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Telephone and Automobile Diffusion in the United States, 1902–1937[1]

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Although the telephone and automobile are two of the most significant technological developments of the modern era, we know little empirically about the conditions that encouraged their adoption. This paper attempts to explain their diffusion across the 48 contiguous states during the time of their initial popularization and fastest growth and examines which macrostructural attributes of states encouraged or discouraged their widespread adoption. It also examines whether these technologies stimulated or inhibited each other. The findings suggest that commercialization in urban centers spurred adoption of both the telephone and automobile. A more complex process occurred in rural America. States with many well-off, independent farmers were relatively quick adopters of both technologies. But states with many tenant farmers—primarily southern—were slow to adopt. The data also point to an important historical watershed, World War I: many of the accelerating factors before the war were less critical after the war, and, perhaps more important, the interaction between the technologies changed around the time of the war.

The study of technology was once central to sociology (see Westrum 1983). William F. Ogburn (1933) argued, in the classic *Recent Social Trends* collection, that technological innovation drove social change, and he pointed in particular to then-new forms of communication and transportation. His and others' contributions in *Trends* credited these "agen-

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cies of communication" (Willey and Rice 1933*a*), notably the automobile, with significantly altering American social life.

Unfortunately, sociologists have not come much further than the informed speculations of Ogburn and his associates (see, e.g., Allen et al. 1957) in establishing *empirically* the social role of technological change. Instead, we tend to lump together many different technological changes into one unitary, unilineal, and inevitable process (e.g., "technique" or "rationalization") that is part of global "modernization." There is little appreciation of the particularities of technologies, the contradictions and reversals of technological development, or the various ways technologies are used (distinctions Willey and Rice [1933*a*, 1933*b*] *did* make). Current theorizing about technology largely assumes an empirical understanding we in fact lack (see Fischer 1985).

Such an empirical understanding should begin by asking how and why specific technologies originally diffused. As part of a larger study on the effects of turn-of-the-century communications technology (see Fischer 1988, 1987*a*, 1987*b*), this paper assesses the macrostructural conditions that influenced the diffusion of the telephone and automobile. Specifically, we describe and attempt to explain the diffusion across the 48 contiguous states of these two technologies during the time of their initial popularization and fastest growth, from about 1900 to the eve of World War II. We examine which macrostructural attributes of states encouraged or discouraged their widespread adoption, and we also examine whether the automobile and telephone stimulated or inhibited each other.

SOCIAL HISTORICAL ISSUES

In 1900, modern means of transportation and communication were not part of everyday private life, even of the middle classes. Telephones had been in use for 20 years but were largely instruments of commerce or a convenience for the affluent; there were fewer than two for each 100 Americans. Automobiles were toys of the rich, with only one registered per 1,000 Americans (U.S. Bureau of the Census [USBOC] 1975, pp. 783–84, table Q-152). But, by 1930, telephones per capita had multiplied ninefold; there was one in 41% of all American homes. And automobiles per capita had multiplied 2,000-fold, reaching a rate of one per five Americans. During the Depression, both automobile and telephone diffusion sagged but managed to recover to and then exceed 1930 levels by 1940. Full saturation of American society did not occur until the 1960s, but the first four decades of the century were the years in which these technologies spread most rapidly and became established as middle-class implements.

Historians and sociologists often credit these technologies with deeply altering American ways of life (the most famous contentions appear in the Lynds's *Middletown* [1929] chap., "A-U-T-O"; cf. Jensen 1979), but, to validate such claims, we should understand the conditions under which these technologies were adopted. "Unintended consequences" notwithstanding, adoption patterns can indicate function, and function can, in turn, suggest consequences. Was diffusion, for example, driven by an increase in mass purchasing power? By technological improvements? By urbanization? Or by strategies of diffusing agents (see Brown 1981)? Speculations abound, but analyses of data are rare.

Telephone history,[2] in capsule, begins with the era of Bell's patent monopoly, 1880–93. Bell exclusively leased telephones and franchised service in urban centers throughout the nation; subscription was expensive and largely restricted to businesses and to the homes of the wealthy. In 1893, the key patents began to expire and literally thousands of telephone ventures emerged—mostly small, cooperative, rural lines, as well as companies competing directly with Bell. Among the consequences were a precipitous drop in rates, populist forms of service (such as party lines), and rapid growth in subscribers. Bell lost half of the market by 1907 but then resurged under new management. Soon faced with federal antitrust threats, Bell made a deal with the "independents," implemented during the 1910s and 1920s, that carved out local-service monopolies and guaranteed exclusive Bell long-distance service: the telephone system as it existed until 1984.

The dawn of automobile history[3] is cloudier. Produced around the turn of the century in the workshops of bicycle manufacturers and hardware dealers, the automobile was initially a touring vehicle for the wealthy. After about 1905, Henry Ford led the way, in both manufacturing and marketing, to popularizing the automobile. Prices dropped rapidly (the average wholesale price of a passenger car in 1905 was about $1,600; in 1917, it was about $600 [AMA 1941, p. 4]). By 1925, there were 172 cars per 1,000 Americans. In the 1920s, the industry "shook out" into an oligopoly and confronted competition with itself in the form of used cars, with model changes, financing systems, and ever more aggressive advertising. Auto ownership sagged slightly in the Depression but recovered

[2] There is little scholarly work on the history of U.S. telephony other than strictly business histories. Nevertheless, some basic sources are Brooks (1976), Brock (1981), Danielian (1939), Willey and Rice (1933*b*), Garnet (1985), Wasserman (1985), MacMeal (1934), and Pool (1977*a*).

[3] There are several histories of the automobile in the United States, including Flink (1970, 1976, 1980), Rae (1965, 1971, 1984), Berger (1979), Wik (1972), Preston (1979), and Moline (1971).

strongly by the end of the 1930s (rebounding considerably better than did telephones).

The diffusion processes of both the automobile and the telephone were affected by World War I. The war itself forced a slowdown in the installation of private telephones and manufacture of automobiles, which, in turn, built up demand that overwhelmed supply shortly afterward. The war also created great rural prosperity but was followed quickly by an agricultural depression; it stimulated inflation; and it was followed, after a short economic downturn, by a prolonged period of urban prosperity. Organizationally, World War I roughly marks the shift from competition to cartel in the telephone industry, as well as consolidation in the automobile industry (Epstein 1927; Lawrence and Dyer 1983, p. 24). Although historians know much about the telephone and automobile businesses, they know surprisingly little about their social histories.[4] We begin filling that vacuum by asking, Where and when were these two major modern technologies soonest adopted?

ANALYTICAL QUESTIONS

The historical concerns bear on certain theoretical interests. One is the process of innovation diffusion across physical and social space. The sociological literature on that topic (see Rogers 1983) has largely explained adoption of innovations by individuals. Variations by personality, social background, and network location predict who will adopt (e.g., Coleman et al. 1966). Another literature, mostly in geography, focuses on ecological variables and identifies, in particular, spatial contiguity and position in the urban hierarchy as two macroscopic determinants of innovation diffusion (e.g., Hagerstrand 1967; Pedersen 1970; Pred 1973). More recently, Brown (1981) has focused on the intermediate level, on how infrastructure (e.g., electrical distribution as a requirement for diffusion of appliances) and marketing organizations (e.g., automobile dealers, agricultural extension agents) shape diffusion. We contribute to this literature a rare sort of study of how structural features influenced the long-term diffusion of major innovations. Unlike most of the literature, in which the classic empirical case is the diffusion of a new farming technique in a small region, our paper deals with the diffusion of significant technologies nationwide over many years.

We also address the debate in the "technology and society" field on the

[4] Except for a few accounts of farmers and the automobile, as well as specialized studies, such as Balascoe's (1979).

supposed "transportation-communication trade-off" (see, e.g., Pool 1977*b;* Solomon 1986; Miller 1980; Clark and Unwin 1981; Falk and Abler 1980; Lee 1980). Technologies in a single mode do replace one another—for example, car for rail travel, telephone for telegraphy (Willey and Rice 1933*b*). But do transportation and communication modes substitute for one another?

This seemingly technical point is significant for sociological theories of modernization.[5] Most empirical research and much theory on national economic and social development subscribe to the assumption that "modern" technologies are all of a kind, impel one another forward, operate synergistically, and, essentially, reflect an underlying "modernization" process. In a cross-national study of economic dependence, for example, Delacroix and Ragin (1981, p. 1320) write: "Development may be viewed in strictly economic terms. This conceptualization warrants the use of indicators of development based on national products. Development may also be viewed as a more diffuse concept indicated by a variety of social and political, or relational, measures. Telephones per 1,000 population is a good example of a relational indicator. Telephone networks approximate a material manifestation of the Durkheimian concept of 'moral density.' " This view, in which transportation and communications interchangeably measure the diffuse, global concept of development, assumes that one kind of technological advance stimulates another or that both reflect a common underlying factor.

Modernization theory, as such, has come under criticism, to be sure (e.g., Bendix 1967), particularly by scholars examining development in the Third World. But in the analysis of technological change—and of American social change (e.g., Wiebe 1967, 1975)—it remains powerful. Although we do not intend to dismiss such important models, we do intend to question whether social changes, even within the single sphere of technology, are as necessarily and functionally linked as the commonplace accounts of 20th-century America suggest. Observing competition among modes of communication would reinforce the argument that we need to "unpack" substantively specific technological changes to see how they may influence social processes synergistically, competitively, or independently.

[5] The question also has policy implications because an affirmative answer suggests that improved telecommunications could be used to replace some portion of far costlier road and rail systems (see, e.g., MITRE 1978; Nicol 1983; Webber 1980; Wellenius 1977). The opposite effect—Pool (1977*b*) has suggested that telephone calls might substitute for trips in the short run, but that, in the long run, they stimulate one another—implies to policymakers that each inhibits use of the other. Or, perhaps, they actually do not substitute for one another (Solomon 1986).

METHOD AND METHODOLOGICAL ISSUES

Our research strategy is an inductive one; we make no pretense of deductively testing a particular theory of technological diffusion. But, informed by the issues discussed above, we explore specific historical and structural conditions that may have accelerated or retarded the diffusion process.

Units.—We use states as units of analysis because they enable us to contrast local conditions in each era. States pose some statistical problems for a question like this one, such as spatial autocorrelation (although results using states seem to be robust [Strauss 1985; Fischer 1987*b*]). More important, using states creates broader analytical problems. States are, in several ways, arbitrary and heterogeneous aggregations of diverse communities. An ideal study would perhaps use counties or cities. (In fact, later phases of this project include analyses of towns and of individual adopters.) But many, if not most, of the macrostructural variables examined here, including number of telephones, are simply unavailable—absolutely or practically—at lower levels of aggregation for the years of interest.[6] At the same time, the states do reflect a very wide variation in local conditions.

In 1902, state levels of telephone diffusion varied by almost 900%, from Alabama with seven per 1,000 residents (both Carolinas had eight) to California with 69 per 1,000 (Washington, Indiana, Ohio, and Iowa were all above 50). In 1937, the range was 600%, from Mississippi with 36 telephones per 1,000 residents (Alabama, Arkansas, and North Carolina were under 50) to California with 253 per 1,000 (those above 200 were Connecticut, New York, Illinois, and Iowa). Levels of automobile diffusion ranged, in 1907, from under .3 autos per 1,000 (Florida, Mississippi, Alabama, Arkansas, and Oklahoma) to over 5.0 (in Massachusetts and California), and, in 1937, from under 100 per 1,000 residents (in Alabama, Arkansas, and Mississippi) to over 300 (in Nevada and California). Thus, there is substantial cross-sectional, as well as temporal, variation in the adoption levels of both technologies among the states.

Nevertheless, because states are potentially problematic units of analysis, we conducted numerous tests, including regression diagnostics such as partial leverage plotting, to identify disturbances owing to specific states in specific years. No substantively significant disturbances were

[6] We may take telephones as a key example. The U.S. Census of Agriculture began inquiring about individual farmers' telephones only in 1920, and the Housing Census's inquiries about telephones began in 1940. AT&T apparently had county-level estimates by 1930, but we have been unable to find them. There may be county-level enumerations available in the regulatory commission records of some states, for some years, after about 1910, but most such records were kept at the company or exchange level—both units are incommensurate with other data.

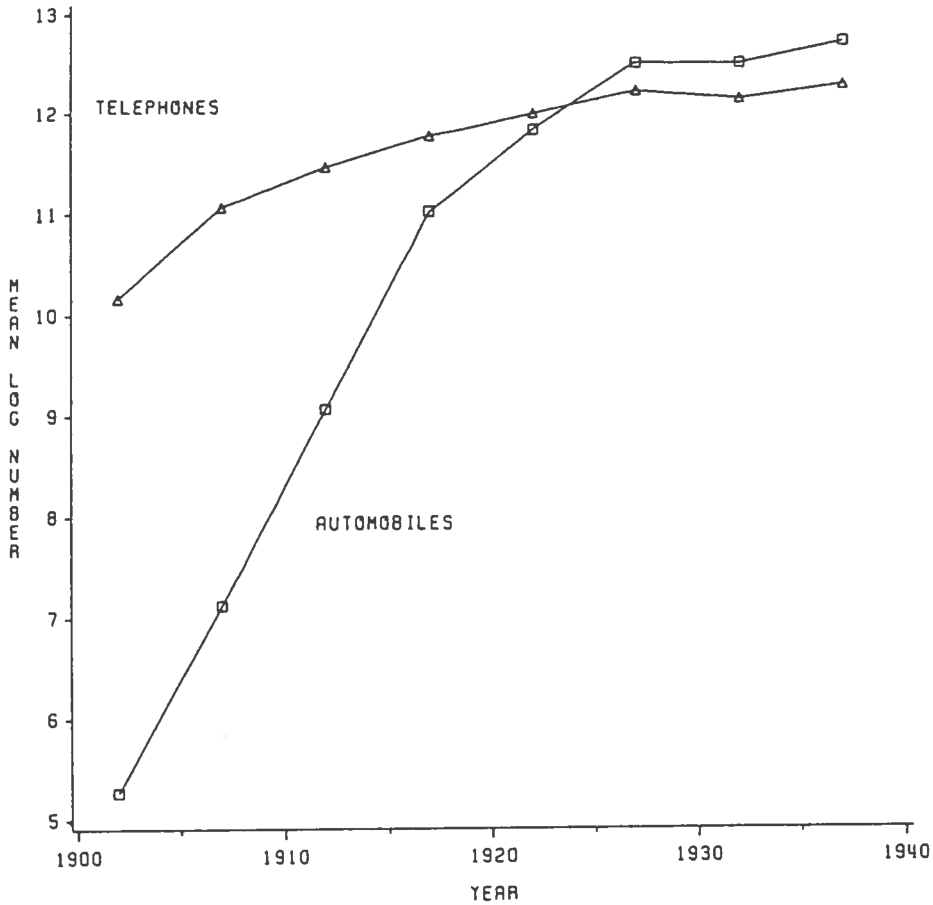

FIG. 1.—Temporal diffusion of automobiles and telephones

found other than the consistently lower performance of southern states (see below). This robustness makes sense since, in the dynamic models we specify, each state at time 1 serves as a "control" for itself at time 2.

Time.—Our data are for every five years, starting with 1902 and ending with 1937. The odd timing necessarily follows the quinquennial censuses of telephones conducted by the Commerce Department. Other statistics are for the same years or are interpolated for those years (see App.). For dynamic analysis, we converted the 48 state units of analysis for each of seven periods into five-year pooled panels of 336 state-period units, in which, for example, case 1 is Maine for the period 1902–7 and case 336 is California for the period 1932–37. Figure 1 displays the average state's time trajectories for the two technologies by plotting the mean adoption levels by year.

Explanatory factors.—We explore the characteristics of states and of events that accelerated or decelerated the processes. For both the automobile and telephone, we sought data in various "domains" of variables that might help explain differential diffusion. For the automobile, they include various components of individual demand for the technology. These are the population of the state, differentiated into urban, rural nonfarm, and farm; the need for such a space-transcending technology, indexed by the land area of the state (which, with population controlled, measures sparcity of settlement); wealth factors including workers' income, value of manufacturing, value of farm lands, and the like; and prices of automobiles, measured nationally.

Infrastructure is captured roughly by (1) occupational distribution, measured by the number of workers in manufacturing, trade, clerical, and related jobs, as well as number and types of farms, such as owner occupied or nonwhite occupied, and (2) road improvements, measured in various ways, such as miles of surfaced roads.

The "hierarchical" feature of geographical diffusion (i.e., that innovations tend to spread from functionally central to functionally peripheral communities in a region) is captured by urban population, and the spatial feature (i.e., that innovations tend to spread to neighboring communities) was explored by systematically looking for regional effects.

For the telephone, the same kinds of measures were pursued. The infrastructural consideration is the nature of each state's telephone industry, indicated by the number and kinds of companies and exchanges found there. This turned out not to be critical in the present analyses. Prices varied greatly from locality to locality. Rate changes were no doubt important in the diffusion process but primarily before our series begins. Unfortunately, no useful price data at the state level exists.[7] This may result in a misspecification of the model.

Models.—There is an "internal dynamic" to the diffusion process, well documented in the literature, whereby, for various reasons, adoptions breed adoptions until saturation is reached. This is familiarly portrayed by the S-shape curve. We cannot and will not document the microdynamics of that endogenous process here but will instead model it as a function of time. Because good parameter estimates of the S-shape curve require observations at the beginning of the process (something we do not have), we use a more general model. Specifically, we begin with the formulation:

$$Y(t + 5) = KY(t)^{b_1},$$

[7] The only possible source of price data, and that for only a few states, can be found in U.S. Department of Agriculture (1938), but the survey method is so flawed that it is simply unusable here. More generally, the immense fluctuations in telephone rates from town to town make aggregate figures both difficult to obtain and difficult to trust.

where $Y(t)$ is the lagged dependent variable—the absolute number of telephones or automobiles in a state five years earlier—and K is a constant. When (as in the estimates we will present below) the parameter b_1 falls between zero and one, the model predicts monotonically decreasing growth, a pattern consistent with the average time trajectories shown in figure 1.

This model has the advantage of being estimable by ordinary least squares (OLS) techniques. Taking the log of each side of the equation yields:

$$\log Y(t + 5) = \log K + b_1 \log Y(t),$$

which is linear in the parameters and, thus, amenable to OLS. The log-log function tested here weights more heavily the state-period variations among smaller states in earlier years. This was, in fact, where most of the temporal and geographic variation occurred.[8] Of course, there are strong similarities in the internal diffusion process across states. Consequently, we began our analysis by searching for an appropriate baseline model to control for the common temporal component. We then proceeded substantively by adding state-level independent variables to the baseline.

Methodological overview.—The strengths of our method over other studies of diffusion include a focus on profoundly significant technologies, an extended historical span, a nationwide geographic scope, and an examination of technological interaction. Its drawbacks include an aggregate level of analysis—states—and some limits in the kinds of variables that can be studied, difficulties often found in quantitative historical research.[9]

FINDINGS

Table 1 shows OLS estimates of four models for the temporal component of diffusion of telephones and automobiles. Equations Tel-1 and Auto-1 are estimates of a baseline model with six dummy variables for each five-

[8] This formulation has the additional attraction of removing heteroscedasticity because large values of the independent variables usually have small marginal effects on the dependent variable.

[9] We know of no comparable studies of telephone diffusion in the United States. Chow (1957) modeled aggregate national demand for automobiles, 1921–53, as a function of price and disposable income. Meir (1981) modeled automobile diffusion across Ohio counties, 1933–67, as a function of roads, wealth, urbanism, spatial influence, automobile dealerships, and distance from Detroit. Despite a few methodological concerns, we shall refer later to this paper.

TABLE 1

Models of Temporal Diffusion

Equation Number	Intercept	Log Telephones	Log Automobiles	Dummy 1907–12	Dummy 1912–17	Dummy 1917–22	Dummy 1922–27	Dummy 1927–32	Dummy 1932–37	Year	Year^2	Dummy Depression	R^2
Tel-1	1.25	.975*	...	−.595*	−.660*	−.758*	−.732*	−1.03*	−.820*	...	...	...	.988
	(.067)	(.006)		(.030)	(.030)	(.031)	(.032)	(.032)	(.031)				
Tel-2	1.37*	.950*	...	...	...	...	...	...	...	−.022*	...	...	.970
	(.012)	(.010)								(.001)			
Tel-3	1.40*	.953*	...	...	...	...	...	...	...	−.026*	...	.112*	.971
	(.102)	(.010)								(.002)		(.043)	
Tel-4	1.73*	.970*	...	...	...	...	...	...	...	−.087*	.001*	...	.980
	(.089)	(.008)								(.005)	(.0001)		
Auto-1	2.23*	...	.927*	.235*	.379*	−.623*	−.713*	−1.32*	−1.10*	...	...	...	.983
	(0.84)		(.013)	(.064)	(.078)	(.097)	(.105)	(.113)	(.113)				
Auto-2	2.96*	...	.931*	...	...	...	...	...	−.055*	...	...	...	.965
	(.092)		(.016)						(.005)				
Auto-3	2.90*	...	.900*	...	...	...	...	...	...	−.034*	...	−.385*	.967
	(.090)		(.017)							(.007)		(.087)	
Auto-4	2.67*	...	.892*	...	...	...	...	...	...	.007	−.001*	...	.967
	(.117)		(.019)							(.016)	(.0003)		

Note.—SEs are shown in parentheses.
* $P \leqq .05$.

year interval covered by the data, except the first. Coefficients should be interpreted as the growth rate for the period relative to the omitted first period, 1902–7. As the estimates in equation Tel-1 indicate, telephone diffusion slowed monotonically through the 35 years, except for a slight resurgence in the last period. Automobiles, shown in equation Auto-1, display a different trend. They increased dramatically between 1907 and 1917, relative to 1902–7, before leveling off in a pattern similar to that for telephones.

The other equations in table 1 report more parsimonious baseline models. With the exception of an indicator for the Depression, these models contain simple functions for time. Equations Tel-4 and Auto-4, which model the growth rates as second-order polynomials, are simple and efficient, so we used them as the baselines in further analyses.

We examined variations in the diffusion process across the states by introducing independent variables into the baseline models. Because most of the variations across states occur in the lower ranges of these variables, we used models of the form:

$$Y(t + 5) = KY(t)^{b_1}X(t)^{b_2}YR(t)^{c_1}YR^2(t)^{c_2},$$

where $X(t)$ measures a state-level characteristic of interest. This variable's effect depends on both the sign and magnitude of its associated coefficient. When the coefficient is negative, then an increase in $X(t)$ decreases the dependent variable but at decreasing rates. A coefficient between zero and one indicates that $X(t)$ has a positive effect, also with decreasing rates. A coefficient above one signifies a powerful positive effect that grows with increases in the size of the independent variable. The estimates we report below are of the first two, more plausible, types of effects.

In conducting the analysis, we typically tested each "domain" of explanatory factors separately, examining the intercorrelations of alternative measures and their correlations with diffusion. Although we tested multiple measures in most domains, many turned out not to be independently important predictors of diffusion. We spare the reader these intermediate equations. (Given the collinearity of the ecological measures, variables not represented in the final equations are often, of course, empirically correlated with diffusion.)

In particular, only measures of farm wealth survived among the income indicators. Automobile price was so confounded with time (and could not be measured state by state) that it was finally dropped. (Also, price, as the outcome of many complex processes, may in fact conceal more than it reveals.) Road development, the basic infrastructure of automobile use, had little consequence in our tests, perhaps because it was so inconsistently and poorly measured during these years or, perhaps, because auto sales in fact determined road construction.[10]

Hierarchical diffusion, as measured by urbanization, was important but was also strongly confounded with commercialization. Spatial diffusion was no doubt important at the local level—neighbors influencing neighbors—but at the aggregate level here, it did not emerge as significant, except in the fact that the southern states were unusually slow to adopt automobiles. (Meir [1981] also found only weak contiguity effects for automobile diffusion, this at the county level.) One should keep in mind that automobiles were marketed nationally and that telephone companies were established in all states—if not all counties—by the beginning date of our analysis.

We turn, then, to the variables that were significant. Table 2 (eqq. Tel-1 through Tel-5) presents estimates of their effects on telephone diffusion in the baseline model established above. Equation Tel-1 simply adds population and area and shows that telephones were responsive to population change. Equation Tel-2 decomposes population and shows a more complex picture: urban population accelerated, but farm population decelerated, telephone diffusion. Equation Tel-3 adds urban economic structure variables. And the fullest model, equation Tel-4, adds economic variables describing the farm population. Equation Tel-5 is a pruned version of Tel-4 (many of the predictors are highly collinear) and shows that the pattern of telephone diffusion can best be described as a positive function of a state's number of workers in trade and transportation (i.e., commercial activities), of average farm value, of the number of owner-occupied farms, and as a negative function of the number of nonowner-occupied farms, as well as of time and inertia.[11]

Substantively, the results suggest that states accelerated in telephone development as their commercial development grew—itself, no doubt, partly a function of urbanization. In the rural sector, an increase in affluent farm owners stimulated telephony, but concentrations of farm tenants—many of whom were nonwhite—retarded it.

Table 3, equations Auto-1–Auto-5, presents a similar analysis for automobiles. Equation Auto-5, which we judge to be the best fitting, shows that automobile diffusion was accelerated by the number of commercial workers in a state and the total farm wealth of a state and decelerated by

[10] Although the conventional argument is that good roads had to precede purchases of automobiles (e.g., Rae 1965, pp. 4–7), others have argued that automobile purchases, especially of durable, high-frame cars, preceded road reconstruction and created demand for it (e.g., Flink 1970, p. 211).

[11] We do not display the many other equations testing variables (from the domains described above) that did not contribute explanatory power or the tests made for spatial effects and the diagnostics for "influential" cases.

TABLE 2

MODELS OF TELEPHONE DIFFUSION

Equation Number	Intercept	Log Telephones	Log Population	Log Area	Log Urban Population	Log Farm Population	Log Rural Nonfarm Population	Log Workers Trade and Transportation	Log Wage Earners Manufacturing	Log Average Value Farmland and Buildings	Log Farm Owners	Log Farm Tenants	Year	Year^2	R^2
Tel-1	1.60*	.935*	.054*	−.003	...	...	...	...	...	...	...	...	−.072*	.001*	.982
	(.121)	(.017)	(.019)	(.008)									(.006)	(.0001)	
Tel-2	1.74*	.841*	...	.037*	.142*	−.038*	.022	...	...	...	...	...	−.061*	.001*	.985
	(.123)	(.021)		(.010)	(.023)	(.015)	(.029)						(.006)	(.0001)	
Tel-3	1.55*	.813*	...	.017	.115*	−.040*	.021	.015	−.030	...	...	...	−.055*	.001*	.985
	(.433)	(.024)		(.014)	(.058)	(.015)	(.034)	(.071)	(.023)				(.006)	(.0001)	
Tel-4	−.011	.626*	...	−.026	.109*	−.047	−.016	.209*	−.001	.139*	.164*	−.023	−.043*	.001*	.987
	(.505)	(.035)		(.014)	(.054)	(.072)	(.034)	(.071)	(.024)	(.024)	(.051)	(.027)	(.006)	(.0001)	
Tel-5	−.015	.709*	...	...	...	...	...	.292*	...	.080*	.066*	−.044*	−.048*	.001*	.986
	(.215)	(.029)						(.030)		(.016)	(.020)	(.011)	(.006)	(.0001)	

NOTE.—SEs are shown in parentheses.
* $P \leq .05$.

the number of rural nonfarm—that is, village—residents and by location in the South.[12] Perhaps the only nonobvious effect concerns the rural nonfarm population. Villagers may have had neither the practical need for automobiles that farmers had nor the commercial impetus city dwellers had. (This is consistent, by the way, with contemporary household budget surveys showing that village residents were less likely, at the same income, to have cars than were farmers [Monroe et al. 1941].)

(What, substantively, does "South" indicate in our equations, other than the fact that southern states tended to fall behind other comparable states in automobile diffusion? It cannot be a proxy, of course, for any one of the various demographic, infrastructural, or economic variables we tested. But, it may reflect a conjuncture of "backward" features, including poverty, sharecropping, underdeveloped markets, a caste system, cultural traditionalism, and, perhaps, reluctance by automobile companies to pursue southern and black customers aggressively.)

World War I.—To investigate whether the war affected the two diffusion processes, we divided the data into the 1902–17 years and the 1917–37 years. Table 4 reports new estimates for the best equations of tables 2 and 3, split into these two periods, and with two versions for the postwar models, one including a dummy for the Depression.

Comparing equations Tel-1 and Tel-3 in table 4 shows that, in addition to the strong effects of the Depression, the direction of coefficients is about the same in both eras, but the stimulative role of farm owners and wealth is much greater in the prewar era than in the postwar one. The postwar period witnessed, in fact, a decline in farm telephones (see Fi-

[12] Although these estimates and those of table 2 seem plausible, they have one potentially serious problem. For OLS to be optimal, an independent variable must be uncorrelated with its equation's disturbance term. In panel models with a lagged dependent variable, this assumption becomes suspect because any error in the dependent variable at time $t + 5$ is likely to be present to some extent at t also. Consequently, we reestimated our best-fitting equations from both tables 2 and 3 several different ways, each using different assumptions about autocorrelation. First, we used two-stage least-squares (2SLS) estimators where the first stage fitted the lagged dependent variable with the two time variables. In the second stage, the predicted values of the lagged dependent variables were used with the other independent variables. This procedure uses an instrumental variable logic to remove autocorrelation as well as to "detrend" the equation for time (for justification, see Johnston 1972). Second, we estimated another set of 2SLS estimates: here, the independent variables measured at time $t + 5$ were used as instruments for the lagged dependent variable. Finally, we took full advantage of the data and applied Parks's (1967) estimator for pooled cross-sectional and time-series data. Using these alternative estimators tends to lower the coefficient associated with the lagged dependent variable and to increase the effects of the other independent variables. The pattern reassures us of our earlier conclusions since it suggests that either autocorrelation is not a problem or, if it is, ignoring it conservatively biases the effects of the variables of interest downward.

TABLE 3

MODELS OF AUTOMOBILE DIFFUSION

Equation Number	Intercept	Log Automobiles	Log Population	Log Area	Log Urban Population	Log Farm Population	Log Rural Nonfarm Population	Log Workers Trade and Transportation	Log Wage Earners Manufacturing	Log Total Wages Earned Manufacturing	Log Total Value Farmland and Buildings	South	Year	Year²	R^2
Auto-1	.620*	.690*	.273*	.042*	...	...	...	...	...	...	...	...	.125*	−.003*	.973
	(.287)	(.030)	(.033)	(.018)									(.021)	(.0003)	
Auto-2	.296	.575*	...	.096*	.326*	.047	−.054	...	...	...	...	...	.188*	−.004*	.975
	(.292)	(.035)		(.023)	(.043)	(.033)	(.064)						(.023)	(.0003)	
Auto-3	−1.83*	.510*	...	−.011	.075	.025	−.079	.586*	−1.37*	...	...	...	.235*	−.005*	.979
	(.950)	(.035)		(.029)	(.123)	(.032)	(.073)	(.139)	(.050)				(.023)	(.0004)	
Auto-4	−3.32*	.477*	...	...	...	...	−.171*	.660*	...	−.092*	.094*	...	.249*	−.005*	.979
	(.493)	(.039)					(.049)	(.067)		(.036)	(.036)		(.022)	(.0003)	
Auto-5	−3.56*	.405*	...	...	...	...	−.126*	.545*	...	...	.144*	−.135*	.275*	−.005*	.979
	(.484)	(.038)					(.055)	(.053)			(.026)	(.048)	(.024)	(.0004)	

NOTE.—SEs are shown in parentheses.
* $P \leq .05$.

TABLE 4

PRE- AND POSTWAR MODELS OF TELEPHONE AND AUTOMOBILE DIFFUSION

Equation Number	Time Period	Intercept	Log Telephones	Log Automobiles	Log Workers Trade and Transportation	Log Average Value Farmland and Buildings	Log Farm Owners	Log Farm Tenants	Log Rural Nonfarm Population	Log Total Value Farmland and Buildings	South	Year	Depression	R^2
Tel-1	Prewar	−.796*	.624*	...	.300*	.151*	.142*	−.033	...	...	...	−.032*	...	.982
		(.376)	(.048)		(.045)	(.030)	(.035)	(.019)				(.005)		
Tel-2	Postwar	−.397	.632*	...	.405*	.080*	.036	−.049*	...	...	...	−.011*	...	.988
		(.295)	(.048)		(.050)	(.023)	(.030)	(.016)				(.003)		
Tel-3	Postwar	−1.09*	.751*	...	.289*	.041*	.005	−.035*	...	...	...	.034*	−.446*	.995
		(.187)	(.031)		(.032)	(.015)	(.018)	(.010)				(.003)	(.030)	
Auto-1	Prewar	−2.49*	...	.556*	.356*	...	...	...	−.191*	.231*	−.139	.151*	...	.977
		(.606)		(.047)	(.080)				(.080)	(.038)	(.078)	(.017)		
Auto-2	Postwar	1.28*	...	.231*	.620*	...	...	...	.034	.097*	−.133*	−.006	...	.971
		(.290)		(.062)	(.059)				(.048)	(.024)	(.040)	(.005)		
Auto-3	Postwar	.103	...	.661*	.272*	...	...	...	.054	.004	−.050	.041*	−.687*	.986
		(.221)		(.055)	(.049)				(.033)	(.018)	(.028)	(.005)	(.056)	

NOTE.—SEs are shown in parentheses.
* $P \leq .05$.

scher 1987*b*), while telephone growth continued in towns until the Depression.

Equations Auto-1 and Auto-3 suggest that the effects of all the independent variables, aside from the number of trade and transportation workers, were considerably more important before than after the war. Possibly the rapid "takeoff" of automobile purchases during the 1920s involved an internal dynamic so powerful that few exogenous factors could affect it. One influential factor, however, was probably the drop in car prices. Unfortunately, it could not be modeled here, because national prices are collinear with year and because state prices varied little (see Chow 1957; Meir 1981).

Mutual influence.—We turn next to the question of how the diffusion of each technology affected the diffusion of the other. Did they stimulate or substitute for each other? Our research strategy was to add to our equations the lagged value of the other technology. Since the lagged variables are predetermined, estimators for simultaneous equations are not required (Kmenta 1971). However, there are likely to be omitted variables specific to each state, such as government regulation, tax rates, political regime, culture, and the like. These omitted factors are likely to affect both diffusion processes and to create mutually correlated disturbances. We controlled for this potential problem by estimating these models with Zellner's (1962) technique for "seemingly unrelated" regressions. Expressed intuitively, Zellner's technique uses the correlation of residuals across equations. With multiple panels such as those used here, the estimates might be interpreted as controlling for time-varying, state-specific effects.

Although table 4 shows that the individual diffusion processes did not differ greatly in the periods before and after the war, we found that the mutual influences of the two technologies did. Table 5 reports the Zellner estimates for these models. Comparing first the telephone equations for the pre- and postwar periods shows the same contrast as in table 4: the influence of trade and transportation workers in accelerating diffusion continues, but the influences of the farm variables weaken considerably. A similar conclusion applies to automobile diffusion: aside from commercial workers, the exogenous factors are less important in the postwar than in the prewar era—population distribution, farm wealth, and southern location.

The cross influences of telephones and automobiles are of greatest interest. Before World War I (eqq. Tel-1 and Auto-1), automobile diffusion apparently spurred telephone diffusion ($b = 0.065$). There is little in the historical literature to predict this effect, although post hoc conjectures are possible, for example, that automobiles and trucks spurred business dispersion in metropolitan areas, necessitating more telephone links; that

TABLE 5

Joint Pre- and Postwar Models of Telephone and Automobile Diffusion

Equation Number	Time Period	Intercept	Log Telephones	Log Automobiles	Log Workers Trade and Transportation	Log Average Value Farmland and Buildings	Log Farm Owners	Log Farm Tenants	Log Rural Nonfarm Population	Log Total Value Farmland and Buildings	South	Year	Depression	Log Automobiles × Depression	R^2
Tel-1	Prewar	−.234	.596*	.065*	.248*	.141*	.152*	−.026	...	...	...	−.051*	...	...	
		(.430)	(.048)	(.026)	(.049)	(.030)	(.035)	(.019)				(.009)			.981
Auto-1	Prewar	−2.86*	−.127	.529*	.461*	...	...	...	−.180*	.272*	−.220*	.168*	...	...	
		(.677)	(.093)	(.051)	(.1[illegible]5)				(.085)	(.050)	(.083)	(.019)			
Tel-2	Postwar	−.541*	.870*	−.315*	.421*	.091*	.026	−.007	...	...	...	.006	...	...	
		(.238)	(.045)	(.050)	(.040)	(.017)	(.019)	(.011)				(.004)			.986
Auto-2	Postwar	1.16*	−.004	.245*	.635*	...	...	...	−.004	.102*	−.108*	−.007	...	...	
		(.258)	(.069)	(.076)	(.066)				(.033)	(.023)	(.031)	(.006)			
Tel-3	Postwar	−.948*	.766*	.021	.260*	.027	−.014	−.026*	...	...	...	.034*	−.463	...	
		(.180)	(.034)	(.044)	(.034)	(.015)	(.017)	(.009)				(.003)	(.038)		.992
Auto-3	Postwar	.004	−.142*	.746*	.374*	...	...	...	.009	.005	−.090*	.036*	−.696*	...	
		(.208)	(.051)	(.066)	(.053)				(.028)	(.017)	(.026)	(.005)	(.055)		
Tel-4	Postwar	−1.37*	.764*	.043	.274*	.028*	−.011	−.028*	...	...	...	.034*	.177	−.053*	
		(.187)	(.032)	(.042)	(.032)	(.014)	(.015)	(.008)				(.003)	(.125)	(.010)	.993
Auto-4	Postwar	−.001	−.147*	.748*	.379*	...	...	...	.007	.005	−.093*	.036*	−.696*	...	
		(.206)	(.051)	(.065)	(.052)				(.027)	(.017)	(.025)	(.005)	(.055)		

Note.—SEs are shown in parentheses.
* $P \leq .05$.

road construction for automobile use made telephone line construction easier; that residential dispersion encouraged by automobiles in turn encouraged telephone subscription; and so forth (e.g., Pool 1977*b*). The theoretical claims that communications modes stimulate one another would be supported by this finding were it not for the negative, albeit nonsignificant, sign of the effect of telephones on automobiles ($b = -0.127$).

Stronger and different mutual influences are found in the postwar period. Automobiles apparently retarded telephones after the war, whereas they encouraged them before the war. Note, however, that the inclusion of a dummy variable for the Depression (shown in Tel-3 and Auto-3) renders this effect statistically nonsignificant. The reason for this is that the effect apparently interacts with the Depression. Equations Tel-4 and Auto-4, which include an interaction term for automobiles and the Depression, suggest that the number of automobiles in a state had no influence on telephones during the 1920s ($b = 0.043$, N.S.), but that there was a significant negative influence during the Depression (b [for Depression $\times$ automobile] $= -0.053$). That is, states with many automobiles lost the most telephones during the Depression, even when population, economic structure, and the like are taken into account.

Consistent with this finding are many contemporary arguments made to explain the weakness of telephone diffusion during the late 1920s (e.g., Page 1928) and the Depression (e.g., Blalock 1940). People in the telephone industry, in particular, worried about being outpaced by automobiles and asserted that the automobile (as well as the radio) had functionally substituted for the telephone. Moreover, the Depression accentuated the problem by forcing many people to make budget tradeoffs, and many of them gave up telephone service. Indeed, the significant interaction term of automobiles and Depression in equation Tel-4 suggests that the Depression hit telephone subscription hardest in states with many automobiles, all else being equal (for full review, see Fischer 1987*b*).

Less expected is the reciprocally negative influence of telephone diffusion on automobiles ($b = -0.147$) in equation Auto-4. It implies that automobile development was retarded in those states where telephony was well developed and provides the strongest evidence for a direct substitution effect. Apparently, automobile diffusion did not spread as fast as it would have otherwise in states with many telephones.

DISCUSSION AND CONCLUSION

To the historical question, How did the automobile and telephone come to be so widespread in America? our analysis suggests a few answers. For one, these were inherently attractive technologies, with great advantages over their predecessors. This is probably the best way to interpret the strong internal diffusion process apparent in our statistics (see tables 1, 2). Beyond that, commercialization in the urban centers (not, however, industrialization) apparently accelerated adoption of both the telephone and automobile. Exactly how this encouraged householders to adopt the technologies requires further study. A more complex process occurred in rural America. Well-off, independent farmers embraced both technologies before World War I, just as the narrative histories suggest (Fischer 1987*a*). At least, states with many such residents were relatively quick adopters. But states with many tenant farmers—heavily southern—were slow to adopt.

That the other state attributes we examined, such as manufacturing and road development, did not emerge in our models as significant does not disprove their importance. Perhaps they were poorly measured, or perhaps they would emerge at lower levels of aggregation. Or, perhaps, they were overwhelmed by the strong internal dynamic (e.g., automobiles may have spurred road development rather than vice versa). But the nil results challenge simple notions that industrialization explains technological development.

Our data point also to an important historical watershed, World War I. A few of the accelerating factors before the war were less important after the war. In a sense, the diffusion process "coasted" after the war. And the substitution effect, weak or inconsistent before the war, becomes sharper afterward, especially during the Depression.

Historians consider World War I a turning point for America for many economic, political, and social reasons. But we might speculate that an important feature then was the consolidation of the telephone industry (which had started a few years earlier) and of the automobile industry. The reduction in competition may have reduced diffusion, thereby creating the "coasting" effect. Narrative accounts suggest that, for much of the 1920s, leaders of both industries, assuming that they had largely saturated their markets, turned from competitively seeking new customers to "milking" existing ones—the auto industry by stressing trade-ins and new model sales and the telephone industry by stressing extensions, long distance, and similar special services. Then, the financial constraints of the Depression may have forced consumers to make hard-nosed trade-offs among the technological alternatives.

On the analytical issues, this case informs the metatheoretical discussion concerning the appropriate explanatory framework for the diffusion process: individuals, structures, or mediating agencies. On the one hand, the prewar influences of farm status and wealth point to aggregated individual traits as altering the internal dynamic of the diffusion process.

One can claim that farmers demanded the new technologies. But that seems to be the only such instance in our data (e.g., wages earned in manufacturing were not significant). Instead, the role of commercialization, the specifying effect of the historical period and our interpretation of it (changes in industry structure), and the substitution effects point more to the roles of structural context and of diffusing agents as described by Brown (1981).

Furthermore, we have evidence here of a transportation-communications trade-off with large-scale technologies, not as a universal process—recall the small positive influence before World War I and the fact that both automobiles and telephones boomed in the 1950s and 1960s—but as one that does occur under specific circumstances. In the postwar, and especially the Depression, years, states doing relatively well in one technology tended to do relatively poorly in the other. We suspect that, forced to examine expenditures in hard times, many people treated automobiles and telephones as interchangeable and forwent one for the other.

The implication of these findings for sociological research on modernization is to raise cautions about using technologies interchangeably as markers of such a diffuse concept. To be sure, the mass use of automobiles and telephones assumes certain conditions commonly associated with modern society—for example, relative wealth and technical expertise. But what we have learned here is that structural conditions, distributed by locale, can accelerate or retard the internal dynamic of diffusion.

We found that the process was accelerated by commercialization but not, so far as we could tell, by other aspects of industrialization. We found that this modernizing process was also accelerated, at least at first, by the declining traditional sector of agriculture; that it was historically specified; that—if our interpretation is correct—it was shaped by particularities of the industries (e.g., the establishment of local telephone monopolies after 1912); and that these technologies were marked at least as much by competition between them as by synergy. These findings encourage efforts to "unpack" overly global concepts of modernization and development.

What we are suggesting, in a more theoretical vein, is that much sociological thinking about modernization presents a too global or unitary process, because it assumes either that specific features are necessarily, functionally, and tightly interdependent or that they are just expressions of a single underlying logos. Instead, a more agnostic approach may be appropriate. There may be several, often independent, axes of change, even in the realm of technology. Consider, as an example different from ours, housework technologies. Ruth Cowan (1983) has cogently argued that the new domestic tools of the past century have had different consequences in different settings. Food preparation and clothing manufacture have, as the standard thesis of family modernization holds, become material functions largely displaced from the household. But the increased access of households to heat, energy, and transportation may have internalized material functions that had been previously performed by outsiders, such as heavy laundering and the delivery of goods. Similarly, such technologies may have increased the productivity of poorer housewives but merely replaced servant labor for the affluent. We can take a different example. The automobile and other developments in rapid transit have no doubt sped up, and have probably increased the frequency of, peoples' daily trips. But they may have, at the same time, lowered the frequency of residential moves.[13] Our evidence contributes to the effort to unpack the global concept of modernization and suggests that change may occur differently in different domains.

This research on technological diffusion should—and, to some extent, will—be pursued in a few directions. One would be to expand the technologies under study to incorporate other forms of communications and transportation, especially postal and rail services, into the models. Another would be to replicate the analysis with more and smaller ecological units, such as counties. A third, planned, project is to look at what kinds of individuals, in which periods, were especially likely to adopt the technologies. Fourth, we also plan to disaggregate telephones and automobiles by sectors, such as farm versus nonfarm and Bell versus non-Bell providers.

Nevertheless, we have charted on a macroscopic scale the basic diffusion patterns of two of the most potent technologies of the modern era. The complexities unveiled here, in particular their negative influence on each other, suggest some caution in using simple ideas of modernization and also call for more detailed empirical study.

APPENDIX

List of Final Variables Used, Their Definitions, and Sources

Number of telephones.—Number of telephone "stations" (i.e., instruments) reported to U.S. Census in 1902, 1907, and so on and published, by state, in USBOC (1906, 1910, 1915, 1920, 1924, 1930, 1934, 1939). Many other attributes of telephone systems are available in these data, but the two we most closely examined—number of central offices and number of systems in a state—made little coherent difference.

Number of automobiles.—Number of registered passenger automobiles

[13] For evidence on declining mobility, see, e.g., Long (1976) and Allen (1977). The explanation would be that the increased ability to commute long distances has reduced the need to move with each job change.

in a state for 1902, 1907, and so on (estimated for a few states in the earliest years) and published in Public Roads Administration (1947).

Urban population.—Interpolated from decennial figures published in USBOC (1975). Rural nonfarm calculated by subtracting urban population and farm population (see below) from total population.

Number of workers in trade and transportation.—The series was first estimated for decennial years, using census counts of persons over age 10 engaged in trade or transportation, 1900; persons engaged in trade plus persons engaged in transportation, 1910 and 1920; persons engaged in trade plus persons engaged in transportation and communications, 1930; and persons over age 14 in wholesale and retail trade and employed in transportation, communications, and other public utilities, 1940. The source is the decennial censuses as coded onto census tapes of ICPSR, Michigan. These figures were then interpolated for 1902–37. There is potential error here in that the interpolations between 1930 and 1940 may not capture well changes during the depth of the Depression. On the other hand, that distortion would have less effect on the between-states variance. There is also a possible circularity, in that telephone development added workers to this group. But, in 1930, when telephone employees numbered 350,000, they represented less than 5% of this category of workers. (Another estimate is that telephone and telegraph operators were 2% of this category in 1900 and 3% in 1930 [Hurlin and Givens 1933].)

Number of workers in manufacturing.—Figures for 1900, 1905, 1909, 1914, 1923, 1927, and 1937 drawn from annual *Statistical Abstracts* and interpolated when necessary for 1902, 1907, and so on.

Total wages in manufacturing.—Same. Series correlated well with related measures, such as value of manufacturing product.

Farm population.—Interpolated from 1900, 1910, 1920, 1925, 1930, 1935, and 1940 figures in USBOC (1975, sec. K).

Number of farm owners and tenants.—Number of farm owners was obtained from the same source. Number of farm tenants actually represents tenants and nonowning managers and was obtained by subtracting owners from total farm operators.

Total and average values of farmland and buildings.—Same source provides average value per state. Total value is product of average and total number of farms. Series correlates well with other measures, such as value of farm produce.

REFERENCES

Allen, F. R., et al., eds. 1957. *Technology and Social Change*. New York: Appleton-Century-Crofts.

Allen, J. P. 1977. "Changes in the American Propensity to Migrate." *Annals of the Association of American Geographers* 67 (December): 577–87.
Automobile Manufacturer's Association. 1941. *Automobile Facts and Figures,* 23d ed. New York: AMA.
Belascoe, W. J. 1979. *Americans on the Road: From Autocamp to Motel, 1910–1945.* Cambridge, Mass.: MIT Press.
Bendix, R. 1967. "Tradition and Modernity Reconsidered." *Comparative Studies in Society and History* 9 (3): 292–346.
Berger, M. L. 1979. *The Devil Wagon in God's Country: The Automobile and Social Change in Rural America, 1883–1929.* Hamden, Conn.: Archon.
Blalock, H. W. 1940. "Streamlining Rural Telephone Service." *Public Utilities Fortnightly* 26 (October 10): 466–73.
Brock, G. W. 1981. *Telecommunications Industry: The Dynamics of Market Structure.* Cambridge, Mass.: Harvard University Press.
Brooks, J. 1976. *Telephone: The First Hundred Years.* New York: Harper & Row.
Brown, L. A. 1981. *Innovation Diffusion: A New Perspective.* New York: Methuen.
Chow, G. C. 1957. "Demand for Automobiles in the United States." *Contributions to Economic Analysis 13.* Amsterdam: North-Holland.
Clark, D., and K. I. Unwin. 1981. "Telecommunications and Travel: Potential Impact in Rural Areas." *Regional Studies* 15:47–56.
Coleman, J. S., E. Katz, and H. Menzel. 1966. *Medical Innovation.* New York: Bobbs-Merrill.
Cowan, R. S. 1983. *More Work for Mother.* New York: Basic.
Danielian, N. R. 1939. *A.T.&T.: The Story of Industrial Conquest.* New York: Vanguard.
Delacroix, J., and C. C. Ragin. 1981. "Structural Blockage: A Cross-National Study of Economic Dependency, State Efficacy, and Underdevelopment." *American Journal of Sociology* 86:1311–47.
Epstein, R. C. 1927. "The Rise and Fall of Firms in the Automobile Industry." *Harvard Business Review* 5 (January): 157–74.
Falk, T., and R. Abler. 1980. "Intercommunications, Distance, and Geographical Theory." *Geografisk Annaler* 62B (2): 59–67.
Fischer, C. S. 1985. "Studying Technology and Social Life." Pp. 284–99 in *High Technology, Space, and Society,* edited by M. Castells. Beverly Hills, Calif.: Sage.
———. 1988. " 'Touch Someone': The Telephone Industry Discovers Sociability." *Technology and Culture,* vol. 29 (in press).
———. 1987*a*. "The Revolution in Rural Telephony." *Journal of Social History* 21 (Fall): 5–26.
———. 1987*b*. "Technology's Retreat: The Decline in Rural Telephony, 1920 to 1940." *Social Science History* 11 (Fall): 295–327.
Flink, J. J. 1970. *America Adopts the Automobile, 1895–1910.* Cambridge, Mass.: MIT Press.
———. 1976. *The Car Culture.* Cambridge, Mass.: MIT Press.
———. 1980. "The 'Car Culture' Revised: Some Comments on the Recent Historiography of Automotive History." *Michigan Quarterly Review* 19 (4): 1–20, 20 (1): 772–78.
Garnet, R. 1985. *The Telephone Enterprise: The Evolution of the Bell System's Horizontal Structure, 1876–1909.* Baltimore: Johns Hopkins University Press.
Hagerstrand, T. 1967. *Innovation Diffusion as a Spatial Process,* translated by A. Pred. Chicago: University of Chicago Press.
Hurlin, R. C., and M. B. Givens. 1933. "Shifting Occupational Patterns." Pp. 268–324 in *President's Commission on Recent Social Trends.* New York: McGraw-Hill.
Jensen, R. 1979. "The Lynds Revised." *Indiana Magazine of History* 75 (December): 303–19.

Johnston, J. 1972. *Econometric Methods*. New York: McGraw-Hill.
Kmenta, J. 1971. *Elements of Econometrics*. New York: Macmillan.
Lawrence, P. R., and D. Dyer. 1983. *Renewing American Industry*. New York: Free Press.
Lee, T. R. 1980. "The Resilience of Social Networks to Changes in Mobility and Propinquity." *Social Networks* 2 (December): 423–37.
Long, L. H. 1976. *The Geographic Mobility of Americans*. Current Population Reports: Special Studies, Series P-23, no. 64. Washington, D.C.: Government Printing Office.
Lynd, R. S., and H. M. Lynd. 1929. *Middletown*. New York: Harcourt Brace.
MacMeal, H. B. 1934. *The Story of Independent Telephony*. Chicago: Independent Pioneer Telephone Association.
Meir, A. 1981. "Innovation Diffusion and Regional Economic Development: The Spatial Diffusion of Automobiles in Ohio." *Regional Studies* 15 (2): 111–22.
Miller, C. E. 1980. "Telecommunications/Transportation Substitution: Some Empirical Findings." *Socio-Economic Planning Sciences* 14:163–66.
MITRE Corporation. 1978. "The Impact of Telecommunication on Transportation Demand through the Year 2000." Report no. 3, National Transportation Policy Study Commission, Washington, D.C.
Moline, N. T. 1971. *Mobility and the Small Town, 1900–1930: Transportation Change in Oregon, Illinois*. Department of Geography Research Paper no. 132. Chicago: University of Chicago.
Monroe, D. L., et al. 1941. *Family Expenditures for Automobile and Other Transportation: Five Regions*. Consumer Purchases Study, Urban, Village, and Farm Bureau of Home Economics, Misc. Pub. no. 415. Washington, D.C.: Department of Agriculture.
Nicol, L. 1983. "Communications Economic Development and Spatial Structures: A Review of Research." Working Paper no. 404, Institute of Urban and Regional Development, University of California, Berkeley.
Ogburn, W. F., and S. C. Gilfallin. 1933. "The Influence of Invention and Discovery." Pp. 122–66 in *President's Commission on Recent Social Trends*. New York: McGraw-Hill.
Page, A. W. 1928. "Public Relations and Sales." In *General Commercial Conference* (Bell System), Shawnee-on-Delaware, Penn., June. In microfilm no. 368B, Illinois Bell Information Center, Chicago.
Parks, R. W. 1967. "Efficient Estimation of a System of Regression Equations When Distributions Are Both Serially and Contemporaneously Correlated." *Journal of the American Statistical Association* 62:500–509.
Pedersen, P. O. 1970. "Innovation Diffusion between and within National Urban Systems." *Geographical Analysis* 3:203–54.
Pool, I. de S., ed. 1977*a*. *The Social Impact of the Telephone*. Cambridge, Mass.: MIT Press.
———. 1977*b*. "The Communication/Transportation Tradeoff." *Policy Studies Journal* 6, no. 1 (Autumn): 74–83.
Pred, A. R. 1973. *Urban Growth and the Circulation of Information: The United States System of Cities, 1790–1840*. Cambridge, Mass.: Harvard University Press.
Preston, H. L. 1979. *Automobile Age Atlanta: The Making of a Southern Metropolis, 1900–1935*. Athens: University of Georgia Press.
Public Roads Administration. 1947. *Highway Statistics Summary to 1945*. Washington, D.C.: Federal Works Agency.
Rae, J. B. 1965. *The American Automobile: A Brief History*. Chicago: University of Chicago Press.
———. 1971. *The Road and the Car in American Life*. Cambridge, Mass.: MIT Press.
———. 1984. *The American Automobile Industry*. Boston: Twayne.

Rogers, E. 1983. *Diffusion of Innovations*, 3d ed. New York: Free Press.
Solomon, I. 1986. "Telecommunications and Travel Relationships: A Review." *Transportation Research* 20A (3): 223–38.
Strauss, M. A. 1985. "The Validity of U.S. States as Units for Sociological Research." Paper presented to the American Sociological Association, Washington, D.C.
U.S. Bureau of the Census. 1906. *Special Reports: Telephones and Telegraphs 1902*. Washington, D.C.: Government Printing Office.
———. 1910. *Special Reports: Telephones 1907*. Washington, D.C.: Government Printing Office.
———. 1915. *Telephones and Telegraphs 1912*. Washington, D.C.: Government Printing Office.
———. 1920. *Census of Electrical Industries 1917: Telephones*. Washington, D.C.: Government Printing Office.
———. 1924. *Census of Electrical Industries 1922: Telephones*. Washington, D.C.: Government Printing Office.
———. 1930. *Census of Electrical Industries 1927: Telephones*. Washington, D.C.: Government Printing Office.
———. 1934. *Census of Electrical Industries 1923: Telephones and Telegraphs*. Washington, D.C.: Government Printing Office.
———. 1939. *Census of Electrical Industries 1923: Telephones and Telegraphs*. Washington, D.C.: Government Printing Office.
———. 1975. *Historical Statistics of the United States, 1790–1970*. Washington, D.C.: Government Printing Office.
U.S. Department of Agriculture. 1938–39. *Income Parity for Agriculture, Part III, Prices Paid by Farmers for Commodities and Services*. Sec. 2: Rates for Electricity for the Farm Home (Preliminary, September 1938); sec. 3: Telephone Rates to Farmers (Preliminary, December 1938); sec. 5: Index Numbers of Prices Paid by Farmers for Commodities (Preliminary, May 1939). Washington, D.C.: USDA.
Wasserman, N. H. 1985. *From Invention to Innovation*. Baltimore: Johns Hopkins University Press.
Webber, M. M. 1980. "The Auto and the Telephone." Paper presented to the American Association for the Advancement of Science, San Francisco.
Weibe, R. 1967. *The Search for Order*. New York: Hill & Wang.
———. 1975. *The Segmented Society*. New York: Oxford University Press.
Wellenius, B. 1977. "Telecommunications in Developing Countries." *Telecommunications Policy*, September, pp. 289–97.
Westrum, R. 1983. "What Happened to the Old Sociology of Technology." Paper presented to the Society for the Sociological Study of Science, Blacksburg, Va.
Wik, R. M. 1972. *Henry Ford and Grass-Roots America*. Ann Arbor: University of Michigan Press.
Willey, M. M., and S. A. Rice. 1933*a*. "Agencies of Communication." Pp. 167–217 in *President's Commission on Recent Social Trends: Report*. New York: McGraw-Hill.
———. 1933*b*. *Communication Agencies and Social Life*. New York: McGraw-Hill.
Zellner, A. 1962. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." *Journal of the American Statistical Association* 63:1180–1200.