View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Research Papers in Economics

This PDF is a selection from a published volume from the National Bureau of Economic Research

Volume Title: Hard-to-Measure Goods and Services: Essays in Honor of Zvi Griliches

Volume Author/Editor: Ernst R. Berndt and Charles R. Hulten, editors

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-04449-1; 978-0-226-04449-1

Volume URL: http://www.nber.org/books/bern07-1

Conference Date: September 19-20, 2003

Publication Date: October 2007

Title: Technology Adoption from Hybrid Corn to Beta-Blockers

Author: Jonathan Skinner, Douglas Staiger

URL: http://www.nber.org/chapters/c0889

18

Technology Adoption from Hybrid Corn to Beta-Blockers

Jonathan Skinner and Douglas Staiger

18.1 Introduction

The idea that differential adoption of new technology can explain productivity differences across regions has gained acceptance in the economics literature. Most of the variation in income per capita across countries appears to come from differences in total factor productivity (TFP) rather than differences in inputs such as capital or labor (Klenow and Rodriguez-Clare 1997; Casselli and Coleman 2006), and income differences have been directly related to differences across countries in technology adoption (Comin and Hobijn 2004). Economic models such as that proposed by Parente and Prescott (1994) imply that relatively small differences across countries in barriers to technology adoption could explain much of the difference in income levels and growth across countries. In medicine, the recent emphasis on accountability has documented a similarly wide variation in medical practice, with most observers agreeing that improvements in compliance with well-established guidelines could lead to substantial improvements in health outcomes of lagging regions (Berwick 2003; Jencks, Huff, and Cuerdon 2003; Skinner 2003).

The real question is why some countries or regions are successful in

Jonathan Skinner is the John French Professor of Economics and professor of community and family medicine at Dartmouth College, and a research associate of the National Bureau of Economic Research. Douglas Staiger is professor of economics at Dartmouth College, and a research associate of the National Bureau of Economic Research.

We are grateful to Martin N. Baily, Ernst Berndt, Bronwyn Hall, Christopher Jencks, and to participants in the NBER Conference on Research in Income and Wealth on Hard-to-Measure Goods and Services: Essays in Memory of Zvi Griliches in September 2003, as well as seminar participants at Duke and Princeton Universities and the University of Michigan. Weiping Zhou and Daniel Gottlieb provided superb data analysis. This research was funded by the National Institute on Aging PO1-AG19783.

adopting efficient technological innovations and why others lag behind. The classic research in economics goes back to the study of state-level hybrid corn diffusion during the 1930s and 1940s by Zvi Griliches (Griliches 1957). For Griliches, the answer was clear: the presence of differential economic incentives and the profitability of innovation determined the wide variations in the pace of diffusion.[1] However, this view of the diffusion of technology was not shared universally. During the early 1960s, there was a long and contentious debate between Griliches and sociologists in the pages of *Rural Sociology* on what caused technology to diffuse. In this exchange, the sociologists, including Everett Rogers, emphasized characteristics of individual decision makers, the structure of networks, and interactions among decision makers in regulating the speed and extent of diffusion (Brandner and Straus 1959; Griliches 1960, 1962; Havens and Rogers 1961; Rogers and Havens 1962; Babcock 1962). While Griliches ultimately acknowledged the potential importance of these sociological factors (Griliches 1962), the literature on diffusion in sociology and the parallel literature in economics has shown little cross-fertilization, at least until quite recently.[2]

In this paper, we return to the debate between Griliches and the sociologists by considering a number of technological innovations in addition to hybrid corn, with a particular focus on the treatment of heart attacks (acute myocardial infarction [AMI]) in the 1990s. Between 1984 and 1998, mortality among the elderly in the year following a heart attack fell from 41 percent to 32 percent, with most of the gain representing progress in medical technology (Cutler 2004; Cutler and McClellan 2001). Despite these gains, there remain large and persistent differences across regions in the survival rates of observationally identical heart attack patients, differences that cannot be explained by variations in expenditures or surgical rates of diffusion (Skinner and Staiger 2006; Skinner, Staiger, and Fisher 2006). These patterns suggest that, like hybrid corn, the diffusion of new innovations in the treatment of heart attacks has been uneven, with some regions lagging behind others.

In a previous study, we found that early adopter states of hybrid corn in the 1930s and 1940s were also the early adopter states of beta-blockers for the treatment of heart attacks in 2000 to 2001 (Skinner and Staiger 2006). Beta-blockers are a highly effective and inexpensive off-patent drug used among appropriate AMI patients to reduce demands on a weakened heart. Clinical trials indicate the use of beta-blockers reduce mortality by 25 percent or more (Gottlieb, McCarter, and Vogel 1998; Yusuf, Wittes, and Friedman 1998) and their beneficial effects have been well understood for

1. Hall (2004) provides an excellent synthesis of both the economic and sociological literature on diffusion.

2. See, for example, Calvó-Armengol and Jackson (2004) and Conley and Udry (2004).

several decades (Yusuf et al. 1985). In this paper, we expand our set of technological innovations to include not just hybrid corn and beta-blockers, but also tractors in the first half of the twentieth century, computers in the 1980s and early 1990s, and more general measures of technological progress in health care: changes and levels in one-year mortality and one-year expenditures for AMI patients during 1989 to 2001. Briefly, we find a strong state-level association in the likelihood to innovate in all technologies, ranging from tractors to beta-blockers.

We next use a factor analysis approach to ask what characteristics of the state are most strongly associated with technological innovation in general and which are most closely associated with higher costs for treating heart attacks. Conventional economic explanatory variables include per capita income and population density to reflect potential geographic spillovers. As well, we also include high school attainment in 1928 (Goldin and Katz 1998) and a measure that reflects social networks or social capital more generally (Putnam 2001), a mechanism stressed in the early work on the diffusion of medical technology (Coleman, Katz, and Menzel 1966). Nearly all of the variables considered in the analysis line up along two latent factors. The first latent factor is highly associated with education (correlation 0.95) and the Putnam social capital index (correlation 0.97). This first factor is also closely associated with the adoption of hybrid corn, tractors, beta-blockers, and both the level and decline in AMI mortality, with somewhat weaker correlation for computer ownership, but is not associated with increased costs for the treatment of heart attacks. The second latent factor is strongly associated with per capita income (correlation 0.84) and population density (correlation 0.89) in the state. While this second factor is largely unrelated to technological diffusion or quality of health care, it is closely associated with higher health care costs (correlation 0.92).

In sum, there appear to be common factors or barriers within regions governing the adoption of cost-effective technology, whether corn, tractors, computers, or beta-blockers, and these are associated with the presence of education (or more effective social or informational networks) in the region. Yet the adoption of these effective technologies was not associated with either per capita income or money spent treating heart attack patients. While Griliches (1957) developed powerful economic approaches to predict early technology adoption, sociological or network models may hold greater promise in explaining why some regions seem to lag so far behind.

18.2 Griliches versus the Sociologists on Technological Diffusion

Griliches (1957) hypothesized that farmers who stand to gain greater profits from an increase in productivity (per acre) would be more likely to adopt the use of hybrid corn, a type of corn that increased yield by about

20 percent. Noting that the dollar value of investing in hybrid corn was larger for agricultural land that was already more productive prior to adoption, he estimated a strong and significant state-level (and crop reporting area) association between adoption and the initial value of agricultural land (see also Dixon [1980], who found similar results). Griliches acknowledged the potential importance of sociological factors in affecting diffusion but dismissed them as relatively unimportant:

> It is my belief that in the long run, and cross-sectionally, these [sociological] variables tend to cancel themselves out, leaving the economic variables as the major determinants of the pattern of technological change. This does not imply that the "sociological" variables are not important if one wants to know which *individual* will be the first or last to adopt a particular technique, only that these factors do not vary widely cross-sectionally. (522, footnote 45)

Sociologists were not entirely pleased with this assessment of their work. They attempted to challenge the Griliches results on statistical grounds by focusing on time series rather than cross-sectional analysis, but this approach was not entirely successful because by appropriate correction for inflation, Griliches (1962) reversed their result to one supporting his profitability hypothesis. More successful was their study showing that hybrid sorghum tended to be adopted not so much where adoption was more profitable, but by farmers who had previously adopted hybrid corn, and was thus supportive of the idea of "congruence," that innovation was easier when one has innovated in the past. The sociologists focused more on the observation that diffusion took place too slowly to conform to a purely economic model:

> The acceptance of improved farming practices is determined largely by economic considerations yet, if economic considerations were the only basis of acceptance, improved practices would be adopted as rapidly as their economic advantages were demonstrated. But, not only is there a considerable lapse of time between initial acquaintance and adoption of a practice, but those who would benefit most from improved practices are frequently the last to adopt them. (Wilkening [1953] quoted in Havens and Rogers [1961, 410]).

Ultimately, Griliches grudgingly acknowledged the importance of sociological factors in diffusion, observing that "If one broadens my 'profitability' approach to allow for differences in the amount of information available to different individuals, differences in risk preferences, and similar variables, one can bring it as close to the 'sociological' approach as one would want to" (Griliches 1962, 330). While Griliches may have ultimately rejected the either-or approach of the earlier debate, others, such as Schultz ([1964, 164], quoted in Dixon [1980]) viewed his work as demonstrating the primacy of economic over sociological models in development economics.

Economic models of diffusion since then have largely remained firmly within the context of profitability and relative advantage as the most important factors determining the adoption of new technologies, as in the two models developed in Jovanovic and Nyarko (1995, 1996) where the relative advantage of the individual agent, for example, his past investments in specific technologies, determines whether a new technology is adopted. The common feature in these models is the absence of individuals interacting with others except indirectly through market forces. The literature in health economics has generally been more sympathetic to the idea of network effect on physician practice style (Fournier, Prasad, and Burke 2002), but even these are often poised in the form of individual Bayesian learning models (for a review, see Phelps 2000).

Exceptions are Foster and Rosenzweig (1995), where farmers learned about their own optimal agricultural inputs by observing what other farmers do (knowledge spillovers), and Berndt, Pindyck, and Azoulay (2003), who allowed for the possibility of network effects in the prescription of antiulcer drugs. More recently, Conley and Udry (2004) were able to establish convincingly the importance of social networks in effecting these knowledge spillovers. They found that in Ghana, pineapple farmers emulated input choices of the more successful farmers inside their social network.

The medical quality-improvement movement has adopted a sociological framework to understand why highly cost-effective treatments such as screening for breast cancer, annual flu shots, and the use of beta-blockers lag behind ideal levels (Berwick 2003). In this literature, physicians are categorized into groups such as early adopters and laggards, and the focus is on individual "change agents" who can shift treatment norms within hospitals (Berwick 2003; see Rogers 1995).

Their emphasis on sociological factors is not entirely surprising. There are few if any economic incentives to prescribe beta-blockers or flu shots, so standard economic models of learning by doing or Bayesian updating could have limited predictive power in explaining diffusion (Skinner and Staiger 2006). What makes the lag in beta-blocker adoption puzzling is that the clinical benefits have been understood for many years. In 1985, Yusuf et al. (1985), concluded in their abstract that: "Long term beta blockage for perhaps a year or so following discharge after an MI is now of proven value, and for many such patients mortality reductions of about 25% can be achieved." In 1996, the National Committee for Quality Assurance adopted beta-blocker use as a marker of quality (Berndt 2001), yet median state compliance with appropriate beta-blocker use in 2000 to 2001 was still just 69 percent (Jencks, Huff, and Cuerdon 2003). For the same reason, it would be difficult to develop an economic model explaining why the use of X-rays for fractures lagged for several decades in the first part of the twentieth century (Howell 1995) or why more than a century passed between the discovery that lemons and limes prevented scurvy

to the date when the British Navy mandated their use in sailors' diets (Berwick 2003).

Education is an important variable considered by all empirical studies of diffusion, but the interpretation of how education matters differs between the economists and the sociologists. For much of the economic literature, education is a measure of human capital, and so innovation may be more likely to take place depending on the nature of the production function and the elasticity of substitution between skilled labor and capital (e.g., Caselli and Coleman 2006). The sociological literature, on the other hand, places greater emphasis on education as affecting the ability of "change agents" and early adopters to process and understand the value of the new technology and to be able to make the jump to a new paradigm (Rogers 1995).

While one might expect differences across farmers in their education levels to affect innovation in hybrid corn, it is more difficult to understand how average education levels of the general population would matter for the use of medical procedures as each physician has completed at least twenty years of formal education.[3] Alternatively, education might be associated with more rapid innovation if the *demand* for innovations were higher among highly educated patients. Explaining the pattern of beta-blocker use in the twenty-four hours following hospital admission as variations in demand by patients would be difficult. The typical Medicare patient is unlikely to be aware of beta-blockers at all, and, among ideal candidates, its use should have been near 100 percent in any case regardless of demand. An alternative hypothesis is that better quality physicians are attracted to regions with higher income and hence greater demand for quality although we do not find evidence for this in the empirical section below.

The classic work in the diffusion of medical technology is Coleman, Katz, and Menzel (1966), who document the diffusion of a new antibiotic, tetracycline, among physicians in several North Central communities. While the diffusion was relatively rapid, with nearly 90 percent of physicians using the drug within seventeen months, there were distinct differences in rates of adoption. Physicians with more interactions among other physicians, such as affiliation with a hospital or group practice, were more likely to adopt early. Importantly, physicians who reported high social participation in the medical community adopted earlier. Among those with low social participation, even after seventeen months the use of the more effective antibiotic lagged by roughly 15 percent (Coleman, Katz, and Menzel 1966, 49). More recent analysis of the original data suggest a more complex mechanism for diffusion, but "contagion" still appears to have played a role (Strang and Tuma 1993).

3. Specialists have more formal education, but the correlation between cardiologists per capita and beta-blocker use across regions is near zero (Skinner 2003).

These results suggest an important interaction between regional levels of education and the extent of social participation or networks (see Barr 2000). The pathway is more indirect as education is highly predictive of social participation in the community, participation in democratic activities, and other factors conducive to the interactions that can lead to more rapid diffusion among health care providers within a community.[4]

In practice, we use indexes of social capital and education in the 1990s from Braatz and Putnam (1996). While the idea of social capital has received increasing attention in economics (e.g., Helliwell 1996; Guiso, Sapienza, and Zingales 2004), economists have also been among the most critical; see Durlauf and Fafchamps (2004) for a distinctly lukewarm review of this approach. Our use of social capital, however, avoids their most serious objections in that we need not identify causality, nor need we do more than to establish that some "factor x" associated with high levels of social capital (*controlling* for income) is also associated with technological innovation. As it turns out, general education levels and even high school graduation rates in 1928 (Goldin and Katz 1998) are highly predictive of these innovations, but reliance upon education alone begs the question, as noted previously, of why beta-blockers were more likely to diffuse in states with higher graduation rates.

We begin the empirical analysis by considering at the state level the association among four technological innovations: hybrid corn, tractors, computers, and beta-blockers. Simple correlations between innovation in hybrid corn and tractors are consistent with either economic or sociological models as the farmers gaining most from hybrid corn adoption would presumably enjoy similar gains that adopting tractors. A correlation between hybrid corn and computers is less likely, although to be fair, farmers were early adopters of computers to keep track of plot yields and animal medical records.[5] Predicting a positive correlation between the adoption of beta-blockers and the adoption of these other technologies is not so obvious as the educational attainment of physicians does not differ much across states, nor is it easy to develop a rational economic model as to why physicians *wouldn't* adopt highly effective treatments that save lives but only cost about twenty cents per dose.

To develop a broader picture of technology gains in the treatment of heart attacks, we also consider risk adjusted one-year mortality rates and risk-adjusted medicare expenditures by state, whether in levels or in changes during the period of analysis 1989–2000. Mortality rates reflect a more general measure of technological innovation that goes beyond beta-

4. Coleman, Katz, and Menzel (1966, 43) also find differences in rates of adoption depending on the location of the physician's medical school, with those attending school in the North Central states being more likely to adopt. See also Strang and Tuma (1993).

5. We are grateful to Ernst Berndt for pointing this out. This pattern is consistent with the international data (e.g., Comin and Hobijn 2004); see also Skinner and Staiger (2006).

blocker adoption. Because these rates are derived conditional on the index AMI and a variety of covariates are included to control for underlying health differences, they are less likely to be confounded by the general health levels of the state.[6] One-year Medicare expenditures capture the total value of inputs to care, given that the Medicare program effectively pays on the basis of inputs (i.e., procedures performed by the physician or subsequent admissions to the hospital) rather than on quality of outcomes. Variations in expenditures capture both differences in total inputs across states and over time as well as differences in reimbursement rates.[7]

The obvious question is, why do some states lag behind in adoption of these innovations? Broadly, there are two ways that we might answer this question. On the one hand, there are factors that are unique to medical care such as regulation, health insurance, or malpractice laws. Alternatively, in some states there may be broad, general barriers to technology adoption such as discount rates, risk aversion, lack of human capital and information networks, or cultural norms (e.g., Strang and Soule 1998). These types of barriers would not be unique to medical care and would imply that some states would be late to adopt a wide variety of innovations.

18.3 The Factor Analysis Model

We adopt a factor analysis approach to quantify the relative importance of state-level factors that could plausibly be associated with technological diffusion. The factor model assumes that all of the state-level variables are linear combinations of a few unobserved factors (representing the state-level characteristics that are barriers to adoption), plus an independent error (Harmon 1967). Thus, the correlations that are observed between our different measures of adoption are assumed to be generated by a few common factors. Furthermore, we can estimate whether any observed state characteristic is strongly correlated with the common factor—that is, are there characteristics of states that are strongly associated with adoption and can account for the common adoption patterns that we observe across technologies.

More specifically, a factor model assumes that the data we observe for each state (Y) depend on a small-dimensional set of latent factors (F):

6. In other words, Louisiana may have higher rates of heart disease than Vermont, but this does not imply that adjusted mortality in Louisiana should be higher conditional on the heart attack. For example, in the empirical section, we find no association between adjusted AMI mortality and per capita income.

7. There are also marked differences in Medicare reimbursement rates across regions because of cost-of-living variation and, more important, government programs such as graduate medical education and disproportionate share hospitals programs. Thus, cross-sectional comparisons in expenditures will reflect these permanent differences, while changes in expenditures will reflect only secular changes in reimbursement rates.

$$Y_j = \mathbf{F}_j \mathbf{\Lambda} + \boldsymbol{\mu}_j$$

where $\mathbf{F}_j$ is a $1 \times j$ vector of factors with dimension less than Y, $\mathbf{\Lambda}$ is a matrix of coefficients (the factor loadings) giving the effect of the factors on the elements of Y, and $\boldsymbol{\mu}_j$ is a vector of independent residuals with $\mathrm{Var}(\boldsymbol{\xi}) = \mathbf{\Psi}$ a diagonal matrix. Without loss of generality we normalize the factors to be independent with $\mathrm{Var}(F) = I$, and normalize the observed data so that each variable has $\mathrm{Var}(Y) = 1$. Thus, the factor loadings ($\mathbf{\Lambda}$) can be interpreted as the increase in Y (in SD units) associated with a one standard deviation increase in each factor. Moreover, with this normalization the factor loadings are equal to the correlation between Y and each factor so that a factor loading near 1 suggests a strong association between Y and a given factor.

The factor structure implies that $E(Y'Y) = \mathrm{Var}(Y) = \mathbf{\Lambda}'\mathbf{\Lambda} + \mathbf{\Psi}$. Thus, the parameters of the factor model ($\mathbf{\Lambda}$, $\mathbf{\Psi}$) can be estimated by fitting the parameters of the factor model to the observed covariance matrix. There are a variety of methods for doing this. We assume normality and estimate the parameters by maximum likelihood (other methods yield similar results).

The main advantage of the factor model is that it summarizes the observed correlation in the adoption measures with only a few factors and thereby focuses attention on a few simple dimensions on which adoption varies. Moreover, if the unobserved factors are strongly correlated with other state characteristics such as education, income, or social capital, then the factors can be given a natural interpretation. There are also a number of important limitations of the factor model. First, the estimated factor loadings are only unique up to an orthonormal rotation. We report estimates from the varimax rotation, which is commonly used in factor analysis because it maximizes the amount that each outcome is associated with a unique factor, thus helping with interpretation of the factors. A second limitation of the factor model is that the appropriate number of factors is not obvious. We choose the number of factors empirically, based on significance of additional factors and the robustness of results.

18.4 Data

Here we describe each of the state-level variables used in the empirical analysis.

18.4.1 Measures of Nonmedical Technology Adoption

We use two state-level measures of technology adoption in agriculture. For hybrid corn adoption, Griliches estimated logistic models for each state of the form $\ln(P_t/(K - P_t)) = a + bt$, where P_t represented the fraction of land planted in hybrid seed in year t, K the maximum fraction of land to

be planted in hybrid seed, b the parameter that captures the speed of adoption, and a the intercept. The parameters K, a, and b were estimated by least squares for each state using annual data on the use of hybrid corn for years ranging from 5 percent to 95 percent adoption (more precisely, K was first chosen by a crude visual method, and then the parameters a and b were estimated by ordinary least squares [OLS]). We use the time (measured relative to 1940) at which the state attained a 10 percent level of hybrid corn; this was given by $(-2.2 - a)/b$, and was reported in table 1 of Griliches (1957) for the thirty-one states on which he had data.

We used an identical methodology to obtain an estimate of the year in which each state attained at least 10 percent levels of use for tractors. Data on the proportion of farms in each state using tractors in the years 1920, 1925, 1930, 1940, 1945, 1949, 1954, and 1959 were taken from Olmstead and Rhode's (2000) analysis of the diffusion of tractors.[8] We assumed that tractors would eventually be adopted by all farms ($K = 1$) and estimated the parameters a and b by OLS for each state.[9]

Finally, using data from the 1993 Current Population Survey, we estimated the proportion of the population of each state that had a computer in their home. Unlike our industry-specific measures of adoption in medical care and agriculture, computer ownership captured the adoption of a new consumer good in the general population.

18.4.2 Medicare Claims Data on Treatment of Heart Attacks

Acute myocardial infarction makes a good case study to use in studying health care productivity. Nearly every AMI patient is admitted to a hospital, and ambulance drivers are generally instructed to drive to the nearest hospital, so the match between hospital and AMI patient is rarely driven by consumer demand. The outcome, survival, is accurately measured, as are measures of inputs and covariates, whether reflecting regional measures in the use of pharmaceutical treatments or demographic and health information (including the type of heart attack).[10]

Data on the mortality and cost of treating heart attacks (AMIs) are constructed from the Medicare Claims data from 1989 to 2000; these data are described in greater detail in Skinner and Staiger (2006). They include 20 percent of Medicare admissions for 1989 to 1991 and 100 percent from 1992 to 2000. We use every fee-for-service heart attack admission to create a longitudinal cohort of 2.5 million fee-for-service enrollees age sixty-five

8. The data on tractor use was originally derived from U.S. Bureau of the Census (1962, 214). We thank Paul Rhode for providing these data.

9. Dixon (1980) reestimated the original Griliches (1957) diffusion parameters to account for what ultimately turned out to be a 100 percent adoption level in each state for hybrid corn but found results consistent with the original analysis.

10. Skinner, Staiger, and Fisher (2006) consider in more detail the role of surgical innovations in both improvements in outcomes and increasing costs.

or over coded with AMI.[11] We created risk-adjusted one-year and inflation-adjusted increases in Medicare expenditures that control for a variety of demographic factors and comorbidities.[12] Thus, differences across states and over time in demographic composition, severity of AMI, and health status are accounted for in both mortality and expenditure measures.

We assigned patients to states based on their residence (rather than where they were treated) and use linked death certificate data to see whether patients survived a one-year window. Payments by Medicare for the initial and all subsequent inpatient (Part A) expenditures were used to construct measures of one-year hospital costs for each patient. To construct overall measures of risk-adjusted mortality and costs, we averaged the measures for each state across the years 1989–2000. To construct measures of the change in risk-adjusted mortality and costs, we used the change from 1989 to 1991 to 1999 to 2000. Overall, in our data, 35 percent of Medicare heart attack victims died within one year of their heart attack, and the average cost of treatment was just under $13,000 in 2000 dollars.

18.4.3 Other Data on the Quality of Medical Care

We obtained from Jencks, Huff, and Cuerdon (2003) additional measures of the quality of medical care in 2000 to 2001 for each state. These measures were derived by the Center for Medicare and Medicaid Services (CMS) from large state-wide random samples of medical records. Jencks, Huff, and Cuerdon reported information for twenty-two quality indicators for each state, ranging from the fraction of the eligible population who receive mammograms or flu immunizations to the proportion of stroke patients who were prescribed a recommended medication at discharge. Thus, these measures were intended to capture the extent to which each state had adopted current medical guidelines across a range of conditions. We use the overall ranking (based on the average ranking across the twenty-two indicators, with 1 being the best) as a general indicator of how close a state is to the frontier in terms of its adoption of medical guidelines. As a specific measure of innovation in the treatment of heart attacks, we also used the percent of heart attack patients who receive beta-blockers within twenty-four hours of admission; as noted in the preceding, median state-level compliance was just 69 percent.

11. Luft (2003) found modest differences in underlying measurable health status between fee-for-service and the health maintenance organization (HMO) population. However, the survival characteristics of AMI patients in HMOs, conditional on the observed comorbidities in his (and our) data, were similar to those in the fee-for-service programs.

12. These include demographic cells by sex, five-year age groups, and race (black of nonblack), and categorical variables for the type of heart attack (anterior, inferior, subendocardial, other), the presence of vascular disease, pulmonary disorders, dementia, diabetes, liver dysfunction, renal failure, cancer (nonmetastatic), and cancer (metastatic). In this data set, we exclude patients reporting previous heart attacks, but to avoid potential secular biases, we did not exclude people appearing twice in the data set.

18.4.4 State-Level Factors That May Influence the Rate of Adoption

In addition to state-level measures of the rate of adoption of various innovations, we considered four variables that may capture differences across states that influence the rate of adoption. Because income could affect the demand for innovative products, we include per capita income based on the 2000 Census. Many theories would suggest that density of the market could influence the rate of innovation because higher density would be associated with greater potential gains from an innovation. Therefore, we use each state's population density in 2000 (also from the Bureau of the Census).

The third factor, education, was measured using two different approaches. The first is whether a state invested early in high school education. As documented in Goldin and Katz (1998), the "high school movement" occurred much earlier in certain regions of the country, and this early development has had lasting effects on each region. As an indicator of which states were early adopters of high school education, we used the number of public and private high school graduates in each state as a percent of the number of seventeen-year-olds in 1928.[13] The second education measure relies on an index developed by Braatz and Putnam (1996). The index is the average of (a) test scores from the National Assessment of Educational Progress, (b) the average Scholastic Assessment Test (SAT) score in the state adjusted for participation, and (c) a measure of the high school dropout rate.

Finally, sociological explanations of technology adoption suggest that measures of social capital, which capture the strength of relationships between individuals in the state, should be important factors. We used a social capital index also developed by Braatz and Putnam (1996), which is the average z-score of (a) nonprofit organizations per capita in 1989, (b) newspaper circulation per capita in 1991, (c) voter turnout in the presidential elections of 1988 and 1992, (d) the number of association memberships per capita from the General Social Survey for the years 1974–1994, and (e) the social trust measure from the General Social Survey for 1972–1996.

18.5 Empirical Results

Summary statistics on the state-level variables are shown in table 18.1. Data are not available for all states in all years owing primarily to lack of data on agricultural innovations in urban states. (Alaska and Hawaii are obviously missing for the historical data.) There is a substantial degree of variation in all variables.

13. See Goldin (1994) for details on the construction of the 1928 high school graduation rate. We thank Claudia Goldin and Larry Katz for providing these data.

Table 18.1 Summary statistics of state data

Variable	No. of observations	Mean	Standard deviation	Min.	Max.
1. AMI mortality and cost					
AMI adjusted 1-year mortality	50	–0.009	0.02	–0.055	0.023
AMI adjusted 1-year ln(cost)	50	9.37	0.19	9.09	9.78
Δmortality, 1989–91 to 1999–2000	50	–0.034	0.020	–0.102	0.031
Δln(cost), 1989–91 to 1999–2000	50	0.63	0.16	0.42	1.22
2. Measures of innovation					
Percentage AMI getting beta blocker within 24hr	50	69.7	7.7	50	86
Jencks quality of care ranking, 2000	50	25.8	14.9	1	51
Year hybrid corn achieved 10%	31	1940.6	3.5	1936	1948
Year tractors achieved 10%	48	1930.6	8.7	1916	1947
Percentage with computers at home, 1993	50	0.28	0.07	0.14	0.44
3. Factors that influence adoption					
Putnam social capital index	48	0.01	0.79	–1.37	2.11
ln(per capita income, 2000)	50	10.24	0.15	9.95	10.63
Putnam education index	48	0.04	0.83	–1.74	1.89
High school graduation rate, 1928	48	0.30	0.12	0.12	0.55
ln(population density in 2000)	50	4.40	1.42	0.10	7.03

18.5.1 Is Early Adoption Related across Innovations?

We begin by comparing the year in which each state adopted hybrid corn and two other measures of technology adoption in the state: the year tractors achieved 10 percent (figure 18.1) and the rate of computer ownership in 1993 (figure 18.2). There is a close association across all three variables with regard to innovation (the graph comparing computers and tractors, not reported here, is similar). The correlation between tractors and hybrid corn is not entirely surprising, but it is perhaps more surprising that the pattern is so similar in figures 18.1 and 18.2. One might normally expect a much closer association of hybrid corn adoption with tractor adoption than with computer ownership, particularly under the assumption that profitability of farm land (rather than general characteristics of the state) is a key determinant of agricultural adoption. Iowa might be expected to have lead in the adoption of hybrid corn and tractors, but it also lead in computer ownership.[14]

In figure 18.3, we show the relationship by state in the proportion of ideal patients receiving beta-blockers during 2001 (Jencks, Huff, and Cuerdon 2003) along with the year in which each state attained at least 10 percent levels of use for hybrid corn varieties, based on the logistics curves

14. As noted in the preceding, this could also be explained in part by early adoption of computers by farmers in keeping track of livestock.

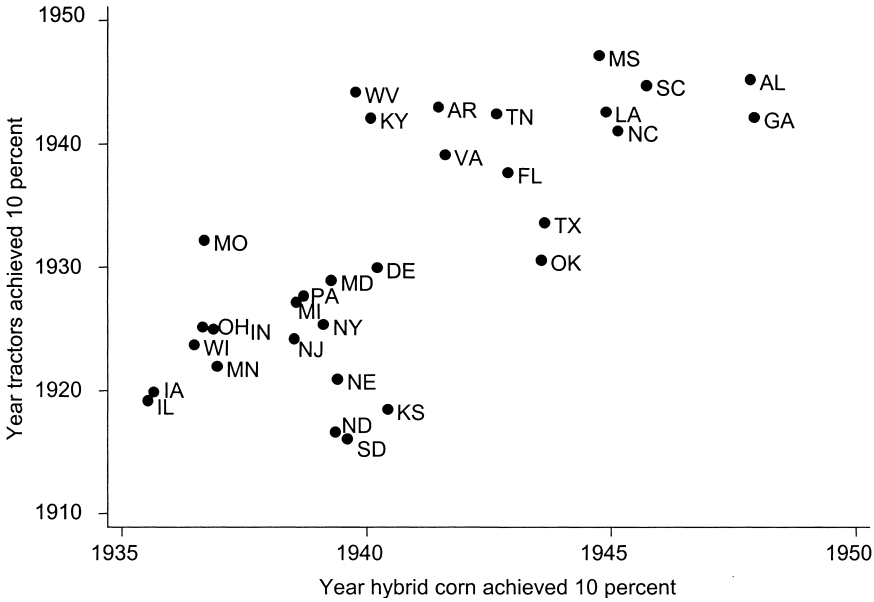

Fig. 18.1 Year hybrid corn use attained 10 percent and year tractor use attained 10 percent: By state

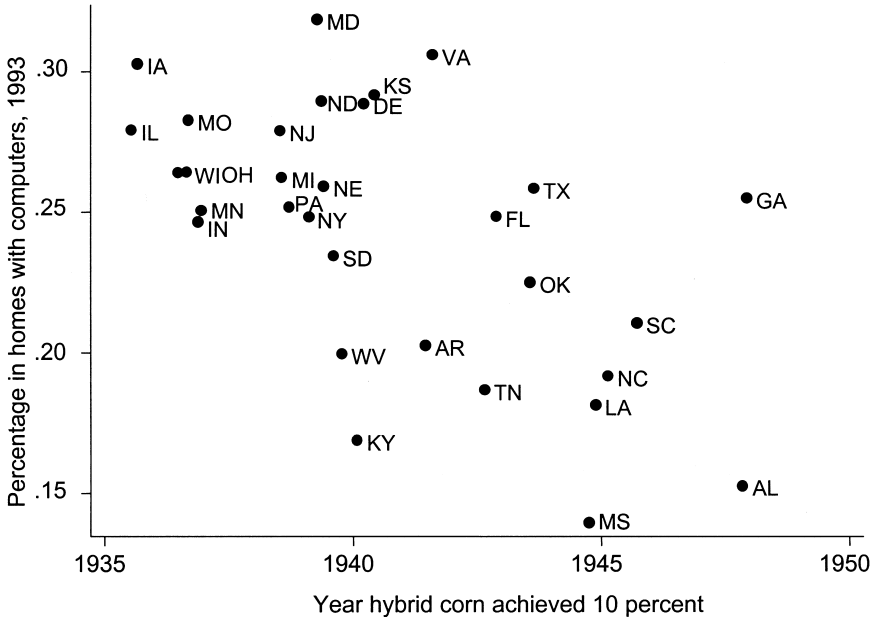

Fig. 18.2 Year hybrid corn use attained 10 percent and percent of population living in homes with personal computer in 1993: By state

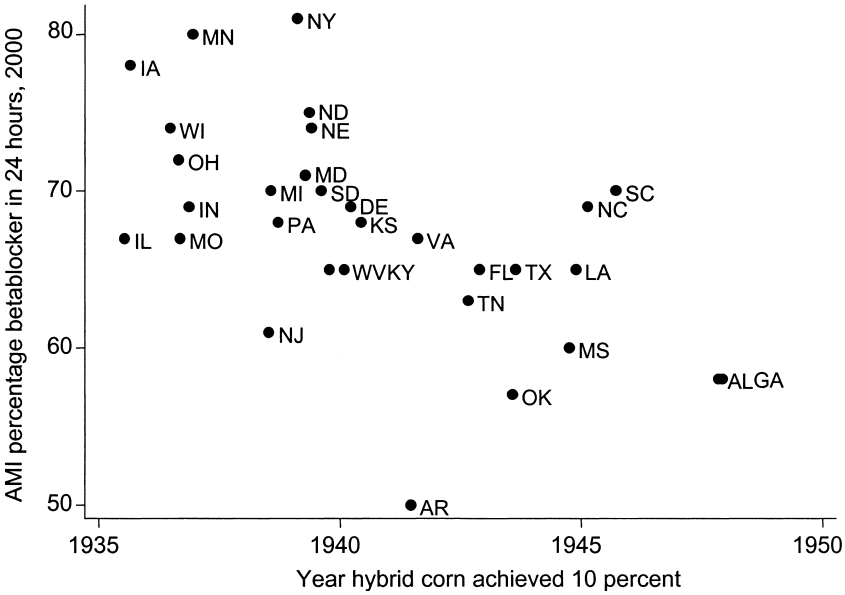

Fig. 18.3 Year hybrid corn use attained 10 percent and use of beta-blockers within twenty-four hours of AMI to 2000 to 2001: By state

Source: Skinner and Staiger (2004), using data from Griliches (1957) and Jencks, Huff, and Cuerdon (2003).

estimated in Griliches (1957). Despite more than one-half century that separates these adoption measures and the very sharp differences in the nature of the outputs (and the markets for these outputs), states that took longer to adopt hybrid corn also had much lower use of beta-blockers in 2000 to 2001 (correlation = –0.57). In other words, there appears to be some common state-level factor that lead to slow adoption of any innovation, whether in the last century or in this century.

18.5.2 Evidence on the Variation in Mortality and Cost of Care for AMI Patients

Cutler and McClellan (2001), Cutler et al. (1998) and Skinner, Staiger, and (2006) have documented recent trends in mortality and the cost of care for AMI patients. The trends between 1984 and 2000 can be roughly characterized as two distinct periods: from 1984 to 1997, there was a steady decline in one-year mortality rates following the heart attack, accompanied by a steady rise in costs. Since 1997, however, costs have continued to climb while mortality has remained unchanged or even risen slightly. In a previous paper using the same data set (Skinner, Staiger, and Fisher 2006), we have demonstrated a lack of association between the cost of care and pa-

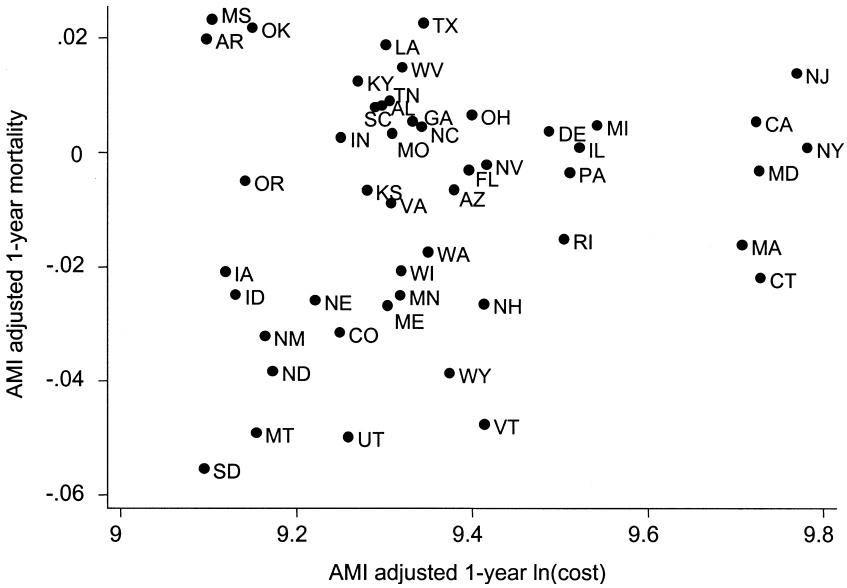

Fig. 18.4 Average risk-adjusted one-year AMI mortality and average risk-adjusted one-year AMI expenditures (1989–2000): By state

tient mortality; this is shown in figure 18.4. States such as California and New York spent 40–60 percent more per patient than states such as Indiana and Oregon, yet their patient outcomes were no better (in fact a bit worse). The time series evidence in that previous study showed a similar relationship: no association between the growth in expenditures and the decline in mortality.

This lack of an association between resources being devoted to patients and patient outcomes suggests that the variation in mortality is the result of productivity differences across regions; that is, the diffusion of new innovations in the treatment of heart attacks has been uneven, with certain states lagging behind. Figure 18.5 provides some direct evidence suggesting that the high-mortality states have lagged behind in adoption effective treatments for heart attacks. Here we plot the risk-adjusted mortality rate in each state (averaged over the entire 1989–2000 period) against the percentage of heart attack patients receiving beta-blockers within twenty-four hours of their heart attack. There is a strong negative relationship (correlation –0.58) between mortality and a state's use of beta-blockers. A simple regression of the risk-adjusted mortality rate on the use of beta-blockers suggests that a 10 percentage point increase in beta-blocker use is associated with a 1.2 percentage point decline in mortality. An effect of this magnitude is somewhat larger than what would be expected on the ba-

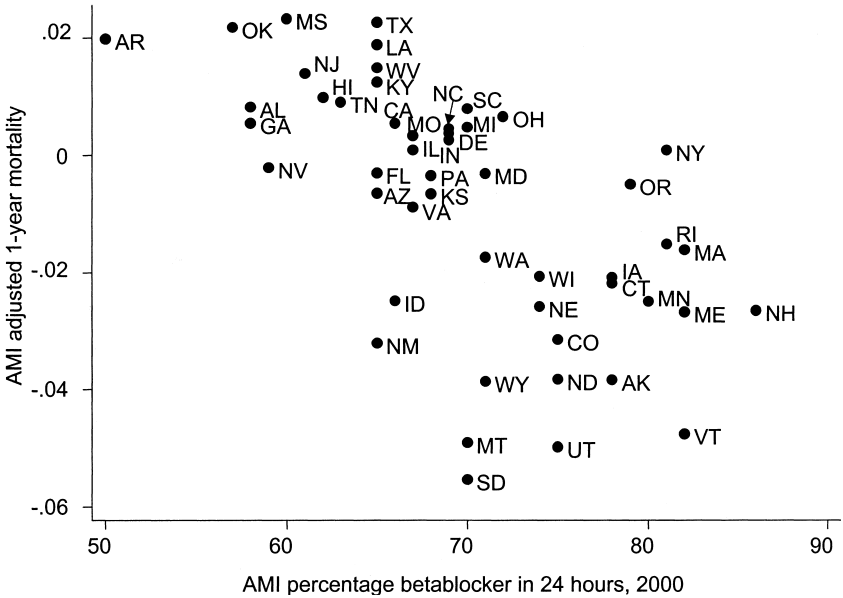

Fig. 18.5 Use of beta-blockers within twenty-four hours of AMI in 2000 to 2001 and average risk-adjusted one-year AMI mortality (1989–2000): By state

sis of clinical trials, given that not every heart attack patient is appropriate for the use of beta-blockers. There were many other innovations in the treatment of heart attacks; states more likely to use beta-blockers were also more likely to adopt other beneficial innovations in patient treatment.

18.5.3 State-Level Factors Related to Adoption of Innovations

In this section, we investigate whether any particular characteristic of a state can explain the strong correlations we observe in the adoption of innovations over time and across technologies. Estimates from the factor model are reported in table 18.2. We used the factor model to explain fourteen state-level variables: four measures of AMI mortality and cost; five other measures of whether the state had adopted various innovations; and five state characteristics that might influence the adoption of innovations. The first two columns report the loading for the first two factors—that is, the correlation between each variable and the first two latent factors. The third column reports an R^2 value, representing how much of the variation in each variable can be explained by these two factors. With the exception of changes in cost (and to a lesser extent changes in mortality), these two factors are able to explain the majority of the variation across states. We

Table 18.2 Factor model estimates

Variable	Factor loadings: Factor 1	Factor loadings: Factor 2	R^2 (1-uniqueness)
1. AMI mortality and cost			
AMI adjusted 1-year mortality	–0.82	0.20	0.71
AMI adjusted 1-year ln(cost)	0.00	0.92	0.85
Δmortality, 1989–91 to 1999–2000	–0.52	0.40	0.43
Δln(cost), 1989–91 to 1999–2000	–0.33	–0.15	0.13
2. Measures of innovation			
Percentage AMI getting beta blocker within 24hr	0.70	0.20	0.53
Jencks quality of care ranking, 2000	–0.77	0.03	0.59
Year hybrid corn achieved 10%	–0.71	–0.27	0.58
Year tractors achieved 10%	–0.92	–0.16	0.88
Percentage with computers at home, 1993	0.68	0.45	0.67
3. Factors that influence adoption			
Putnam social capital index	0.97	–0.14	0.96
ln(per capita income, 2000)	0.42	0.84	0.88
Putnam education index	0.95	0.05	0.91
High school graduation rate, 1928	0.80	–0.15	0.66
ln(population density in 2000)	–0.35	0.89	0.92

Notes: Estimates based on thirty-one states used in Griliches (1957). Factor model estimated by maximum likelihood with varimax rotation.

limited the model to two factors because the third factor added little to the explanatory power for any of the variables.[15]

These estimates imply that the variation across states in AMI mortality and cost can be adequately explained by two quite distinct factors. The first factor is strongly related to mortality, with a correlation of –0.82. This same factor was also strongly associated with all five measures of innovation: the correlation is about 0.7 with all positive indicators of adoption (rates of beta-blocker use in 2000 and computer ownership in 1993); and a correlation of between –0.7 and –0.9 with all negative indicators of adoption (quality-of-care ranking in 2000 and year achieved 10 percent in hybrid corn and tractors). Moreover, this first factor is correlated 0.97 with the Putnam social capital index, correlated 0.95 with the Putnam education index, and correlated 0.80 with the high school graduation rate from

15. With three factors included, the first factor accounted for 64 percent of the explained variance, the second factor accounted for 28 percent, and the third factor accounted for only 8 percent. The third factor primarily loaded on to the Jencks overall quality rank and beta-blocker use (but not the AMI measures), explaining a bit more of the variation (and correlation) in these two measures but adding little else to the model. Because beta-blocker use was a component of the Jencks ranking, this third factor may have captured a mechanical correlation between these two measures.

1928. Thus, the first factor suggests that high levels of social and human capital in a state are generating early adoption across a wide range of innovations.

The second factor, in contrast, is only weakly correlated with the measures of innovation. Instead, this factor is closely related to the cost of AMI care, to per capita income in 2000, and to the population density in 2000. Thus, the variation across states in the cost of care appears to be associated with very different characteristics of the state.

Overall, this factor model suggests that the differences across states in AMI mortality and in the adoption of a range of innovations can be explained by a single factor that is closely related to the human and social capital of the state that facilitates the adoption of innovations. This can be seen most clearly in the simple two-way graphs that show the association between the social capital index and the adoption of hybrid corn (figure 18.6) and the adoption of beta-blockers (figure 18.7). Similar patterns are apparent when educational attainment is substituted for social capital.

More strikingly, figure 18.8 plots Putnam's social capital index against the level of risk-adjusted AMI mortality. Again, this is not a measure of overall health in the population (as in Putnam's [2001] own analysis of social capital and mortality rates), but instead the survival rate *conditional* on an index event and controlling for a wide variety of comorbidities, and the result holds even when controlling for differences across states in income

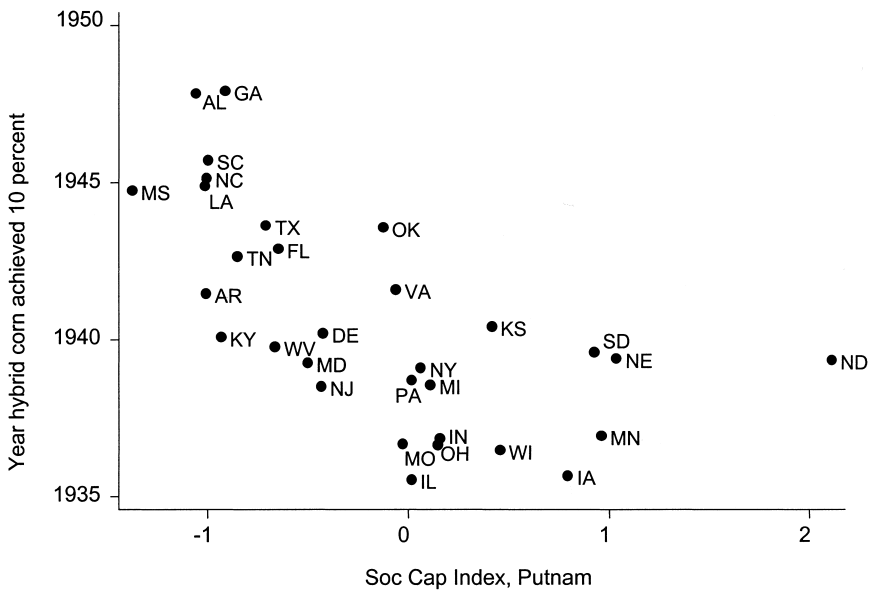

Fig. 18.6 Putnam's social capital index and year hybrid corn achieved 10 percent: By state

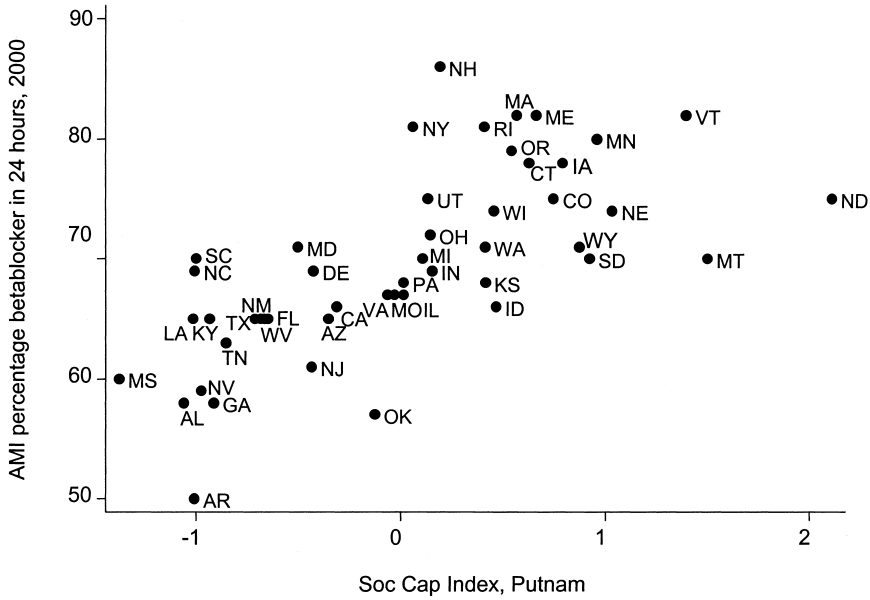

Fig. 18.7 Putnam's social capital index and use of beta-blockers within twenty-four hours of AMI in 2000 to 2001: By state

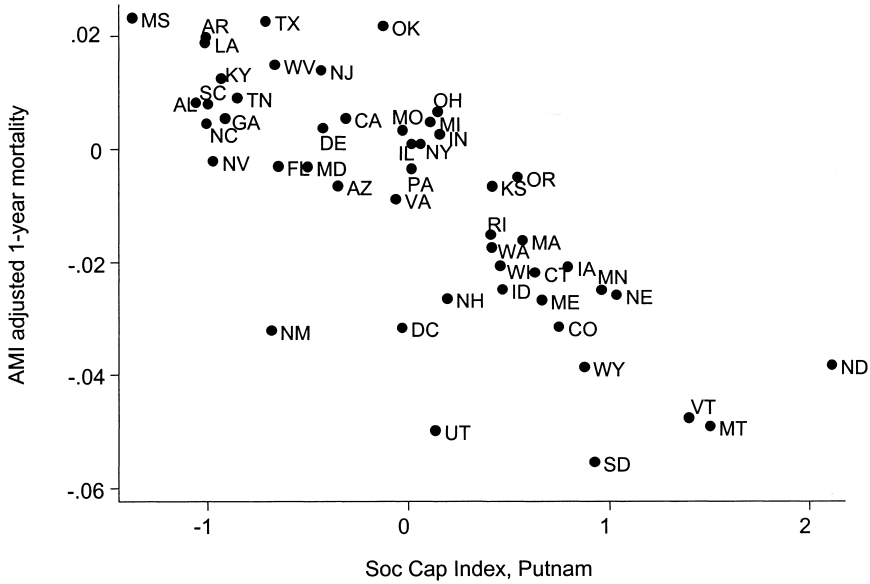

Fig. 18.8 Putnam's social capital index and average risk-adjusted one-year AMI mortality (1989–2000): By state

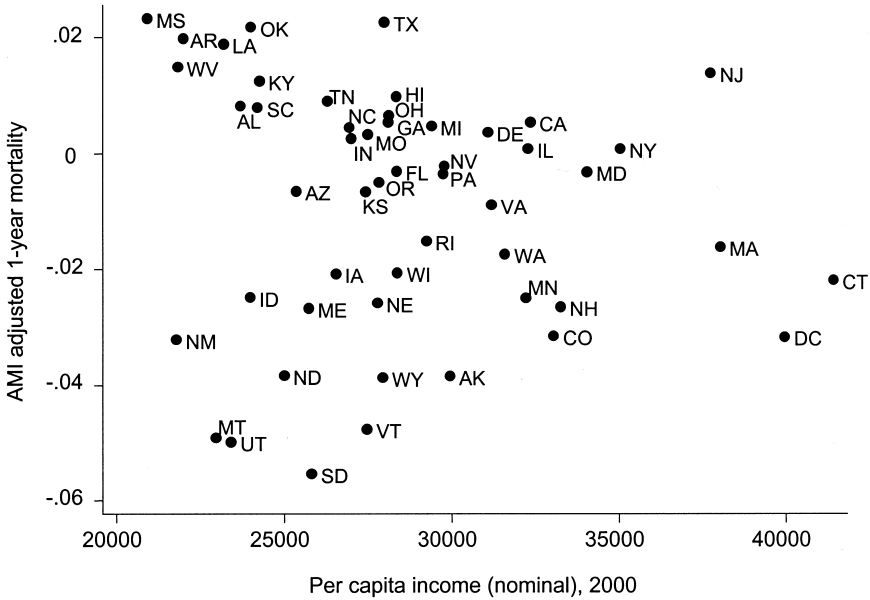

Fig. 18.9 Income per capita in 2000 and average one-year AMI mortality (1989–2000): By state

levels (e.g., table 18.2). By contrast, there is little association between the level of per capita income and mortality rates (figure 18.9). Indeed, there appears to be two groups of states, one with a positive association (on the Southwest-Northeast quadrant), from Utah to New Jersey, and the other with a negative association (on the Northwest-Southeast quadrant), from Mississippi to Connecticut.

As noted in table 18.2, there is also a strong association between overall technological improvements in AMI mortality and social capital. Figure 18.10 shows this significant negative association between the change in AMI mortality and social capital, while figure 18.11 displays the lack of association between the change in AMI mortality and the level of income in 2000. Once again, state-level income is shown to have little association with technological improvement in health care.

18.6 Conclusion

We have revisited the 1960s debate between Zvi Griliches and the sociologists by comparing the adoption of several important innovations during the twentieth century, ranging from advances at midcentury in hybrid corn and tractors to medical innovations in the treatment of heart attacks at the end of the century. We found first a very strong correlation with re-

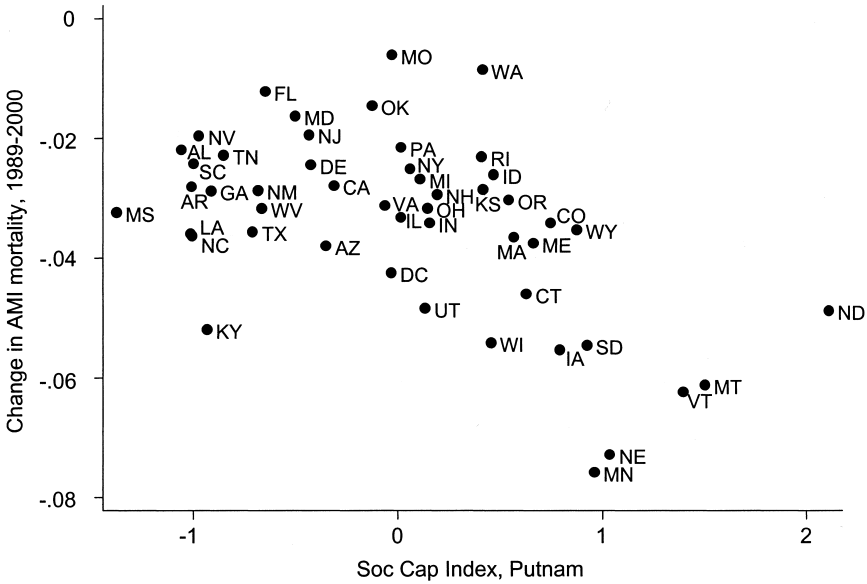

Fig. 18.10 Putnam's social capital index and decline in one-year AMI mortality (1989–2000): By state

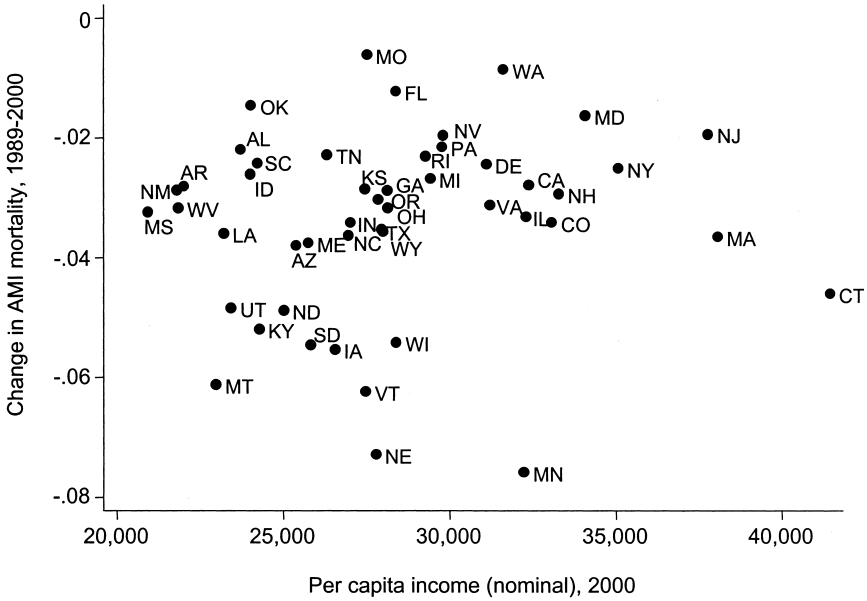

Fig. 18.11 Income per capita in 2000 and the decline in one-year AMI mortality (1989–2000): By state

gard to the adoption of new and effective technology, and this correlation held across a variety of industries and time periods. These results are suggestive of state-level factors associated with barriers to adoption. One might further expect a priori that these barriers could be related to information or network flows, given that farmers, physicians, and individual computer users conduct their business in often small and isolated groups and therefore are most vulnerable to potential information asymmetries.

Second, we found that measures of social capital or education appear to explain a large fraction of these state-level variations in the diffusion of innovation. We cannot and need not make any claims about causality. However, it is not unreasonable to conjecture that there are systematic differences across states with regard to the frequency and likelihood of informational exchanges through networks or other social activities and that these are systematically related to both average educational attainment and other measures of social capital.

Finally, we view the debate between Griliches and the sociologists as being a particularly useful guide to better understanding what causes technological diffusion. Often differences between the economic and sociological view were simply a matter of labeling and semantics; what was congruent behavior for the sociologists (i.e., that farmers who innovate in one technology are more likely to innovate in another) could potentially be relabeled Bayesian learning-by-doing by the economists, as in Griliches (1962). But there remain more fundamental disagreements uncovered in this debate. For economists, people who innovate first do so because of relative advantage, better access to credit, greater profitability, and so forth. Most economic models assume innovation doesn't occur because it is more profitable to wait, whether because of second-mover advantage, risk aversion, credit constraints, uncertainty, or other factors.

By contrast, sociologists are more interested in why innovation can be so slow even when it seems highly appropriate to do so, going so far as to label the noninnovators "laggards," a value-laden term economists typically avoid.[16] Both groups agree that economic incentives are very important in affecting the likelihood of adoption, but the disagreements arise over the behavior of people who are slow to innovate; are they slow because they lack (or have rejected) the appropriate decision tools or because they do so optimally?[17]

Despite these caveats, it is important to note the potential importance

16. Economists may be quick to label behavior "inefficient," but this is typically because of faulty incentives and not a lack of self-interest. The growing literature on behavioral economics, particularly in health care (e.g., Frank 2004), holds promise in bridging this gap between economists and sociologists.

17. In developing countries, it can sometimes be the case that native people who are "laggards" in the adoption of modern agricultural methods do so for very good reasons that may not be apparent to the western agricultural advisors (Rogers 1995).

of economic incentives to get around the problem of slow diffusion. While Coleman, Katz, and Menzel (1966) did not find a strong association between physicians having contact with drug detailers and adoption, it is still the case that the drug had largely diffused within eighteen months, a much better record than the off-patent beta-blockers. Indeed, one reexamination of the Coleman data views this relatively rapid diffusion as being the consequence of marketing efforts rather than social contagion per se (Van den Bulte and Lilien 2001). As well, the critical importance of drug detailers has been noted in the context of antiulcer drugs; Berndt et al. (1997) documented that detailers both shifted market share and expanded the overall diffusion of the drug. Economic factors such as expected profitability are clearly a necessary condition for the adoption of new technologies; the insight of the sociologists is that they are not always sufficient conditions.

References

Babcock, Jarvis M. 1962. Adoption of hybrid corn: A comment. *Rural Sociology* 27:332–38.

Barr, Abigail. 2000. Social capital and technical information flows in the Ghanaian manufacturing sector. *Oxford Economic Papers* 52:539–59.

Berndt, Ernst R. 2001. The U.S. pharmaceutical industry: Why major growth in times of cost containment? *Health Affairs* 20 (March/April): 100–114.

Berndt, Ernst R., Linda Bui, David Reiley, and Glen Urban. 1997. The roles of marketing, product quality and price competition in the growth and composition of the U.S. anti-ulcer drug industry. In *The economics of new goods,* ed. Timothy Bresnahan and Robert Gordon, 277–322. Chicago: University of Chicago Press.

Berndt, Ernst R., Robert S. Pindyck, and Pierre Azoulay. 2003. Network effects and diffusion in pharmaceutical markets: Antiulcer drugs. *Journal of Industrial Economics* 51 (June): 243–70.

Berwick, Donald M. 2003. Disseminating innovations in health care. *Journal of the American Medical Association* 289 (April 16): 1969–75.

Braatz, Jay, and Robert Putnam. 1996. Families, communities, and education in America: Exploring the evidence. Harvard University, Working Paper.

Brandner, Lowell, and Murray A. Straus. 1959. Congruence versus profitability in the diffusion of hybrid sorghum. *Rural Sociology* 24:381–83.

Calvó-Armengol, Antoni, and Mathew O. Jackson. 2004. The effects of social networks on employment and inequality. *American Economic Review* 94 (June): 426–54.

Caselli, Francesco, and Wilbur John Coleman II. 2006. The world technology frontier. *American Economic Review* 96 (3): 499–522.

Coleman, James S., Elihu Katz, and Herbert Menzel. 1966. *Medical innovation: A diffusion study.* New York: Bobbs-Merrill.

Comin, Diego, and Bart Hobijn. 2004. Cross-country technology adoption: Making the theories face the facts. *Journal of Monetary Economics* 51:39–83.

Conley, Timothy G., and Christopher R. Udry. 2004. Learning about a new technology: Pineapple in Ghana. Yale University. Mimeograph.
Cutler, David M. 2004. *Your money or your life: Strong medicine for America's health care system.* New York: Oxford University Press.
Cutler, David M., and Mark McClellan. 2001. Is technological change in medicine worth it? *Health Affairs* 20 (5): 11–29.
Dixon, Robert. 1980. Hybrid corn revisited. *Econometrica* 48 (November): 1451–61.
Durlauf, Steven N., and Marcel Fafchamps. 2004. Social capital. NBER Working Paper no. 10485. Cambridge, MA: National Bureau of Economic Research, May.
Foster, Andrew D., and Mark R. Rosenzweig. 1995. Learning by doing and learning from others: Human capital and technical change in agriculture. *Journal of Political Economy* 103 (December): 1176–1209.
Fournier, Gary M., Kislaya Prasad, and Mary A. Burke. 2002. Physician social networks and treatment variations in coronary inpatient care. Florida State University. Mimeograph.
Frank,, Richard G. 2004. Behavioral economics and health economics. NBER Working Paper no. 10881. Cambridge, MA: National Bureau of Economic Research, November.
Goldin, Claudia. 1994. Appendix to: "How America graduated from high school, 1910 to 1960." Construction of state-level secondary school data. NBER Working Paper no. H057. Cambridge, MA: National Bureau of Economic Research, June.
Goldin, Claudia, and Lawrence F. Katz. 1998. Human capital and social capital: The rise of secondary schooling in America, 1910 to 1940. NBER Working Paper no. 6439.
Gottlieb, Stephen S., Robert J. McCarter, and Robert A. Vogel. Effect of beta-blockade on mortality among high-risk and low-risk patients after myocardial infarction. *New England Journal of Medicine* 339 (August 20): 489–97.
Griliches, Zvi. 1957. Hybrid corn: An exploration in the economics of technological change. *Econometrica* 25 (October): 501–22.
———. 1960. Congruence versus profitability: A false dichotomy. *Rural Sociology* 25:354–56.
———. 1962. Profitability versus interaction: Another false dichotomy. *Rural Sociology* 27:325–30.
Guiso, Luigi, Paola Sapienza, and Luigi Zingales. 2004. The role of social capital in financial development. *American Economic Review* 94 (June): 526–56.
Hall, Bronwyn. 2004. Innovation and diffusion. In *The Oxford Handbook of Innovation,* ed. Jan Fagerberg, David C. Mowery, and Richard R. Nelson, 459–85. New York: Oxford University Press.
Harmon, Harry H. 1967. *Modern factor analysis.* 2nd ed. Chicago: University of Chicago Press.
Havens, A. Eugene, and Everett Rogers. 1961. Adoption of hybrid corn: Profitability and the interaction effect. *Rural Sociology* 26:409–14.
Helliwell, John. 1996. Economic growth and social capital in Asia. In *The Asia Pacific region in the global economy: A Canadian perspective,* ed. Richard G. Harris, 21–42. Calgary, Canada: University of Calgary Press.
Howell, Joel D. 1995. Technology in the hospital: Transforming patient care in the early twentieth century. Baltimore: Johns Hopkins University Press.
Jencks, Stephen F., Edwin D. Huff, and Timothy Cuerdon. 2003. Change in the

quality of care delivered to Medicare beneficiaries, 1998–99 to 2000–2001. *Journal of the American Medical Association* 289 (January 15): 305–12.

Jovanovic, Boyan, and Yaw Nyarko. 1995. A Bayesian learning model fitted to a variety of empirical learning curves. *Brookings Papers on Economic Activity, Macroeconomics:* 247–99.

———. 1996. Learning by doing and the choice of technology. *Econometrica* 64 (November): 1299–1310.

Klenow, Peter J., and Andres Rodriguez-Clare. 1997. Economic growth: A review essay. *Journal of Monetary Economics* 40 (3): 597–617.

Luft, Harold S. 2003. Variations in patterns of care and outcomes after acute myocardial infarction for Medicare beneficiaries in fee-for-service and HMO settings. *Health Services Research* 38 (August): 1065–79.

Olmstead, Alan L., and Paul W. Rhode. 2000. The diffusion of the tractor in American agriculture: 1910–60. NBER Working Paper no. 7947. Cambridge, MA: National Bureau of Economic Research, October.

Parente, Stephen L., and Edward C. Prescott. 1994. Barriers to technology adoption and development. *Journal of Political Economy* 102 (April): 298–321.

Phelps, Charles E. 2000. Information diffusion and best practice adoption. In *Handbook of health economics.* Vol. 1A, ed. A. J. Culyer and J. P. Newhouse, 223–64. New York: Elsevier Science.

Putnam, Robert D. 2001. *Bowling alone.* New York: Simon and Schuster.

Rogers, Everett M. 1995. *Diffusion of innovations.* 4th ed. New York: Free Press.

Rogers, Everett M., and A. Eugene Havens. 1962. Rejoinder to Griliches' "Another false dichotomy." *Rural Sociology* 27:330–32.

Salim, Richard Peto, Jacqueline Lewis, Rory Collins, and Peter Sleight. 1985. Beta blockage during and after myocardial infarction: An overview of the randomized trials. *Progress in Cardiovascular Disease* 27 (March/April): 335–71.

Schultz, Theodore W. 1964. *Transforming traditional agriculture.* New Haven, CT: Yale University Press.

Skinner, Jonathan. 2003. Geography and the use of effective care in the United States. Dartmouth College. Mimeograph. http://www.dartmouth.edu/~jskinner.

Skinner, Jonathan, and Douglas Staiger. 2006. The diffusion of health care technology. Dartmouth College. Mimeograph.

Skinner, Jonathan, Douglas Staiger, and Elliott Fisher. 2006. Is medical technology always worth it? The case of acute myocardial infarction. *Health Affairs* 25 (2): w34–w47.

Strang, David, and Sarah A. Soule. 1998. Diffusion in organizations and social movements: From hybrid corn to poison pills. *Annual Review of Sociology* 24: 265–90.

Strang, David, and Nancy Brandon Tuma. 1993. Spatial and temporal heterogeneity in diffusion. *American Journal of Sociology* 99 (November): 614–39.

U.S. Bureau of the Census. 1962. *Census of agriculture 1959.* Vol. 2. Washington, DC: Government Printing Office.

Van den Bulte, Christophe, and Gary Lilien. 2001. Medical innovations revisited: Social contagion versus marketing effort. *American Journal of Sociology* 106 (5): 1409–35.

Wilkening, Eugene A. 1953. Acceptance of improved farm practices in three coastal plain counties. NCAES Technical Bulletin no. 98. Raleigh, NC: North Carolina Agricultural Experiment Station.

Yusuf, Salim, Janet Wittes, and Lee Friedman. 1998. Overview of results of randomized clinical trials in heart disease I. Treatments following myocardial infarction. *Journal of the American Medical Association* 260:2088–93.