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The Interweaving of Diffusion Research and American Science and Technology Policy

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Dedication

To Tena, whose love and laugh have enabled me to live the life I have always aspired to, and more.

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Contents

The Interweaving of Diffusion Research and American Science and Technology Policy

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ABSTRACT

This monograph interweaves an intellectual history of theories of the diffusion of innovations with a brief history of US science and technology policies between 1960 and the present, tracking thereby their independent developments as well as their relative influences on each other. The monograph's opening line of analysis treats diffusion research as a discrete field of study, focusing on the intellectual ferment in the 1960s and 1970s in which new, or more precisely expanded, discipline-based paradigms emerged in economics, political science, geography, and organizational theory to variously complement and compete with longer standing research traditions in anthropology, sociology and communications. A second line of analysis reinterprets major developments in US science and technology policy — Johnson's Great Society; Nixon's New Federalism; international economic competitiveness-in terms of the fluctuating recourse in these policies to findings advanced by diffusion research, and reciprocally the impacts of changing national and state science and technology policy agendas on the salience and direction of diffusion research. A concluding section describes

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the status of academic interest and external funding in diffusion research circa 2000 to the present, noting also the current limited ties between this research and science and technology policy formulation.

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Introduction

Keynes' assertion about the power of academic scribblers to influence policy makers remains one of the best known perorations of any academic treatise. Converted from an axiom into a hypothesis, it also contributed to spawning a rich and continuing research tradition on the connections between policy oriented research and public policy formulation. (National Research Council, 1974; Lindblom and Cohen, 1979; Weiss, 1980; Lynn, 2001). By comparison the influence that the interests of those in power have upon the content and scale of academic research, while apparent in ways big and small, is less often considered systematically. Concurrently interweaving both perspectives — the asserted puissant power of ideas with their "uncertain connection" to power — in a single narrative rather than as discrete accounts, holds promise for a fresh interpretation of otherwise oft-treated material.

This essay seeks to fulfill this promise by weaving together a history of theories of the diffusion of innovations in selected academic disciplines, tracing their waxing, waning, and settling into normal science, with a similar synoptic history of the waxing and waning of the influence of these theories in the formulation of national science and technology policies. To give specificity to the narrative as well as to bound an

obviously ambitious undertaking, the analysis is set within the content of US science and technology policy between 1960 and the present.

The literature on the diffusion of innovations is large and diverse. As characterized by (Kelly and Kranzberg, 1978), it is "...so fragmented by specialized concerns that even the dimensions of an adequate general theory are poorly demonstrated. It is a conceptual cartographer's dream... or nightmare" (pp. 120–121.) This characterization is readily understandable because as noted by Rogers, citing the number of publications produced on diffusion between 1962 and 2005, "No other field of behavior science research represents more effort by more scholars in more disciplines in more nations" (Rogers, 2005, p. xv).

It is the "more disciplines" more so than the "more effort "(and output) that constitutes the primary challenge in arraying and distilling diffusion research. The cumulative published output on diffusion research is susceptible of being described by any 1 of 3 competing metaphors variously used to describe the course of science: cumulative knowledge, symbolizing the shoulders upon which one stands to see further; blind men touching different parts of an elephant; drunks looking for their lost keys under a lamp post because that's where the (disciplinary) light is located. And indeed at times, assessments as well as debates among competing theories contain suggestions of each metaphor.

Yet a different organizing metaphor here is used here: interweaving. The term is used to denote how selected themes, or threads, in the emergence of theories of diffusion research and histories of US science and technology policies between 1960 and the present had different discernible colors but became woven together at various times and for various reasons to form definable swatches. Manifestly only a select number from among the many threads identifiable in the respective literatures on the diffusion of innovations and US science and technology policy can be treated here. The selection principle is their interconnectedness. In contrast to the expansiveness or deep disciplinary drilling of other inventories of diffusion research traditions (Rogers, 1962; Rogers, 2005; Kelly and Kranzberg, 1978; Tornatzky *et al.*, 1990; Dosi, 1991; Karshenas and Stoneman, 1995; Strang and Soule, 1998; Hall, 2005; Stoneman and Battisti, 2010), its coverage of theories, models and empirical findings within and across disciplinary fields is

filtered through an appraisal of their connection to the articulation, design and implementation of national and subnational science and technology policies. Relatedly, although existing well regarded survey articles provide coverage of seminal work in their respective disciplines, none does so in a side-by-side manner that allows their theoretical and methodological areas of convergence and divergence with other disciplines to be readily seen. As such, the monograph's format has a complementary if different focus from the works it cites as well as from close neighbor literatures on "innovation studies," "science policy," "technology policy," or "science and technology studies" (Faberberg *et al.*, 2013; Godin, 2017). There indeed is a retro character to its focus as it serves to reconnect linkages between theories of diffusion and innovation that attended the early association between the two, say as found in Mansfield's research, but which as suggested by Nelson' observation that "with only a few exceptions, scholars of innovation... have done little in the way of diffusion studies" (Nelson, 2013, p. 191) have frayed over time.

Similarly, the coverage of US science and technology policy is selective, limited to those aspects that most closely relate to the extent to which adoption and diffusion were deemed key components of the policies and programs being considered, enacted, and assessed.

Finally, even as it notes the contribution of European scholars to the formulation of theories of diffusion, the connections it advances between diffusion research and science and technology policy are cast solely in terms of the US experience.

The monograph moves along two main warps — disciplinary traditions of diffusion research and a synoptic history of US science and technology policy — weaving them together at times and in places to demonstrate both their singular threads and crisscrossing patterns. The first line of analysis treats diffusion research as a discrete field of study. Receiving special attention in this line of analysis are the debates that occurred in the 1960s and 1970s about whether the intellectual ferment then evident in the new, or more precisely expanded, discipline-based paradigms in economics, political science, geography, and organizational theory that variously both complemented and competed with prior longer standing research traditions in anthropology, sociology and

communications yielded, as Rogers once proposed, a generalizeable set of tested propositions that could withstand critical analytical and methodological scrutiny.[1] For if the goal was in fact being attained, or indeed attainable, findings from such research would provide reliable guides — evidence based findings in current jargon — for an actor such as a government agency to more expeditiously and effectively promote the rapid and/or extensive adoption of innovations that contributed to the attainment of its mission objectives. Conversely however, if in the main diffusion research constituted a body of particularistic, competing, at times contradictory, and in the aggregate contextually dependent set of theories and findings, researchers would soon arrive at Candide's judgment that it was best to tend to one's own (disciplinary) garden, while policy makers would be left with the tasks of systematically (or opportunistically) sifting and sorting disparate options or turning elsewhere for programmatically operational and organizationally defensible approaches.

The second line analytical warp is a recounting of components of US science and technology policy development between 1960 and 2017. Here both familiar and less familiar events are (re)-interpreted from the perspective of how changing national policy agendas shaped the rate and direction of diffusion research. At their core, both diffusion research and policy formulation share a common underpinning. They each relate to change: how much, how fast (or slow), by whom, by what mechanisms, with what consequences (outputs/impacts). Thus, whenever change is a salient purposeful component of the policy agendas of national or subnational governments, the putative utilitarian values of diffusion research comes to the fore.[2] At such times policy makers personnel have intermittently and somewhat idiosyncratically turned to, or at least cited, the theoretical or empirical findings emerging from the research literatures on diffusion for guidance on how to achieve

[1] As expressed by Rogers and Shoemaker in 1971 in a then more self-congratulatory manner, "Diffusion research is thus emerging as a single, integrated body of concepts and generalizations, even though the investigations are conducted by researchers in several scientific disciplines" (1971, p. 47).

[2] For example, "... the Research-Development-Diffusion Model has perhaps been the most influential model of change in American education" (Bhola, 1977, p. 10).

overarching national or subnational governmental objectives. Similarly, program personnel within mission agencies likewise have supported or distilled findings from such research for insights on how to foster a more rapid and extensive adoption of innovations held to promote the attainment of intended societal objectives.

For their part, even when primarily curiosity driven, diffusion researchers have not been unmindful of the latent policy implications in their work, (although for the most part diffident in advancing specific proposals). As Dosi has observed, noting that differentiated patterns of adoption and diffusion, once understood, had implications for regional growth, international trade, and development, "... all these complex and intertwined features of innovation diffusion have equally crucial normative (policy) dimensions" (Dosi, 1991, p. 203).

The analysis throughout though remains centered on intellectual and policy history. Only passing coverage is given to policy or programmatic debates over an agency's choice of diffusion framework and subsequently upon its performance with respect to attainment of mission objectives. Legislative and political emphasis on results, performance, and evidence, ever present in various guises throughout the period under study-program, planning budgetary; zero based budgeting; management by objectives; performance assessment rating tools — continue to hold force in the contemporary neoliberal era of the Government Performance and Results Act and its accompanying performance based resource allocation criteria. Connecting diffusion research and agency performance requires its own review, however.

Given the monograph's shifting focus back and forth between intellectual history and science and technology policy history over a 50+ year time period, it is useful to first set out its organizing themes, or theses, and chapter organization. They are as follows:

Chapter 2 describes:

(a) the concurrent rapid conceptual development and empirical testing in the 1960–1970s of models of diffusion of innovation in economics, geography, political science, and organizational theory that arose alongside but often in competition with prior

"traditions of research" in sociology, anthropology, rural sociology, and anthropology (Katz *et al.*, 1963; Rogers, 1962);

(b) intra- and interdisciplinary battles over competing theories of diffusion in these two decades for theoretical/disciplinary hegemony and policy relevance.

Chapter 3 describes:

(c) shifts from intellectual history to science and technology history. Included in this narrative is an account of the accompanying repositioning from the late 1960s through the early 1980s of diffusion research from Bohr-like inquiries to Pasteur-like questions associated with the major policy thrusts of the Johnson Administration's Great Society programs and the Nixon Administration's New Technology Opportunities and New Federalism initiatives;

(d) intellectual disarray and research quiescence in the 1980s following major critiques of the conceptual and empirical underpinnings of the extant research literature, and an accompanying loss of policy dynamism in public sector policy agendas, compounded by the disenchantment of agency and research sponsors with the results of diffusion-shaped agency innovation policies (Aghion *et al.*, 2009);

Chapter 4 describes the:

(e) urgent shifts beginning in the 1980s and continuing since then in policy agendas, conceptual models, and framing of US science and technology policies (as well as among OECD nations) towards economic growth and competitiveness, thereby replacing attention to diffusion processes with preoccupations with national innovation systems, manufacturing modernization, technology transfer, triple helixes, innovation ecosystems, and the like;

Chapter 5 describes the:

(f) re-emergence in variegated forms of academic interest and external funding in diffusion research circa 2000 to the present, noting also the current limited ties between this research and science and technology policy formulation.

1.1 Boundary markers

Delimiting boundaries among oft-connected and seemingly inextricably linked concepts and terminologies is a necessary prefatory action, even if somewhat arbitrary and admittedly at times difficult to maintain, in order to minimize conceptual or definitional thickets. For a field as diverse in frameworks and methods as diffusion research yet employing seemingly common vocabularies, words and meanings can readily become conflated or confused for one another. For example, as detailed below, substantive terminological, conceptual and policy issues arise in parsing the seeming equivalence of diffusion and technology transfer, and even more so in unbundling diffusion/technology transfer programs and mechanisms from diffusion processes, per se.

By theories is meant the postulation and empirical validation of statements regarding the systematic and predictable determinants of patterns of adoption of any of a given variety of innovations, or what at times has variously been termed "theories" of the diffusion of innovation(s), or research traditions. By diffusion is meant the spread, or inversely, the adoption or acceptance, of one or more innovations, specially here technologies or government policies, by some defined population, political entity, or geographic region.

In its weaving together of diffusion theories with US science and technology policy, the monograph's primary focus is on the diffusion of technological innovations, processes and products used in the production of goods and services. Accordingly, its primarily focus is on the research traditions or components of these traditions that related to technological innovation and to public policy design. This concentration is most direct in its treatment of the economics literature. In its coverage of research traditions in geography, political science, and organizational theory, literatures that also connect directly and indirectly to science and technology matters, the review however encompasses an expansive range of innovations, such as the installation of close circuit television systems in school districts designed to improve the educational performance of elementary school students from low-income families (Yin *et al.*, 1976, p. 7), as well as legislatively based policy changes, such as state laws of compulsory school attendance (Gray, 1973a; Gray, 1973b).

An added complication arises from this expanded focus. Consideration of the diffusion of other than technological innovations involves studying diffusion processes in non-market as well as market settings. The applicability of models developed to study the latter setting, primarily those rooted in economic concepts, to account for diffusion in the former setting is a matter of disagreement. Thus, Downs, commenting of the applicability of economic approaches to the diffusion of innovations in the public sector, contended that, "(F)or the most part economists have been concerned with technological rather than program innovation, with the private sector rather than the public sector, and with research issues only vaguely related to the characteristics of the organization that cause it to be innovative" (Downs, 1976, p. 23).

Finally, reflexively, the very disciplinary breadth of research into the diffusion of innovations that compels selective coverage itself is a question worthy of inquiry. Disciplinary approaches, according to Morgan (2011, p. 31) are like "roadways" in that they may facilitate the traveling of facts, but "like rails may also limit the range of possibilities for travel." Laid out along different routes, disciplinary approaches may coexist in a non-competitive manner, that is to the extent that they are headed to different destinations (or audiences) or more importantly perhaps vade mecums for different cargoes. Thus, in the formative period of focus here political scientists studied the diffusion of policy innovations among the American states (Walker, 1966; Gray, 1973a; Gray, 1973b) while geographers established a similarly respected and essentially unchallenged approach to the spatial diffusion of innovations (Gould, 1969; Hagerstrand, 1967; Brown, 1968; Berry, 1972) without either necessarily treading upon or influencing research conducted in other traditions, at least at first.

However, a substantial portion of the mainstream diffusion research consists of questions that are amenable and subject to different conceptual models and methodological approaches both within and across disciplines (Antonelli, 2009). Among the most oft-studied of such questions are what accounts for (a) the rate and extent to which any single innovation is adopted?; (b) differences in the pace and extent to which different or even seemingly similar innovations diffuse within specified sets of adopting populations?; (c) differences in the

timing, ordering, and extent of adoption of a single innovation or clusters of innovations by different populations, be these individuals or organizations (market or non-market)?

Each of these questions in turn could be (and were) further subdivided into any number of readily identifiable classification of adopter characteristics (e.g., age, education; race, income, political jurisdiction, geographic area). Likewise, the many, finely defined ways in which questions relating to the innovation–diffusion processes may be constructed (attributes of the innovation; attributes of the population of adopters; attributes of the milieu — economic/cultural/social/political/other) gives rise to a large number of permutations and combinations of independent and dependent variables, unavoidably crisscrossing disciplinary boundaries. As illustrated by the debates surrounding the diffusion of hybrid corn and medical innovations noted below, boundary crossing has at times been a source of disagreement about the applicability, explanatory power, or empirical accuracy of particular disciplinary approaches, especially when such crossings are treated as trespassing by those with historical traditional claims on specific fields of inquiry.[3]

Each question in turn is of interest because its connection to identifying and explaining the causes and consequences of change, the foundational subject matter of many social and behavioral sciences. As noted by Rogers, "When new ideas are invented, diffused, and adopted or rejected, leading to certain consequences, social change occurs' (Rogers, 2005, p. 6). But additionally, the questions are of interest because answers to them undergird narratives and propositions about the consequences of change, or resistance thereto, another staple line of inquiry within several social science and behavioral science disciplines. As an example, Cameron termed the diffusion of technology a "problem in economic history" because the application of new technologies in all aspects of economic activity has by general agreement been "the principal dynamic factor in the economic growth of the last

[3]Or if questions about the relevance of a particular disciplinary approach to studying diffusion processes were not asked, thus avoiding overt disagreements, in part it was due to the limited familiarity or technical command researchers had of work being done outside their own field.

two centuries... (Cameron, 1975, p. 218; also, Landes, 1969; Mokyr, 2002).

Cameron's problem statement. "why the new technologies are not more widely and evenly diffused...", appears in various forms in numerous historical accounts. To cite perennial questions from economic history, his own field of research, what were the effects of the Revocation of the Edict of Nantes in 1598 and the subsequent exodus of France's Huguenots to England and Holland on the diffusion of the manufacturing skills and arts needed to produce silk, linen and other commodities to these two countries, and what effects in turn did these differences in patterns of diffusion have on the subsequent industrialization of these countries? (Scoville, 1952a; Scoville, 1952b)? Other examples of historical accounts keyed to differential rates of diffusion are readily cited. To what extent was the loss of competitiveness of the New England textile industry in the early 20th century due to its asserted slow adoption of the Draper Loom (Feller, 1966) or that of the US steel industry after 1960 to its slow adoption of the basic oxygen furnace? (Oster, 1982). Were these adoption rates in fact slow, (and by what standard of comparison)? And if they were slow, what accounted for, or nominally held back, this pace? Answers to these questions have to varying degrees been based on propositions about the determinants of the diffusion of technologies or other material and non-material practices. Or in alternative formulations, they have been cast in terms of the readiness, reluctance or resistance of different groups of individuals or classes and types of organizations to accept or adopt innovations.

Finally, a qualifying note about the recurrent references to science and technology policy actors, decisions, or communities. With respect to the 1960s, the term refers primarily to the decentralized and episodic decisions and actions of federal, state, and local government mission agencies as they sought operational guidance on whether or not to adopt an innovation or how to promote its wider use.[4] Although several examples of what now would be considered the organizational components of a reasonably well articulated science policy apparatus

[4] "United States S&T policy, with the exceptions noted below, is largely uncodified: it must be deduced from the laws and organization of government and by observation of the actions of government managers and agencies" (Branscomb, 1993, p. 5).

were in existence prior to the 1960s — President Eisenhower appointed James R. Killian, Jr., President of MIT, as his Special Assistant for Science and Technology, in 1957 — for most of the 1960s into the early 1970s and the 1976 enactment of the National Science and Technology Policy, Organization, and Priorities Act, there was little there there. (Brooks, 1996; Smith, 1990; Teich, 2018).[5]

1.2 Selection of disciplines

Summarily subsuming earlier theories of the diffusion of innovations in anthropology and sociology, as recounted by Godin in Models of Innovation (Godin, 2017), this monograph focuses on the emergence and evolution of theories of diffusion in economics, political science, organizational theory, and geography.

Two factors shape the choice of these four fields. The first is purposeful: it is to offer a more complete and analytically detailed account of fields lightly treated in other compendia or treated separately in more specialized reviews. For example, Sociology, both for its inherent attention to processes of social change and the early paradigm setting influences of its studies of the diffusion or agricultural and medical innovations, is a well recognized disciplinary contributor to diffusion research (Rogers, 1962, pp. 28–38; Godin, 2017). By way of contrast, Economics, Political Science, Organizational Theory, and Geography are not included in either Katz and Levin's 1959 or Rogers' 1962 listing of "major" diffusion research traditions; likewise they receive but scant treatment in Rogers otherwise encyclopedic treatment (Rogers, 2005, 5th Edition, pp. 44–45, 101), of 10 major traditions.

[5] As examples of these early post-World War II beginnings, the National Academy of Science's Committee on Science and Public Policy (COSPUP) was formed in 1963, with support from NSF; Nixon's 1972 message on science and technology is considered the first such presidential address; the American Association for the Advancement of Science's annual forum on science and technology policy, today a major event, annually bringing together public officials, academics, and others to address contemporary science and technology policy first began in 1976; academic programs or centers devoted to science and technology policy begin to surface in the late 1960s, loosely linked together in a Science and Public Policy Studies Group. For a fuller account of the formative period of the US science policy apparatus see (Teich, 2018).

The second factor is personal: the four traditions are the ones in which I conducted extensive empirical research in the initial decades of a 50-year academic career, and upon which I have frequently drawn in addressing contemporary science and technology policy issues. Thus, writing about them today provides an opportunity for reflection and reconsideration. This experiential engagement spills over yet further. Although the monograph draws extensively on the published literature to document its historic tracings, its interpretative sections of how the literature on diffusion research became interwoven with national science and technology policy agendas is shaped heavily by my personal engagement — being present at the creation — in many of the national and state government policy settings and debates recounted in the narrative.

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