the lead in their diffusion. London's first central station failed and was eventually abandoned, and although other more successful attempts were made, by the 1890's London and most of the rest of Great Britain were labeled backward by electrical engineers of the time, especially in comparison to New York, Chicago, Berlin, and Hamburg.[50] And while the French had begun to electrify major government projects such as naval facilities (1884) and the Suez Canal (1886), private distribution of electricity was markedly slower and discussions in the French legislature expressed dismay at the sluggish rate of domestic diffusion, jealously citing the rapid progress experienced in the US, Germany, and decentralized Switzerland.[51] The transition from lighting to traction and stationary power reveals a similar lag in the centralized states, which trailed far behind the decentralized states in per capita generating capacity, power usage, tram mileage, and factory electrification. Perhaps one telling indicator of the size of the general gap between decentralized and centralized electrification is the fact that neither Britain, France, nor Japan developed during this time period a powerful electrical-industrial conglomerate comparable to America's General Electric or Germany's Seimens.

The blood case reveals similar patterns in government structure and technological diffusion. Despite being the lead innovator in AIDS research and developer of the first proto-type HIV-antibody test, France did not see public usage of the HIV test until five to six months after it was widely available in Germany and the United States. And the fact that the French also suffered amongst the earliest and highest rates of HIV infection does not seem to have affected the outcome. The UK, although not an AIDS research powerhouse on the level of the United States or France, still possessed highly competitive pharmaceuticals firms and innovative medical scientists who managed to isolate the HIV virus and create a prototype blood test before the Americans. Yet, neither the HIV ELISA test nor heat-treated blood products were available

[50] Hughes
[51] Levy-LeBoyer Maurice and Henri Morsel *Histoire Generale de L'Electricite en France Vol I: Espoirs et Conquetes 1881-1918* (l'Association pour l'histoire de l'electricite en France, 1994).

to the British until months after their appearance on the American and German markets. By some measures, Japan was by far the greatest laggard of the group, taking 4-6 years after HIV and transfusion AIDS were first identified, and 3-4 years after HIV first infected the Japanese blood supply, to diffuse the life-saving technologies. On the other hand, Germany, which identified its first domestic AIDS cases later than any other country except Japan, and was last to specifically experience HIV transmission via transfusion of blood products, was the fastest to widely diffuse both HIV ELISA tests and heat-treated blood products. Perhaps most puzzling is the fact that both of these blood technologies, as well as the technologies in the electricity cases, were readily available to Europe and Japan from American and/or German firms which were not only producing these technologies cheaply and efficiently, but were also aggressively trying to sell them on the French, British, and Japanese markets. The answer to this puzzle is the subject of the third hypothesis, which begins to address the political economy of technological progress as observed in the case studies.

As a brief sidenote, the difference in diffusion rates discussed above may help to explain the possible difference in "late" vs. "early" innovation rates in electricity mentioned as a caveat to the first hypothesis. Generally speaking, technology must be used in order to be improved upon. Also, empirical research has shown that, in a wide cross-section of industries, significant innovations often come from the users or component suppliers of new technology, rather than its producers.[52] Therefore, given their higher usage rates of new technology, fast diffusers might be expected to produce "late" innovations more quickly than slow diffusers. That is, certain kinds of innovation may be dependent on diffusion. Again, this relationship was observed only anecdotally in the electricity case and is outside the scope of the blood case which covered too brief a time span, thus additional research is required to further substantiate this hypothesis.

The third hypothesis suggested by the case studies is that technology, and the problems which technology solves, are not neutral, rather they create winners and losers, and the losers act politically to defend themselves. These losers will seek to influence or capture government policy in order to slow or

obstruct technological changes which threaten them. Each of the new technologies covered by the case studies created political-economic "losers" who moved to block the technological progress which threatened them. The "losers" with respect to electricity included: the seventy-year old gas industry, which had a near monopoly on lighting in most cities and sought to retain it; municipal governments, whose power was threatened by the ever increasing size and scope of the local electricity monopolies; consumers, who feared exploitation by monopoly pricing and service; and a broad cross-section of people who felt that electrical fires and electrocution posed a serious threat to their lives and assets. Each of these interest groups campaigned for stiff regulatory limitations on electricity in order to protect their political or economic assets. The overall result of these political efforts was tighter and costly regulation of electricity, though to a lesser degree in Japan, which either raised the costs of electricity production, raised the price of consumption, put ceilings on rates and therefore profits, prevented standardization, prevented concentration and hence the achievement of profitable economies of scale, or banned outright certain types of production, any of which inevitably slowed the rate of electrification.

The technological losers in the blood case included each nation's executive branch, whose economic and/or military goals would have been compromised by budgetary outlays for AIDS and blood safety programs; the blood industry and medical insurers and providers, whose profits were hurt by the costs of testing and heat-treatment; and the domestic pharmaceuticals and blood products manufacturers, whose markets were threatened by foreign imports of the new technologies. The funding activities of the executive branch were most relevant during the first stages of the epidemic, when there was no clear profit for industry, and the high level of uncertainty and lack of information regarding the AIDS significantly raised the costs of action to private actors. This left government, specifically the executive branch, as the main provider of scientific research on AIDS. However, each of the executives in the countries surveyed put priority on economic and/or military goals and generally opposed any budget outlays for AIDS research. Even in France, where the executive branch was in the hands of a Socialist-Communist coalition at the time, spending on AIDS research was all but non-existent. This opposition to spending by the executive branch had its greatest affect in the centralized states, where the cabinet and bureaucracy

[52] Hippel, Eric von, *The Sources of Innovation* (Oxford Univ. Press, 1987).

controlled most, if not all, public research institutes, universities, and even (in France) a significant part of business sector.[53] The blood industry in every country resisted the diffusion of testing and heat-treatment technologies for multiple reasons. First, the whole blood sector depended on either volunteers or poorly paid donors for its blood supply, and either segment might be frightened away by the prospect of their blood being tested, especially in collections districts which had a large percentage of gay donors; while people in high risk groups might be adversely selected, giving blood in order to be tested. Also the added costs of testing and heat-treatment dramatically affected the bottom lines of the both medical insurers and the entire blood products industry. In Japan, cheap imports of unheated foreign blood products were an important source of profits for Japanese physicians and hospitals, who were reimbursed by the government at more expensive domestic price levels. [54] Hence, the Ministry of Health and Welfare (MHW), which had regulatory jurisdiction over pharmaceuticals imports and was advised by members of the medical community who profited from them, not only did nothing but refused for years to report the presence of transfusion AIDS in Japan.[55] [56] Perhaps the most effective opposition to technological diffusion came from the domestic blood products and pharmaceuticals firms who sought to protect local markets. In France, Japan, and Britain, domestic firms were unable to mass produce heated-blood products or ELISA test kits in time to compete with American exports and therefore pressured the executive branch for protection.[57] In France, for example, under pressure from industry, the executive branch refused to open the French market to heat-treated imports, since imports of foreign blood would divert profits from domestic firms; meanwhile the Ministry of Health's technical and licensing body, the National Health Laboratory (LNS), was instructed by the Prime Minister's office to temporarily block the approval of Abbot's ELISA in order to

[53] Berridge, Virginia *AIDS in the UK: The Making of Policy, 1981-1994* (Oxford Univ. Press, 1996); Smith, G. Teeling and D. Taylor "Health Services" in Goldsmith, Maurice (ed.), *UK Science Policy: A Critical Review of Policies for Publicly Funded Research* (Longman, 1984); Street, John and Albert Weale "Britain: Policy-making in a Hermetically Sealed System" in Kirp and Bayer (1992); Kellerman, E. Walter *Science and Technology in France and Belgium* (Longman, 1988); Feldman and Yonemoto (1992); Frankenberg, Guenter "Germany: The Uneasy Triumph of Pragmatism" in Kirp and Bayer (1992); Feldman, Eric A. "HIV and Blood in Japan: Transforming Private Conflict" in Feldman and Bayer (1999); Dressler, Stephen "Blood 'Scandal' and AIDS in Germany" in Feldman and Bayer (1999).
[54] Feldman (1999).
[55] Feldman and Yonemoto (1992).
[56] Swinbanks, David "Japanese AIDS Scandal Over Trials and Marketing of Coagulents" *Nature* 331(6157) (Feb. 18, 1988) p. 552; "AIDS Researcher Hid Hemophiliac's Death" *Japan Times* (February 26, 1996) p. 1.
[57] The American ELISA was denied entry by the UK Department of Health and Social Security ostensibly because the Abbot test provided too many false-positives. Health officials concerned about the psychological impact of high numbers of incorrect diagnoses, as well as insisting that domestic performance trials be conducted on any foreign test. However, observers note that this

buy time for Diagnostics Pasteur to perfect its HIV-antibody test.[58] Similar, though less successful, forms of industry resistance to costly or competing technological change in the blood case can be found in the United States and Germany.[59]

Note that the sources of political resistance to new technology observed in the blood and electricity case studies were, with few exceptions, relatively similar across the five countries considered. Yet, despite these common sources of resistance, the case studies suggest that political action by resistors may have been more successful in the centralized states than in the decentralized states. The question prompted by these observations is therefore: what, if any, are the characteristics of centralized government that may have prevented the rapid diffusion of easily obtainable technology for which there existed strong and widespread public demand? In other words, if government structure matters, then perhaps it matters in how it affects the political battles over the costs and benefits of technological change, and whether and how it serves to aid those who support or oppose new technology. The next two findings from the case studies therefore concern the mechanisms by which decentralization may favor, and centralization may slow, the diffusion of new technology.

The fourth hypothesis suggested by the case studies is that, in the decentralized states, the supporters of new technology can "venue-shop" around political resistance, while this option does not exist in the centralized states. This ability to "venue-shop" between various levels of decentralized government (both horizontal and vertical), *ceteris parabis*, increased the likelihood of finding a favorable political environment for regulatory or budgetary policies conducive to rapid diffusion.[60] In the decentralized countries, power over electricity regulation was originally left to the cities. In the U.S., this generally meant corrupt local officials manipulating the regulatory process so as to exact heavy bribes and payments from electricity providers and traction franchises. The electricity industry responded by organizing legislation so as to elevate regulatory authority to the less corrupt state government level where

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licensing delay gave Abbot's UK competitor, Wellcome, a substantial time-frame to enter a market worth hundred of millions of dollars. Berridge (1996); "Testing Time for AIDS Screening" *Financial Times* (July 31, 1985).

[58] Feldman (2000); Steffan (1999); Steffan (1992).

[59] Feldman (2000), Shilts (1987)

the environment was more favorable. In Germany, local regulatory authority often meant the threat of municipal socialism or tight restrictions by a city government which happened to own the competing gas utility. The German electricity industry responded by appealing either to the Federal government or to the judiciary who successfully kept municipal interests at bay. None of these options were available in the centralized states, where the electric industry was simply stuck with the regime set down by the central government, which in France and Great Britain was dominated by interests hostile to the electricity industry.

The blood case reveals similar mechanics to the electricity case, with private citizens, government officials, and elected politicians taking courses of action in the decentralized states, which were simply not available in the centralized democracies, to press for a technological response to the HIV threat. In the U.S., the legislature was able to override the fiscal priorities of the executive branch, with individual legislators inserting subsidies for AIDS research and safety programs over and above the objections of the President and his cabinet.[61] This phenomenon was repeated in the governments of several American states. For example, in California, Republican Governor George Deukmejian was likewise concerned with reducing deficits, taxes, and the role of government, and consistently allocated funds for AIDS research below that recommended by health authorities.[62] The state legislature then forcibly supplemented Deukmejian's research budgets, overriding his vetoes in order to subsidize research.[63] In a similar move, researchers at California's premier state-owned universities were able to temporarily circumvent resistance to AIDS research by appealing directly to the legislature, and successfully won millions of funding dollars.[64] Where the federal and state governments did not act, the city and country governments stepped in, providing some of the first public funding for research, education, and clinics. In the West German blood case, we find in the judiciary getting involved, with hemophiliacs bringing suit against the Federal government for nonfeasance, and calling upon the Federal Constitutional Court to force legislative action.

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[60] Also, in allowing for greater access to the policymaking process, decentralization may also have increased the costs of policy capture by resistors to new technology, and therefore decreased the likelihood of successful political resistance to technological diffusion. Additional research is required to further substantiate this hypothesis.
[61] Congress Henry Waxman's inquiry on April 12/13 1982 in Shilts (1987) p. 143; Journalist Larry Bush quoted in Shilts (1987) p. 187.; Shilts (1987).
[62] Shilts (1987).
[63] Shilts (1987).
[64] Shilts (1987).

Though eventually dismissed, this case acted as a form of "saber-rattling" by those Germans most threatened by HIV, demonstrating their willingness and ability to act against the executive and legislative branches through the judiciary. And by dismissing the case, the court implicitly rejected the claim that AIDS was a "special" disease in need of special action, and thus removed some of the legal basis for a more centralized command-and-control response being pressed for by Chancellor Kohl and the state of Bavaria, which in turn could have provided an opening for protectionist industry groups to restrain technological diffusion.[65] While this might seem somewhat toothless at first, compare the West German experience to the performance of the judiciaries in France and Japan. In either of these other countries, the courts got involved only after the crisis had passed and thousands of people infected by transfusion AIDS sought justice after the fact. In France, it took until the later half of the 1980s to get a case against the government before a court, and then it was not until late-1992 that a ruling was made. And even though the French ruling came down against the executive branch, none of the senior bureaucrats who were jailed or fined for their actions were members of the Socialist party which had governed during their tenure, and are judged by some observers to have been sacrificed for the Socialist ministers then in office.[66] In Japan, where some 40% of those testing HIV-positive were hemophiliacs, lawsuits were not filed until 1989, and then only against the pharmaceuticals industry.[67] These cases dragged on for years, until the brief occupation of both the Prime Minister's office and Ministry of Health and Welfare by the Japan Socialist Party in 1995 put into power senior politicians sympathetic to the hemophiliacs' situation, and within a year settlements were quickly concluded in favor of the plaintiffs.[68]

The fifth hypothesis suggested by the case studies is that decentralization, in providing for relatively autonomous local governments, alters both the political incentives for technological change and the aggregation of interests surrounding such change. When local governments have fiscal and regulatory

[65] Frankenberg, Gunter and Alexander Hanebeck "From Hysteria to Banality: An Overview of the Political Response to AIDS in Germany" in Rolf Rosenbrock and Michael T. Wright *Partnership and Pragmatism: Germany's Response to the AIDS Crisis* (Routledge, 2000); Frankenberg (1992).
[66] Feldman, Eric A. "Blood Justice: Courts, Conflict, and Compensation in Japan, France, and the United States" *Law & Society Review* 34(3) (2000).
[67] Feldman (1999).
[68] Feldman (2000).

autonomy, they have the capacity to capture for themselves some of the gains of technological diffusion rather than returning these gains to the national level for redistribution. These gains can be financial, such as a share of the revenues generated by diffusion, or political, as an increase in policy jurisdiction and hence local government power. In any case, the ability of subnational governments to capture these gains appears to increase their interest in successful technological diffusion. Also, decentralization allows for the location of decision-making power at a lower level of aggregation, where political deals concerning technological progress can be made away from national political fights and without linkage to distant interests or issues which might complicate or confound a political solution.

In the electricity cases, since regulatory power over electricity was necessarily located at the national level in the centralized states, decisions over electricity policy had to be balanced against a large number of disparate issues and interests, such as national security, industrial performance, competition policy, social welfare, employment, home-rule movements, etc. And since policy was made at the national level, interest groups from anywhere in the country could, and did, interfere with electricity regulation, even if merely as leverage for unrelated political issues. For example, in France, even though electricity was primarily an urban issue during its early stages, rural interests which were worried about urban-industrial political dominance inserted themselves into the policy process to slow diffusion. They successfully pressured the central government to put priority on the rights of the French state over those of private interests in the design of electricity regulation which in turned lowered the incentives for investment.[69] Contrast this with the German case, where the autonomous local governments could share directly in the fruits of electrification.[70] In Germany, the governments of urban districts could use electricity as a source of revenue and therefore supported diffusion, while rural governments sought electrification as a means to ward off incorporation of part or all of their areas into other districts as well as a method by which to promote decentralized control of services and decentralized economic development. Also, political "deals" might sometimes take the form of bribes or kickbacks, were likewise cheaper and easier arrange at the local rather than the national level with its greater media coverage and higher political

[69] Levy-LeBoyer & Morsel (1994)
[70] Todd, Edmund Neville III "Technology and Interest Group Politics: Electrification of the Ruhr, 1886-1930" Ph.D. Dissertation (Univ. of Pennsylvania, 1984); Hughes (1983).

and economic stakes. For example, in the United States, when Edison or his contemporaries needed permits or franchise rights for their central power stations, they often paid off city aldermen and council members for their support.[71] In Britain, this was a far more complicated and costly prospect since any new power station required either an act of Parliament or a provisional order from the President of the Board of Trade, either of which in turn required a delicate balancing of national interests.[72]

Similar dynamics were found in the blood technology cases. In the United States, blood regulation was centralized at the national level and was designed and implemented by the Food & Drug Administration (FDA). The FDA's key advisory committee on blood policy was chaired by a representative of the blood industry who used his position at the FDA to downplay the threat of AIDS and campaign against regulations which might drive up the costs of production, including testing and heat-treatment.[73] Conversely, where policy was decentralized, such as spending on AIDS research and diffusion programs, we find faster rates of change. Politicians in city and state level governments were able to more successfully balance local interest group policy preferences so as to support technological progress in blood safety; while at the national level, questions of national morality and political contests over broader economic and military concerns confronted policymakers, and often could not be balanced favorable for technological progress. For example, the city of San Francisco began spending money on AIDS programs in mid-1982, far earlier in the epidemic than the federal government's first budget outlays, and by some measures San Francisco's research allocations surpassed those of the National Institutes of Health by spring 1983.[74]

Finally, four other hypotheses relevant to variations in technological progress were suggested by the case studies. Due to their peripheral relationship to my focus on decentralization, these observations were made with less evidentiary strength than those listed above and with as yet indeterminate connection to government structure, however their apparent association with rates of technological progress suggest areas of future research.

[71] Hughes (1983).
[72] Hughes (1983); Hannah (1979); Hennessey, R.A.S. *The Electric Revolution* (Oriel Press, 1972).
[73] Shilts (1987)
[74] Shilts (1987)

First, electoral institutions appeared in the background of most of the case studies and may have played a role in determining the effectiveness of interest groups in resisting or supporting technological progress, and of the incentives for elected politicians to respond to these interest groups. For example, in the blood case, relatively low electoral hurdles, due to either low minimum vote thresholds or small district sizes, may have allowed gay groups to get effectively involved in the government's response to the AIDS threat at all levels of government in Germany and the United States. In France and Great Britain, where individual legislators were elected by closed-list and had disincentives to oppose the party line, gay communities were not as politically active, perhaps due to a lack of public access to policymaking, which left little to be gained by collective action by such a small and marginalized minority.[75]

Second, important instances of pork-barreling and log-rolling to support technological progress were also observed across several countries in both case studies, but more research is required to discern if this was balanced by similar actions to obstruct technological change and therefore whether they had any overall effect.

Third, the extent of political resistance to new technology appears to be proportional to the amount of capital invested in the assets threatened by it and their specificity. That is, all else equal, the more capital which is invested in a particular economic activity, then the larger and more powerful the interest group with assets associated with it appears to be; and the more powerful the interest group, then the greater the likelihood that it will be able to launch successful political resistance to technological change which threatens their assets. Asset specificity also seems to matter since mobile asset holders in both the electricity and blood cases appeared to be less resistant to technological change than specific asset holders. For example, Green Cross of Japan had enormous stocks of unsold unheated blood products, and therefore staunchly opposed the admission of foreign heat-treated blood into Japanese markets; while some of electricity's strongest opponents were the holders of specific assets in the gas industry.[76]

[75] Fillieule, Olivier and Jan Willem Duyvendak "Gay and Lesbian Activism in France" in Adam, Barry D., Jan Willem Duyvendak, and André Krouwel (eds.) *The Global Emergence of Gay and Lesbian Politics* (Temple Univ. Press, 1999); Duyvendak, Jan Willem "Identity Politics in France and the Netherlands: The Case of Gay and Lesbian Liberation" in Blasius, Mark (ed.) *Sexual Identities, Queer Politics* (Princeton Univ. Press, 2001); Suleiman (1974); Suleiman, Ezra N. *Elites in French Society* (Princeton Univ. Press, 1978); Hayward (1986).
[76] Starr (1998); Feldman (2000); Feldman (1999).

Finally, regardless of structure, technology proceeded fastest in all states when government removed itself from managing the specific technical aspects of technological change. For example, Britain and France did not merely demand safety and fair treatment from their electric industries, but stipulated precise voltages, asset prices, customer rates, profitability deadlines, notification times in order to achieve these goals. The Germans and Americans sought the same goals but were somewhat less interventionist, generally letting the market determine the technical means to the political ends, and where micromanagement did occur policy was set collegially between industry and local government.

V. Implications

Although the research and analysis reported in this paper did not produce any conclusive explanations for the observed variation in national rates of technological progress, and although the hypotheses generated by the case studies still need to be tested, the insights produced by this exercise do appear to reframe the debate and imply some more specific avenues of research. A number of these research possibilities have already been specifically mentioned or implied above, hence only a few will be discussed here. First, the case studies suggest the importance distinquishing between innovation and diffusion, each with a potentially different relationship with government structure. Future research should focus on testing this hypothesis using quantitative measures of diffusion for various technologies across time, and investigating the possible implications for economic growth, the evolution of national production systems, and the varieties of capitalism debate. The case studies also pointed to the importance of horizontal decentralization, which is largely ignored in prior analysis. Future research should address this weakness, and test this hypothesis, by employing more sophisticated measures of decentralization, and perhaps even distinguish between different types of vertical or horizontal decentralization (e.g. taxation vs. expenditure vs. administrative etc.). Much of this quantitative information is already available in raw form for use in constructing new measures. Third, changes in government structure amongst the democracies during the past century should be investigated in order to determine whether there exist any cases that meet the conditions necessary for a natural experiment. Recent changes in structure in Great Britain, France, Belgium, New Zealand, and Italy are potential candidates as are older instances of structural change such as the unifications of Germany, the United States, Switzerland, and Italy. Fourth, Mancur Olson has

specifically argued that the devolution of economic institutions results in the proliferation of narrow special-interest groups, which in turn tend to generate inefficient policy and poor economic performance.[77] This would appear to contradict both the theoretical basis of my research and the case study observations above. Some consideration should therefore be given to this theoretical contrast and whether the electricity and blood case studies meet the criteria for critical cases to resolve the conflict. Finally, while the research thus far has produced some useful intermediate results, a more sophisticated and concise theory should be constructed before further research can be completely effective. My current research has taken place outside of the major debates currently taking place in political economy and comparative politics, hence some thought might also be given to how my research on comparative rates of technological progress might bear on some of the more mainstream issues such as comparative capitalism, comparative federalism, and globalization.

[77] Olson, Mancur "The Devolution of the Nordic and Teutonic Economies" *American Economic Review* 85(2) (May 1995); Olson Mancur *The Rise and Decline of Nations* (Yale Univ. Press, 1982).

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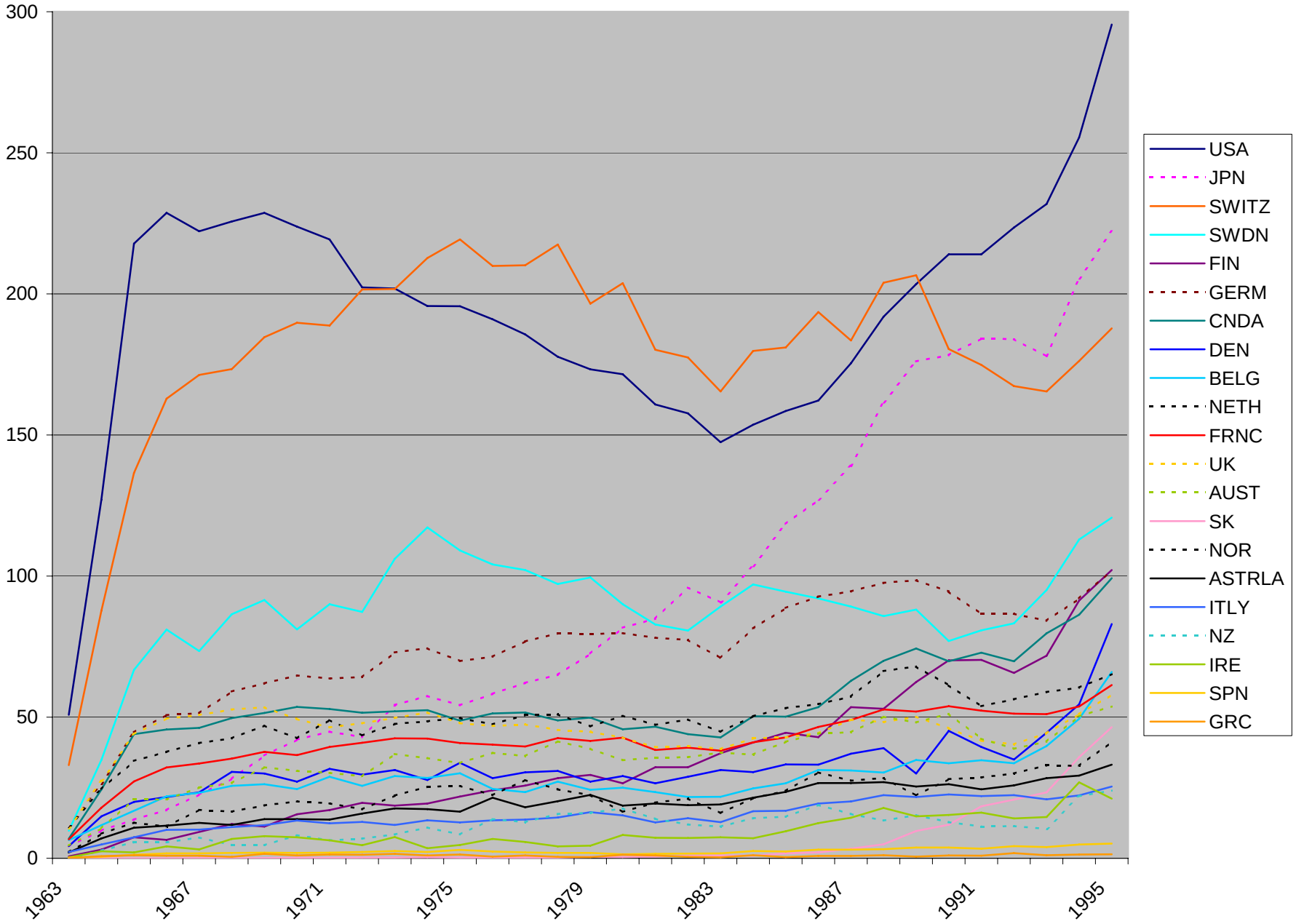
Chart 1: Patents Per Million People



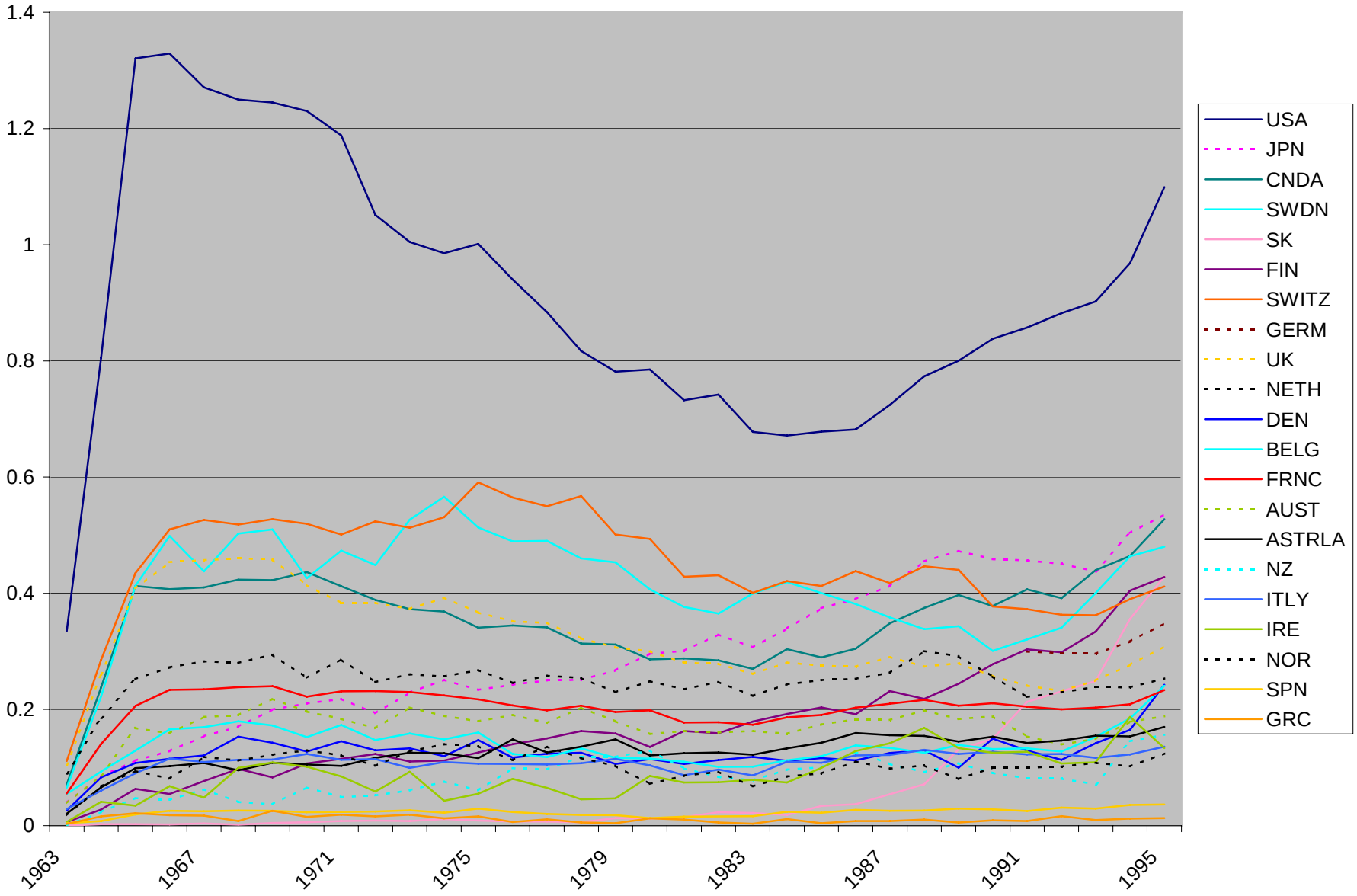


Chart 2: Patents Per GNP

Chart 3: Corporate Leaders of Various Industries

Most Competitive Aerospace Companies Worldwide, 1996[78]

1. Standford Telecommunications (United States)
2. Orbital Sciences Corp (United States)
3. Wyman-Gordon (United States)
4. Miltope Group (United States)
5. EDO Corp (United States)
6. Canadian Marconi (Canada)
7. Dynamics Research Corp (United States)
8. Alliant Techsystems (United States)
9. Fairchild Corp (United States)
10. Heroux (Canada)

Top Chemical Companies Worldwide, 1996[79]

1. DuPont (United States)
2. Ciba (Switzerland)
3. Bayer (Germany)
4. Hoechst (Germany)
5. Monsanto (United States)
6. Dow Chemical (United States)
7. BASF (Germany)
8. L'Air Liquide (France)
9. PPG Industries (United States)
10. Imperial Chemicals (UK)

Top Software Companies Worldwide, 1995[80]

1. Microsoft (United States)
2. Computer Associates (United States)
3. Oracle (United States)
4. Novell (United States)
5. SAP (Germany)
6. Sybase (United States)
7. Adobe Systems (United States)
8. Informix Software (United States)
9. SAS Institute (United States)
10. Symantec (United States)

Top Engineering Plastics Firms, 1997[81]

1. G.E. Plastics (United States)
2. DuPont (United States)
3. Hoechst (Germany)
4. Bayer (Germany)
5. BASF (Germany)
6. Mitsubishi Gas Chemical (Japan)
7. Asahi (Japan)
8. Dow Chemical (United States)
9. Toray (Japan)
10. Allied Signal (United States)

Top Pharmaceutical Companies, March 2000 (by # of products in development)[82]

1. Aventis (France)
2. NIH (United States)
3. AstraZeneca (UK)
4. SmithKline Beecham (UK)
5. Pharmacia & Upjohn (United States)
6. Novartis (Switzerland)
7. Warner-Lambert (United States)
8. American Home Products (United States)
9. Johnson & Johnson (United States)
10. Schering AG (Germany)

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[78] Source: *Aviation Week & Space Technology* (June 9, 1997) p. 53
[79] Source: *Financial Times* (January 7, 1997) p. IV
[80] Source: *Financial Times* (December 4, 1996) p. 2
[81] Source: *Chemical Week* (May 28, 1997) p. 28
[82] Source: Parmaprojects/PJB Publications in *Parexel's Pharmaceutical R&D Statistical Sourcebook 2000*