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GRADUAL INCORPORATION OF INFORMATION: PHARMACEUTICAL STOCKS AND THE EVOLUTION OF PRESIDENT CLINTON'S HEALTH CARE REFORM*

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ABSTRACT

We examine the effect of the evolution of President Clinton's health care reform proposal over January 1992–October 1993 on pharmaceutical stock prices. We identify a 52.3 percent decline in market-adjusted prices, which we then associate with health care reform. Applying a new technique, isotonic regression, we find most of the decline occurred gradually. Much of the decline occurred as the Clinton plan adopted strategies to contain health care costs, including "managed competition" and implicit regulation. Indirect evidence suggests that the wealth lost by pharmaceutical companies may have been largely an anticipated transfer. Our results are relevant to understanding the likely effects of the Clinton plan and more recent proposals. Many other policy changes are marked by gradual public revelation of information, which may not be completely observable by a researcher. Our approach may uncover information about the anticipated effects of policies unavailable from a traditional event study.

I.   INTRODUCTION

> The provision of healthcare to U.S. citizens at an appropriate cost remains "the problem that won't go away." [Henry J. Aaron, The Problem That Won't Go Away, in The Problem That Won't Go Away: Reforming U.S. Health Care Financing 1 (Henry J. Aaron ed. 1996)]

$\mathbf{V}$ICTOR FUCHS predicted that "given the trends in medical technology and demography, the problem of financing health care for the elderly will soon equal

and then surpass the problem of financing retirement."[1] Provision of pharmaceuticals in particular has been a major focus of policy initiatives, both because they are often paid for out of pocket and also because expenditures on them have been a growing part of a health care consumer's budget.[2]

The most ambitious and significant health care reform initiative in decades was the Clinton proposal of 1992–94, the focus of this study of the pharmaceutical industry. Although it did not achieve legislative success, indeed perhaps because it failed, several of its important elements have been reborn in recent policy proposals: expanding Medicare to include prescription drug coverage was a prominent element of the earlier health care reform package. In June 1999, President Clinton called for Medicare to include prescription drug coverage. "Health insurance purchasing cooperatives" were proposed in 1992 to give consumers more "buying clout," as were some forms of indirect regulation of drug prices. These themes are resurfacing in a series of proposals being considered by state legislatures.[3] In May 2000, Maine became the first state to adopt such a proposal, providing for "buying pools" and a "fair pricing commission."[4] "Health-care reform is back from the dead, and drug pricing is center stage again" in Washington.[5]

Among the more vocal opponents of the "Clinton Plan" as it jelled in the summer and fall of 1993 was the pharmaceutical industry. They were, after all, one of the sectors most likely to have been affected, directly or indirectly, by the Clinton plan. In particular, price controls and other forms of cost containment on pharmaceuticals were mentioned as possible policies during this period. In any case, any Clinton plan would have sought to change dramatically the way pharmaceuticals were purchased and paid for.

It is not clear a priori that increased government intervention in the form of health care reform should necessarily have negative consequences for the pharmaceutical industry. For instance, achieving the goal of universal coverage could lead to higher consumption of all health products and services, including pharmaceuticals. Alternatively, an emphasis on overall cost-effectiveness could result in a shift away from more costly surgical procedures toward cheaper drug therapies.[6]

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of this paper was circulated as "Gradual Incorporation of Information into Stock Prices: Empirical Strategies."

[1] Victor R. Fuchs, The Future of Health Economics, 19 J. Health Econ. 141, 152 (2000).

[2] In 1998, the percentage was 7.9 percent, up from a fairly constant 5 percent during the 1980s. See the Health Care Financing Administration Web site, http://www.hcfa.gov.

[3] New England Law Makers Consider Drug Strategies, N.Y. Times, December 17, 1999, at A20.

[4] Maine Gets Law Designed to Reduce Cost of Drugs, New York Times, May 12, 2000, at A18.

[5] Steven Gerber, pharmaceutical industry analyst of CIBC Oppenheimer, quoted by Robert Langreth & Robert McGough, Drug Makers' Juggernaut Could Weaken, Wall St. J., December 15, 1998.

[6] As Burton A. Weisbrod points out in his discussion of the effects of diagnosis-related payment on pharmaceutical firms, not all pharmaceutical products would be equally affected. Many products, such as cholesterol-lowering drugs, can further overall cost-effectiveness goals, as they can substitute for higher cost procedures. Some may not, such as Prozac and Viagra, because they create treatment

Therefore, it is perhaps not surprising that the pharmaceutical industry was not united in opposition to health care reform from the beginning. Roy Vagelos, the CEO of Merck and a visible if unofficial spokesman for the industry, supported Bill Clinton for president and publicly agreed with campaign statements he made about the need for reform. By February of 1993, however, he publicly expressed "disappointment" with President Clinton and called statements he had made about the pharmaceutical industry "a tremendous slam."[7] Roy Vagelos's shifting perceptions are in some ways emblematic of the shifting fortunes of the pharmaceutical industry over this period as the Clinton plan took shape.

The purpose of this article is threefold. First, we want to quantify the effect that health care reform discussions had on pharmaceutical firms as measured by the value of a portfolio of pharmaceutical stocks. Second, we wish to trace out the effects that can be linked specifically to a gradual shift in Clinton's focus away from simply guaranteeing universal coverage toward containment of health care costs, including pharmaceuticals. And finally we want to explore indirect evidence on whether this stockholder wealth loss was a transfer to other parties or a welfare loss.

Of course, as scholars such as Lacy Glenn Thomas[8] and Burton A. Weisbrod[9] have emphasized, the health care regulatory and payment regimes can have interesting and subtle feedback effects on the investment incentives of pharmaceutical firms. Since the Clinton plan was not adopted, we cannot perform a detailed before-and-after test that would tease out all of these subtle effects. Our empirical approach, based on using the information in forward-looking stock prices, will reveal the net effect of the Clinton plan, but not the expected incidence of each of its elements. Nonetheless, our empirical approach will exploit the information contained in the evolution of the Clinton plan. This will shed light on the major tension within health care reform and later proposals, the conflict between ensuring wider health care coverage and containing health care costs.

Our results tell us three things. First, investors thought health care reform was bad news for the pharmaceutical industry. The loss in the market-adjusted value of our pharmaceutical portfolio was sizeable. Consider an investment in a portfolio of brandname pharmaceutical company stocks on January 19, 1992, just before candidate Clinton issued a vague "five-point plan" during the New Hampshire presidential primary campaign. By October 4, 1993, when President Clinton

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options where none existed before. Furthermore, some drugs, such as certain antibiotics, complement expensive surgical procedures. In addition, cost containment can be implemented not by capping overall expenditures but rather by separately capping individual categories of expenditures, thus not resulting in a substitution into pharmaceuticals. Burton A. Weisbrod, The Health Care Quadrilemma: An Essay on Technological Change, Insurance, Quality of Care, and Cost Containment, 29 J. Econ. Literature 523 (1991).

[7] Michael Waldholz, Clinton Attack "Disappoints" Merck's Chief, Wall St. J., February 19, 1993, at B2.

[8] Lacy Glenn Thomas, Industrial Policy and International Competitiveness in the Pharmaceutical Industry, in Competitive Strategies in the Pharmaceutical Industry 107 (Robert B. Helms ed. 1996).

[9] Weisbrod, *supra* note 6.

had unveiled a more specific, and different, proposal before Congress, and Hillary Rodham Clinton had advocated it impressively at congressional hearings, that investment would have lost 38 percent compared to buying and holding the value-weighted market portfolio. Alternatively, cumulating a series of abnormal returns of the pharmaceutical stocks with compounding over this period would produce a 52.3 percent decline in value.

Second, the decline in pharmaceutical values closely coincided with the Clinton plan's growing emphasis on containing costs rather than merely securing universal coverage. We find that the pharmaceutical loss was not associated with a number of identifiable developments in the evolution and political prospects of the Clinton plan, and not concentrated near the official unveiling of the plan. The sum of the information contained in the Clinton plan was revealed to the market gradually. But a considerable portion of the gradual information incorporation was clustered in periods in which the Clinton plan adopted containment of health care costs as a major goal. Thus we are able to associate declines in pharmaceutical stocks with efforts to control health care costs, whether those efforts were to be effected through "managed competition" or more direct government regulation. This confirms Thomas's[10] judgment that although a health care reform quite different than that proposed might have benefited U.S. pharmaceutical firms, the "details and general philosophy" of the Clinton plan "represent a confusion of 'cost suppression' with 'cost effectiveness'" and so would likely harm the U.S. industry.[11] This has current relevance since particular elements of the Clinton plan have resurfaced in recent proposals.

Finally, we offer some tentative evidence on the extent of wealth transfer from the pharmaceutical companies as opposed to welfare loss. A major concern was that health care reform, by directly and indirectly limiting payments that pharmaceutical companies would receive for new drug innovations, would reduce the incentive to engage in research and development (R&D) and thereby reduce innovation. We use a portfolio of generic drug manufacturers, who do not conduct research to discover new drugs and therefore have small R&D expenditures, as a comparison group for the more research-intensive branded pharmaceutical companies. We find a time-series pattern of market value losses by generic drug firms similar to that of their branded counterparts. Thus health care reform was perceived by market participants to have had adverse consequences for pharmaceutical companies, but the extent of this wealth loss was not sensitive to our measure of research intensity.

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[10] Thomas, *supra* note 7.

[11] *Id.* at 126. Thomas's critique of the Clinton plan is telling, since he has argued that prior regulatory interventions have been helpful to the U.S. pharmaceutical industry. In particular, he argues that stringent safety and efficacy regulations in conjunction with the absence of controlled prices result in R&D effort being concentrated in areas of large potential therapeutic benefit instead of the development of "me-too" drugs, providing only incremental benefits. He argues further that U.S. firms have benefited enormously from this regulatory regime and its implicit incentives for R&D departments.

We join a large literature in exploiting stock market reactions to evaluate the impact of (proposed) public policy changes.[12] Recent studies have involved policy questions as diverse as tax reform[13] and deregulation of interstate trucking.[14] Other positive issues have been explored in industrial organization[15] and international economics.[16]

But our setting poses a major methodological hurdle, the gradual incorporation of information into stock prices. The most common methodology for investigating stock market reactions is the event study. In event studies, the impact of some firm decision or public policy change is evaluated by examining the immediate stock market reaction to an ex ante identifiable set of news events. A. Craig MacKinlay[17] surveys the event study literature and discusses the successful application of event studies to corporate finance. He then notes the following: "An important characteristic of a successful event study is the ability to identify precisely the date of the event. For example, the wealth effects of regulatory changes for affected entities can be difficult to detect using event study methodology. The problem is that regulatory changes are often debated in the political arena over time and any accompanying wealth effects generally will be gradually incorporated into the value of the corporation as the probability of the change being adopted increases."[18]

The Clinton health care reform initiative began with stump speeches during the 1992 presidential primaries, while concrete legislative proposals did not emerge until 1993, and so gradual incorporation of information is likely to be a significant problem. We introduce a new technique, isotonic regression, to address this problem. Because of its potential for future application, we devote a considerable portion of this article to explaining our methodology. Our main use of isotonic regression, to paraphrase a famous political query, is to find out "what did the market know, and when did it know it?" Equivalently, given the substantial 52.3 percent decline in pharmaceuticals, what fraction of this information was incorporated into stock prices at various points in time? What periods experienced the most dramatic incorporation of information? Although we do not know the precise date on which changes to the Clinton plan were conveyed to the market, we do know the weeks or months in which some changes to the

[12] G. William Schwert, Using Financial Data to Measure Effects of Regulation, 24 J. Law & Econ. 121 (1981).

[13] David M. Cutler, Tax Reform and the Stock Market: An Asset Price Approach, 78 Am. Econ. Rev. 1107 (1988).

[14] Nancy L. Rose, The Incidence of Regulatory Rents in the Motor Carrier Industry, 16 RAND J. Econ. 299 (1985).

[15] John M. Bizjak & Jeffrey L. Coles, The Effect of Private Antitrust Litigation on the Stock-Market Valuation of the Firm, 85 Am. Econ. Rev. 436 (1995).

[16] Gene M. Grossman & James A. Levinsohn, Import Competition and the Stock Market Return to Capital, 79 Am Econ. Rev. 1065 (1989).

[17] A. Craig MacKinlay, Event Studies in Economics and Finance, 35 J. Econ. Literature 13 (1997).

[18] Id. at 37.

Clinton plan were considered. The isotonic regression reveals the market's re-action to those changes and so their expected impact on the pharmaceutical industry. Further questions are answered. Was the incorporation of information clustered around identifiable smaller events? Was most of the incorporation achieved well before the official unveiling of the Clinton plan? In other words, we are interested in tracing the effect of health care reform on pharmaceutical stock prices, not just in total but also its pattern over time.

Consider the price of an asset, such as a pharmaceutical portfolio, in which the fluctuations in its value associated with general stock market movements have been taken out, as we will make formal later. Call this the market-adjusted price. Our primary focus in using isotonic regression is to extract a particular type of information from the fluctuations in this market-adjusted price to estimate an expected price path conditional on the total effect of the "larger event." We interpret this expected price path as the pattern with which information about the larger event is incorporated into the stock price. We make two important assumptions.

First, as in event studies, we will maintain the semistrong form of the "efficient market hypothesis"; stock prices fully reflect all publicly available information. So although the legislative process creates a gradual flow of information, we assume that this information, once revealed, is immediately incorporated into the market-adjusted price. As a result, the expected price path will take a step form. Beyond that, we want to impose the weakest restrictions necessary on the expected price path, since it will be the direct result of the rate at which information is publicly revealed, which is indeterminable a priori.

Nevertheless, we want to impose as a second restriction that the expected price path be monotonic. Note that by doing so, we effectively define what we mean by information. In other words, we want to extract the information that is revealed at the final date, the presentation of the Clinton plan, to have been true, as opposed to "information" that is revealed ex post to have been misinformation. We are therefore interested in what we call "persistent information," in contrast to the latter, transitory information. Since our large event is the presentation of the health care reform proposal that had an adverse effect on pharmaceutical stocks, all persistent information, in our definition, will also have an adverse effect. In other words, conditional on the larger event, any "information" that moves stock price up during our event period, anything ex post false, will be treated as misinformation.

Given those two assumptions, the appropriate estimation technique is isotonic regression on market-adjusted prices. Isotonic regression is a nonparametric estimation method that does not impose functional form restrictions on the regression function but does impose more general shape restrictions: that the function be nonincreasing or nondecreasing and that the function take a step form. The isotonic regression is the function that minimizes the sum of squared deviations of the observations from the estimated regression function among the class of functions that satisfy the shape restrictions.

Using isotonic regression techniques, we estimate the expected market-adjusted price path of a pharmaceutical portfolio over January 19, 1992–October 4, 1993, a period that constitutes the revelation of the Clinton plan. The result is a step function, free of functional form restrictions, that can be easily graphed over the same time period, and the "steps" have a straightforward and intuitive interpretation. The location of the steps indicates when persistent information was incorporated into prices; the height of individual steps indicates the portion of the total effect incorporated into prices at that time.

The remainder of this article is organized as follows. Section II presents our model of the gradual incorporation of information into stock prices. We also discuss other techniques that researchers have used to confront this gradual incorporation and why isotonic regression is an appropriate technique in our setting. Section III describes the Clinton plan and evaluates its likely effect on the pharmaceutical industry. We also report a chronology of the plan's evolution, which gradually placed greater emphasis on controlling health care costs. Section IV offers results. Our primary result is our graph of the expected price path over the event period produced by isotonic regression. We find that the major portion of the decline in stock prices occurred gradually. Moreover, a substantial portion of the decline occurred as the Clinton plan adopted and revised strategies to contain health care costs, including both "managed competition" and direct government regulation. Section IV also presents the results of a traditional event study, a "reverse" event study, and a plot of cumulative abnormal returns. These other results serve the substantive purpose of enriching our picture of the effect of health care reform on pharmaceutical stock prices. Methodologically, they allow us to contrast the information we gain from those methods with that gained from the expected price path to clarify differences. The traditional event study misses much of the wealth effects that the isotonic regression detects, while the "reverse" event study helps establish that the stock price movements we detect are due to health care reform rather than other systematic factors affecting pharmaceutical companies. Section V concludes.

II. Model and Technique

Before we discuss gradual incorporation of information and the technique we will use to address it, it will be convenient to discuss briefly our treatment of the data. In particular, we discuss how we take market movements into account in our analysis of pharmaceutical stocks.

A. Market Model

Although much of the literature in financial economics concerns equity returns, in our environment it is clearer if we speak in terms of prices. Since we nevertheless wish to control for movements in a security's price that are generated by its comovements with the overall stock market, we compute market-adjusted prices in the following way.

TABLE 1

FIRMS IN PHARMACEUTICAL PORTFOLIOS

Company	Ticker Symbol
Branded portfolio:	
Abbott Laboratories	ABT
American Home Products	AHP
Bristol-Myers Squibb	BMY
Glaxo	GLX
ICN Pharmaceuticals	ICN
Eli Lilly & Co.	LLY
Merck, Sharpe, & Dohme	MRK
Pfizer	PFE
Rhone Poulenc Rorer	RPR
Schering-Plough	SGP
Smithkline Beecham	SBH
Warner Lambert (Parke Davis)	WLA
Generic portfolio:	
Alpharma	ALO
Barr Laboratories	BRL
Baxter Labs	BAX
Faulding	FAUL
Forest Labs	FRX
Gensia	GNSA

Our main set of firms consists of 12 publicly traded branded[19] pharmaceutical companies, listed in the top of Table 1. We first form an equally weighted portfolio of these pharmaceutical stocks in order to average out the noise from firm-specific shocks. We assume that expected or normal returns are given by the market model below.

Using the realized returns on the pharmaceutical portfolio, we first estimate an ordinary least squares (OLS) market model over the 250 trading days ending October 30, 1991, and the 250 trading days beginning November 14, 1994.[20] The 768 trading days we omit from October 31, 1991, to November 11, 1994, constitute the potential reform period and span the broadest possible definition of the Clinton health care reform period, from just before Harris Wofford won a U.S. Senate seat in Pennsylvania on a health care reform platform to just after the Republicans won the 1994 midterm congressional elections. Our choice of sample period therefore allows us to estimate market model parameters free from information leakage about health care reform.

We estimate the equation

[19] In constructing this portfolio, we used firms whose main line of business was manufacturing pharmaceuticals and who conducted research to discover novel, patentable pharmaceutical products. Our portfolio is by no means an exhaustive list of such firms; in particular, firms that are not publicly traded in the United States were not included.

[20] In calendar time, this period runs from November 5, 1990, to October 30, 1991, and then from November 14, 1994, to November 8, 1995.

$$R_{it} = \alpha_i + \beta_i R_{mt} + \nu_{it}, \qquad\qquad (1)$$

where R_{it} is the return on portfolio i and R_{mt} is the return on the Center for Research in Security Prices (CRSP) value-weighted index for day t.[21]

We form prediction errors over the potential reform period,

$$A_{it} \equiv R_{it} - \hat{\alpha}_i - \hat{\beta}_i R_{mt}, \qquad\qquad (2)$$

where $\hat{\alpha}_i$ and $\hat{\beta}_i$ are OLS estimates from the market model estimation period; A_{it} is an indicator of abnormal performance on day t, a standard measure used in many stock market studies.

Drawing upon the results in Ariel Pakes[22] and Gene Grossman and James Levinsohn,[23] under certain assumptions we can interpret these abnormal equity returns as reflecting "the percentage change in the expected discounted value of future net cash flow caused by information accumulated during the period over which the return is calculated."[24] The theory is fully developed for the case of risk-neutral agents. There are two core assumptions. First, firm managers choose their investment levels (such as pharmaceutical R&D) to maximize the expected present discounted value of net cash flows. Second, the stock market is forward looking and so assesses the value of the firm at time t as the (optimal) value of net cash flows conditional on the information available at time t. So changes in the stock market valuation of the firm fully reflect how the firm's managers will react optimally to the new information. If market participants are risk averse, similar, albeit more ad hoc, assumptions are required. In particular, we assume that expected returns are given by the market model.[25]

A related interpretation will carry over as we translate A_{it} into a market-adjusted price $p_{i,t}$ by the formula

$$p_{i,t} = (1 + A_{it})p_{i,t-1} \qquad\qquad (3)$$

after having normalized $p_{i,1} = 1$. So the percentage change in the market-adjusted price on any single day is equal to the change in the expected discounted value of cash flow from that day's information, both persistent and transitory.

Intuitively, if all fluctuations in a stock's price during the potential reform period could be accounted for by market movements, there would be no abnor-

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[21] Employing the CRSP equally weighted index as the market measure had negligible effects on the estimated market model parameters.

[22] Ariel Pakes, On Patents, R&D, and the Stock Market Rate of Return, 93 J. Pol. Econ. 390 (1985).

[23] Grossman & Levinsohn, *supra* note 16.

[24] *Id.* at 1066.

[25] *Id.* at 1071.

mal performance and no information. Therefore A_{it} would equal zero each day, and the market-adjusted price $p_{i,t}$ would be flat, equal to one each day.[26]

Although our initial task is to identify gross wealth effects of health care reform, we are also interested in the ways in which health care reform may have altered firm R&D behavior and so have generated welfare losses. Pakes[27] offered a theoretical framework and empirical results that demonstrated a linkage between shocks to the value of a firm's R&D program, its R&D expenditures, and the stock market value of the firm. We conduct a different exercise. Given the effects on the stock market value of the firm, can we disentangle whether those effects are due to changes in the value of the firm's R&D program or whether they are due to changes in firm value not related to the firm's R&D program? In the latter case, we should not expect R&D expenditures to be affected. As an indirect attempt to disentangle these factors, we use the stock market reaction of a portfolio of generic[28] drug firms as a comparison group. The six publicly traded generic pharmaceutical companies are listed in the bottom of Table 1, and we compute market-adjusted prices for this portfolio according to the procedures outlined in this section.

B. *Information and Monotonicity*

For concreteness, let I be the total effect on stock prices of the larger event of interest; $I = \sum_t I_t$, so I_t is the portion of the total effect revealed and incorporated at time t. For the larger "bad news" event considered here, I_t takes only nonpositive values by construction. (If the larger event was "good news," I_t would take only nonnegative values.) In other words, by definition, I_t is the new information about the larger event added at time t that is revealed to be true ex post. If the larger event is bad news, conditional on that total negative effect, any persistent information (as we define it) must also be bad news and can only move stock prices down. This construction is the crux of our monotonicity assumption.

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[26] This market-adjusted price avoids some measurement problems raised in the literature. The standard measure of long-run abnormal performance is the buy-and-hold abnormal return (BHAR), which is the difference between a firm's multiperiod compounded gross return and the multiperiod compounded gross return on a benchmark portfolio, such as the market. Mark L. Mitchell & Erik Stafford, Managerial Decisions and Long-Term Stock Price Performance (unpublished manuscript, Univ. Chicago 1997), points out that the compounding in the BHAR formula means that the BHAR is increasing in the holding period, the number of days of compounding, even if true abnormal performance exists over a short time interval. Our measure avoids this problem since we compound only the indicator of single-period abnormal performance. A separate concern is that if $\hat{\alpha}$ was substantially removed from zero, then compounding could impart erroneous drift to our market-adjusted prices. This is not a problem here, since for the branded portfolio, $\hat{\alpha} = 0.0008$, and a similar decline emerges if we constrain $\alpha = 0$. Similarly, for the generic portfolio, $\hat{\alpha} = 0.001$.

[27] Pakes, *supra* note 22.

[28] In constructing this portfolio, we used firms whose main line of business was manufacturing pharmaceuticals but who did not conduct research to discover novel, patentable pharmaceutical products. In other words, they are firms who primarily produce chemically equivalent versions of drugs whose patents have expired.

What, then, is not "persistent information"? Clearly, any small event within our larger event period that moves stock prices up is treated as noise. Also, any transitory shock, up or down, is treated as noise. A few examples will illustrate both the power and the limitations of this formulation.

First, suppose that the only news at date 1 was a rumor that the Clinton plan would not cover prescription drugs. And at date 2 this rumor was credibly denied. If the market-adjusted pharmaceutical price falls at date 1 and fully recovers at date 2, then this series of events has not further informed the market about the larger event, the effect of the Clinton plan. We would like to, and our procedure does, treat such a series of events as noise. Consider the case instead where the individual effects of a series of related small events, leaks, actions, or announcements are themselves of interest. Even if these events are related, they could have opposite effects on stock price. In the above example, the date 1 rumor could be one small event, and the date 2 denial could be the second small event. If one is interested in the separate effects of those two small events, as one might be in an event study, the restriction to a monotonic expected price path would be incorrect.[29]

Second, a classic example from another context may clarify the monotonicity assumption. A researcher wants to estimate the effects of fertilizer on corn yield. The researcher observes two variables from a number of 1-acre plots of land: the quantity of fertilizer applied and the realized corn yield. The researcher is very unsure of the exact relationship between fertilizer application and expected corn yield and so does not want to impose a functional form a priori. A step function can nonetheless parsimoniously summarize the data. Nevertheless, the researcher would probably want to impose monotonicity on the relationship: expected corn yield should be nondecreasing in the fertilizer application. Of course, the realized corn yields will be influenced by additional factors unobserved by the econometrician, such as rainfall or pests, and so the realized corn yields will depart from the expected yields. In particular, some plot of land may have received less fertilizer but have a higher yield than another plot. Nonetheless, this does not contradict the assumption that expected corn yield is nondecreasing in the fertilizer application. Finally, if applied too heavily, fertilizer becomes a poison: at those levels, expected corn yield would be decreasing in the fertilizer application. So if the researcher believes a priori that the data include fertilizer applications at such counterproductive levels, then assuming an isotonic (nondecreasing) relationship would not be a good assumption. But if the data are believed to include only applications at lower levels, then isotonicity is a good assumption, and isotonic regression is an appropriate technique.

Third, the choice of the event period effectively defines the "big event" in which we are interested. Owing to the monotonicity assumption, we treat as noise both intermediate smaller events that have the opposite effect of the larger

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[29] Although we offer settings in which our approach would be preferable, this example illustrates that our approach is not so much superior to, as different from, an event study.

event on stock prices and also intermediate smaller events that have the same direction effect but are transitory. To take an extreme illustration, suppose a researcher wanted to treat the rise of the U.S. automobile industry as a big event, focusing on the presumably adverse effect of this development upon manufacturers of buggy whips for horse-drawn carriages. In that case, the researcher would impose monotonicity over a period of several decades. There were, presumably, smaller events, such as the commercial failure of the first U.S. automobile company, the Duryea Manufacturing Company, which were positive events for the buggy whip industry but which were treated as noise in the first analysis. If one were interested in the effect of the commercial failure of the Duryea on buggy whip stock prices, one would choose an event period encompassing just information leakage about that commercial failure and obtain, appropriately, a very different result. Because researchers choosing the different event periods are asking different questions, the procedures appropriately extract different information from the stock price series.

Finally, since we define (persistent) information as that which is true (as revealed by its effect on stock prices), it is this effect that we take to be monotonic, rather than the political prospects of the Clinton plan per se.

A related point is that we will not be able to identify separately the evolution of the two factors that would have influenced stock prices: the probability that health care reform would occur and the impact that passage would have. Certainly, both components were changing over this period, and as documented in Haynes Johnson and David Broder's *The System*,[30] important elements of the Clinton plan were assembled during the primaries and general election. But of course over any period of time in which only one of these elements was changing, the stock price movements can be attributed to those changes.

A final analogy illustrates the difference between transitory and persistent information. Consider a basketball game between the Chicago Bulls and the Utah Jazz, with a fictitious asset that pays $1 if the Bulls win and $0 otherwise. If this asset trades throughout the game in an efficient market, then its price fully reflects spectators' contemporaneous assessments of the probability that the Bulls will win. For illustration, suppose that this probability/price was .60 at the beginning of the game, and the Bulls do win the game. So at the end, this asset has price of $1. During the game, the price falls as Utah builds a first-quarter lead. It falls further as Michael Jordan leaves the game with uncharacteristic foul trouble. But then the Bulls rally, and this price rises as they dominate the second half and win the game. These price fluctuations trace out contemporaries' assessments of the effect of these events.

But consider another perspective, that of a researcher afterward who knows that the Bulls won. So if one conditions on that final outcome, after the resolution of all uncertainty, one knows that the probability of the Bulls winning increased

[30] Haynes Johnson & David S. Broder, The System: The American Way of Politics at the Breaking Point (1997).

from .60 at the start of the game to 1.00 at the end. And one could be interested in the time series of the persistent information, which is monotonically increasing during the game. Developments that looked to be bad news for the Bulls, such as Utah's early lead, turned out to be noise, or misinformation.[31]

Our approach reflects the latter perspective. So while contemporaneous assessments of the probability and impact of the Clinton plan both rose and fell over time, that is not our focus. Rather, it is to extract persistent information from the stock price series.

C.   Isotonic Regression

Isotonic regression is an appropriate technique when the true regression function is monotonic but when other shape characteristics of it are unknown.[32] The output of isotonic regression, the estimated regression function, will be monotonic and constant between observations or take a step form. It is the function with those characteristics that minimizes the sum of squared deviations from the data. Although our true regression function, the continuous flow of information about our larger event, does not take a step form, the fact that our estimate of it does affords us an interesting interpretation. Certainly even a continuous flow of information can be incorporated into stock prices only at discrete intervals and viewed by the researcher at (different) discrete intervals, so our estimate of the information flow can be interpreted as its estimated effect on stock prices. Furthermore, each step can be interpreted as an estimate of the incorporation of a discrete portion of the total effect we estimate.[33]

To illustrate how isotonic regression separates persistent from transitory information, we offer two examples based on hypothetical Bulls basketball games. We have already sketched our first hypothetical: the Bulls price begins at .60, declines in the early part of the game, and then gradually rises to 1.00 at the end. Figure 1 displays this price series and, in the thicker line, the corresponding isotonic regression, which is the expected price path conditional on the outcome of the game. The isotonic regression begins with a lengthy flat portion, which corresponds to the Bulls early deficit. So the Bulls early deficit and the start of their comeback are classified as transitory news. The isotonic regression then coincides with the price series for nearly the latter half of the game.

The second example involves more ups and downs. The Bulls price rises from its initial value of .60 as they take the lead. They retain this lead for a substantial part of the game, but then lose the lead in the fourth quarter. The Bulls price

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[31] A development is misinformation if it turns out ex post not to have persistent effects in the correct direction. So Utah's early lead is misinformation, even though their points do not disappear from the scoreboard.

[32] Another application of isotonic regression in the economics literature is provided by J. A. Hausman, Jason Abrevaya, & F. M. Scott-Morton, Misclassification of the Dependent Variable in a Discrete-Response Setting, 87 J. Econometrics 239 (1998).

[33] This statement relies on pointwise consistency of the estimate. The Appendix offers a few more details of the argument.
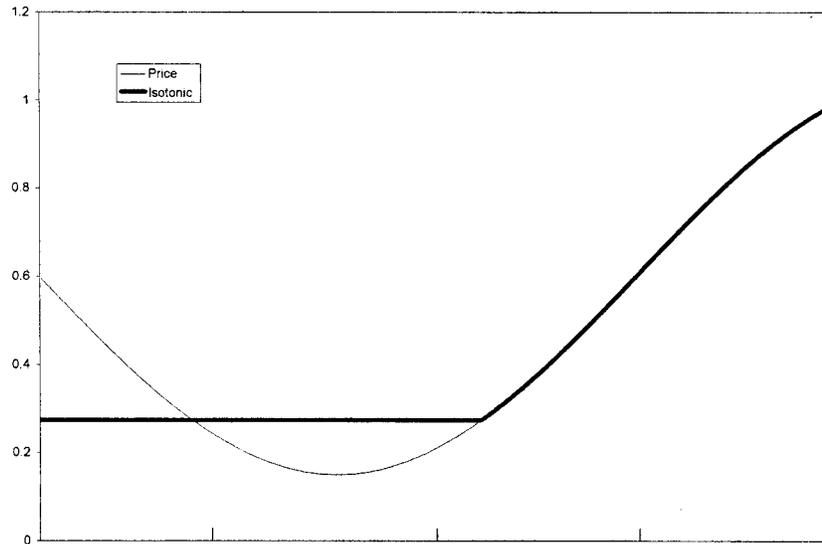
FIGURE 1.—Bulls overcome early deficit

falls to .10 as the Bulls trail in the game's final second, but the Bulls win on a shot at the buzzer. So by construction, the Bulls' probability of victory jumps from near zero to 1.00 at the end. Figure 2 displays the price series and, in the thicker line, the corresponding isotonic regression. Here the expected price path rises slightly from .60 to .67 in the game's initial minutes and remains flat until it jumps to 1.00 at the buzzer. Interestingly, this treats the Bulls early lead and their late game deficit as largely noise; the expected price path rises only a little above .60. Much of the persistent information is contained in the jump up at the end, with the shot at the buzzer.

Finally, we want to clarify the difference in focus and purpose between our methodology and a traditional event study. Were we concerned solely with the total effect of the Clinton plan, as would be the case with an event study, and prepared to attribute the entire price decline to health care reform, we could simply compare the market-adjusted prices at the start and end points of this estimation period, without conducting an isotonic regression. The value of the isotonic regression is in identifying the timing of this information. Since we know the general timing of the evolution of the Clinton plan, with its increasing emphasis on cost containment, we are therefore able to uncover the stock market's estimate of the impact of these proposed policy elements and the overall evolution of the Clinton plan.
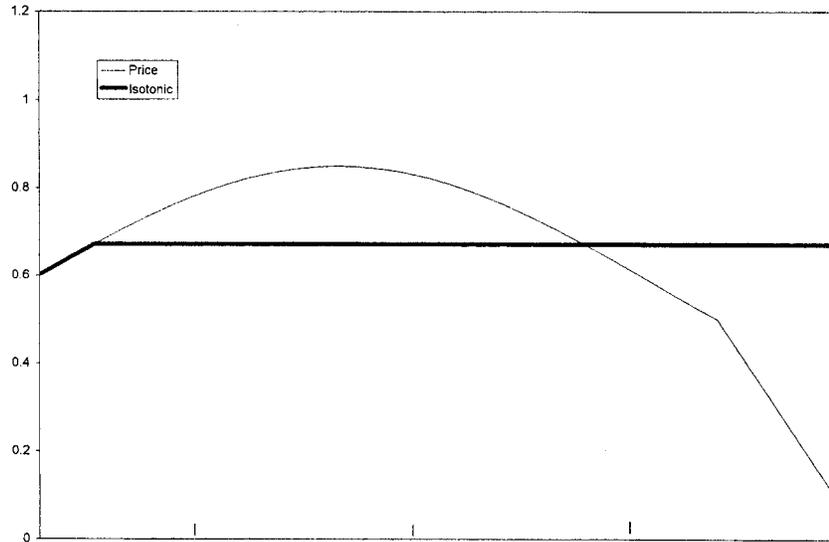
FIGURE 2.—Bulls win at buzzer

D. Related Techniques

As long as researchers have been using stock market data to infer changes in the value of firms, importance of events, and so forth, they have been concerned about the gradual incorporation of information into stock prices. This concern is most evident in the performance of event studies. John Y. Campbell, Andrew Lo, and A. Craig MacKinlay[34] devote a chapter to event study analysis and implementation issues. Some researchers may widen the event window so as not to miss the impact of the event. As Michael Salinger[35][36] notes, that procedure as typically applied results in incorrect standard errors, and he provides an appropriate correction. Note that our approach is not just equivalent to applying a larger window for "small events." Rather, we jointly estimate the timing of information release (the location of steps) and the effect of that information (the height of steps).

Clifford Ball and Walter Torous[37] address the situation of event-date uncertainty, in which the researcher knows that an event took place on a single day

[34] John Y. Campbell, Andrew W. Lo, & A. Craig MacKinlay, The Econometrics of Financial Markets (1997).

[35] Michael Salinger, Standard Errors in Event Studies, 27 J. Fin. & Quantitative Analysis 39 (1992).

[36] Michael Salinger, When Do Peeping Toms See Something (Statistically) Significant? (unpublished manuscript, Boston Univ. 1994).

[37] Clifford A. Ball & Walter N. Torous, Investigating Security-Price Performance in the Presence of Event-Date Uncertainty, 22 J. Fin. Econ. 123 (1988).

within some time period but does not know which date. But in their setting, the news event and its incorporation into stock prices occurs at a single, albeit unknown, date instead of occurring gradually through a series of small events.

Other researchers concerned with gradual incorporation over a long period produce graphs of cumulative abnormal returns (CARs) over multiple days, weeks, or months around an event. The problems with this approach have been addressed by a number of researchers. Paul Malatesta[38] faults the CAR as a relatively poor measure of the wealth effects of an event on shareholders and instead proposes using the abnormal *dollar* return cumulated over a long window. Michael Salinger[39] demonstrates that the CAR does not measure the effect of an event on firm value if there are dividends during the event window. This is likely to be a problem for event studies of public policy changes, which often employ long event windows. In Section IV, we directly compare our method with a CAR plot and point out some of the more general shortcomings of the CAR procedure.

Finally, there have been efforts to address the partial anticipation of an event by specifying and estimating a particular parametric model of the information revelation process. Malatesta and Rex Thompson[40] note that when an event is partially anticipated, the effect of an event announcement will be an underestimate of the event's economic impact, "the capitalized value of future net cash flows resulting from the event's occurrence." They model the partial anticipation of events in the context of firms that have embarked on acquisition programs, so any given acquisition announcement is partially anticipated. Using the multiple announcements of acquisitions as repeated observations for each firm, they find significant economic impacts that would otherwise have been obscured by the insignificant announcement effects. Sara Fisher Ellison and Wallace Mullin[41] offer a simple parametric model to account for the gradual incorporation of information into stock prices in the setting of congressional debate on sugar tariffs.

A procedurally very different but closely related methodology is described by K. L. Willard, T. W. Guinnane, and H. S. Rosen.[42] They identify events from an asset price series by estimating break points in the series. The similarity to our isotonic regression technique is that both techniques attempt to identify periods of information incorporation on the basis of not only the magnitude but also the persistence of their effects. Their ultimate purpose is to identify important events that might have been unobserved by the researcher. Ours, however, is to identify price movements not necessarily related to important events, observed or unobserved, but perhaps due to more subtle changes in public information.

[38] Paul H. Malatesta, The Wealth Effect of Merger Activity and the Objective Functions of Merging Firms, 11 J. Fin. Econ. 155 (1983).

[39] Michael Salinger, Value Event Studies, 74 Rev. Econ. & Stat. 671 (1992).

[40] Paul H. Malatesta & Rex Thompson, Partially Anticipated Events, 14 J. Fin. Econ. 237 (1985).

[41] Sara Fisher Ellison & Wallace P. Mullin, Economics and Politics: The Case of Sugar Tariff Reform, 38 J. Law & Econ. 335 (1995).

[42] Kristen L. Willard, Timothy W. Guinnane, & Harvey S. Rosen, Turning Points in the Civil War: Views from the Greenback Market, 86 Am. Econ. Rev. 1001 (1996).

III.   EVALUATING HEALTH CARE REFORM

Our main goal in applying this methodology is to uncover the actual effects of the Clinton plan. It will first be informative, however, to discuss the likely effects. In order to do so, we address some fundamentals of the U.S. pharmaceutical industry. The branded drug sector, in particular, is very R&D intensive. These R&D expenditures constitute a large fixed cost for any pharmaceutical product. Once these substantial discovery and development costs are sunk, however, a therapeutic compound is manufactured at a relatively low marginal cost. In the United States, drug prices are well above this marginal cost.[43]

The short-term impact of any health care reform initiative on the pharmaceutical industry is therefore driven by two opposing effects. The first is the demand expansion effect that would occur through universal coverage or other mechanisms. If no changes are made to the pricing mechanism, this demand expansion would raise pharmaceutical industry profits on the margin. But health care reform initiatives also may include direct or indirect changes to the pricing mechanism. This, second, cost containment effect could dramatically reduce pharmaceutical industry profitability.[44]

Furthermore, strong enough cost containment can easily overshadow even a very large demand expansion effect. If prices are driven close to marginal production cost, even a large increase in pharmaceutical utilization would not offset the profit loss. (If prices are driven below average cost, accounting for development expenditures, then in the short run pharmaceutical companies cannot simply make up the losses through greater volume.)

A.   *Chronology of Health Care Reform*

To set the stage for our estimation, we recall some of the identifiable events that occurred during a broadly defined "reform period."[45]

In November of 1991, Harris Wofford won a special election for the U.S. Senate in Pennsylvania on a health care reform platform. This election would later be seen as a precipitating event for placing health care reform squarely on the agenda in the upcoming presidential campaign.

On January 19, 1992, candidate Clinton issued a white paper on health care reform. "The January 19 position paper was the opening round in what became

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[43] See Stuart O. Schweitzer, Pharmaceutical Economics and Policy 101 (1997), for instance.

[44] Broadly defined, containment of overall health care costs could raise utilization of pharmaceuticals and industry profitability since pharmaceuticals are often the most cost-effective treatment. For lack of a better term, we will refer to the latter strategy as cost-effectiveness and strategies narrowly targeted at reducing the amount spent on pharmaceuticals as cost containment. We make this distinction because the implications for the industry could obviously be quite different.

[45] Much of this chronology is taken from Johnson & Broder, *supra* note 30.

an eight-month internal struggle to get Bill Clinton to define his approach to reform."[46]

The New Hampshire primary was held on February 18. Clinton came in a strong second to New Englander Paul Tsongas. Candidates Clinton and Tsongas entered Super Tuesday, March 10, as the front-runners, and Clinton dominated, winning a string of primaries in the South. April 7 saw the New York primary, considered crucial for Clinton. "[Clinton] needs a strong showing here to regain his status as a the clear Democratic front-runner."[47] He won again.

As health care reform became an increasingly central issue in the presidential campaign, House Republicans offered a plan of their own on June 4 to grab a bit of the spotlight. Bill Clinton solidified the nomination over the late spring, and his health care rhetoric began to shift to emphasize "managed competition."

On July 16, Bill Clinton accepted the Democratic nomination, a foregone conclusion at that point. Clinton never lost the sizeable lead he had in the polls over the incumbent George Bush after that. On September 24, Bill Clinton gave a speech at Merck broadly outlining his plans for health care reform, which emphasized a market-based approach but left most details unspecified.

Bill Clinton was elected on November 3. On January 25, 1993, Hillary Rodham Clinton was named head of the Healthcare Task Force (HCTF). In February and March, rumors circulated that the HCTF, which was operating in secrecy, was going to include regulation of drug prices in its plan. Such fears seemed supported by statements by President Clinton and Hillary Rodham Clinton attacking the high prices of vaccines and other pharmaceuticals.[48] We know from contemporaneous accounts that these statements triggered a fall in pharmaceutical companies stock prices, but we do not use that information in the estimation.

The HCTF continued to work throughout the spring, disbanding on May 31. The *New York Times* and the *Washington Post* analyzed a leaked Clinton plan on September 11. The plan was officially unveiled on September 22 and subsequently presented in testimony by Hillary Rodham Clinton on Capitol Hill. October 3, 1993, is identified in *The System*[49] as the possible high point politically for health care reform.

A series of distractions—Somalia, Haiti, Troopergate, and Whitewater—and defeats for the Clinton plan ensued, culminating in the July 21, 1994, announcement by congressional leaders that the Clinton plan was dead.[50]

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[46] See *id.* at 76.

[47] William Clinton, Players in Familiar Roles as Vote Nears; Clinton Faces Questions about His Past and Spars with Rivals, N.Y. Times, April 6, 1992, at A1.

[48] Harsh Medicine: Attack on Drug Prices Opens Clinton's Fight for Health-Care Plan, Wall St. J., February 12, 1993, at A1.

[49] See Johnson & Broder, *supra* note 30, at 189–90.

[50] On October 3, 1993, U.S. soldiers were killed in Somalia and their bodies dragged through the streets in dramatic television footage. Only days later, U.S. engineers were prevented from landing at Port-Au-Prince, Haiti, and President Clinton dispatched warships to the area. Troopergate was the scandal sparked by a December 1993 report from Arkansas state troopers of then Governor Clinton's

B. The September 1993 Clinton Plan

As the Clinton plan was revealed, the cost-containment elements received more emphasis. The formal Clinton proposal was laid out in the book *The President's Health Security Plan*.[51] We highlight the essential elements for our purposes.

1. Universal Coverage, Managed Competition, and Cost Containment

All U.S. citizens would be guaranteed health care coverage, largely through an employer mandate. There would be two mechanisms to control costs. First, the health care market would be reorganized. Networks of health care providers would compete to supply a standard benefits package to all who enrolled. On the demand side, states would set up health insurance purchasing cooperatives,[52] and small employers and the self-employed could purchase policies through these large pools. This was a particular vision of "managed competition." Employees would pay 20 percent of the cost of their health plan premiums, which would make them sensitive to plan costs. The health insurance purchasing cooperatives, representing a large pool of these customers, would monitor health plans' performance and negotiate premium rates.

Second, the Clinton plan also established an overall national health budget, limiting growth in health care costs to growth in gross domestic product. This was intended as a "backstop" measure to contain expenditures should managed competition fail to achieve that on its own.[53] But it included direct regulatory components that would restrict health care provision or strictly limit its price. After a 3-year phase-in, the growth in premiums for standard health plans would be limited to the growth in the consumer price index.[54] This was a price cap, which could bind very stringently, as health care costs had regularly been growing faster than the rate of inflation.[55]

2. Elements Especially Important to the Pharmaceutical Industry

Coverage for outpatient prescription drugs would be part of the benefits package guaranteed to all citizens.[56] In providing this benefit, health plans would be permitted to establish restrictive formularies, drug utilization review, and generic

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extramarital liaisons. Whitewater was an Arkansas land development that Bill and Hillary Clinton had purchased with Jim and Susan McDougal in 1978. Questions about the Clintons' involvement in any Whitewater improprieties expanded in late 1993 and early 1994, and eventually led to the appointment of independent counsel Kenneth Starr. Further details of these political developments are available in Johnson & Broder, *supra* note 30.

[51] White House Domestic Policy Council (WHDPC), The President's Health Security Plan (1993).

[52] Also known as regional health alliances.

[53] WHDPC, *supra* note 51, at 6 & 7.

[54] *Id.* at 102.

[55] See the Health Care Financing Administration's Web site, http://www.hcfa.gov.

[56] WHDPC, *supra* note 51, at 21–22.

substitution.[57] Sara Fisher Ellison's analysis of price discounts in antibiotic drugs argues that certain purchasers, such as health maintenance organizations (HMOs) with restrictive formularies, can credibly threaten not to buy particular drugs and so receive substantial price discounts.[58] Thus health plans operating under the Clinton plan would have the tools and incentives to extract similar discounts.

Furthermore, for the first time the elderly and the disabled would receive coverage for outpatient prescription drugs under Medicare.[59] Drug manufacturers would be required to sign rebate agreements with the federal government in order to participate in Medicare and Medicaid. The Clinton plan offered these details:

> For single source and innovator multiple source drugs, manufacturers pay a rebate to Medicare for each drug based on the difference between the average manufacturer price (AMP) to the retail class of trade and the weighted average of the prices of the drug in the non-retail market, or 15 percent of the AMP, whichever is greater. The Secretary [of Health and Human Services] has the authority to verify the AMP.
>
> For single source and innovator multiple source drugs, an additional rebate is required on a drug-by-drug basis for manufacturers who increase prices at a higher rate than inflation. The baseline indexed price is the average manufacturers price from April through June 1993.
>
> In the case of new drugs that the Secretary determines are excessively or inappropriately priced, the Secretary has the authority to negotiate a special rebate with the manufacturer. Such a determination by the Secretary would be based on such factors as the prices of other drugs in the same therapeutic class, cost information supplied by the manufacturer to the Secretary, prices of the drug in other comparable countries, and other relevant factors. If the manufacturer refuses to negotiate or the Secretary is unable to negotiate a price that the Secretary determines to be reasonable, the Secretary may exclude the new drug from coverage under Medicare.[60]

Unsurprisingly, the drug companies "organized a small army of lobbyists" against these ideas.[61] Some rebate requirement, such as linking government rebates to prices obtained by other buyers, is a reasonable safeguard in a procurement context. (If the government offers a demand curve for drugs with zero price elasticity, the prices could rise quite dramatically.) But the extent of the rebates required here would have significantly lowered drug prices. The requirement of an additional rebate from manufacturers who increase their prices more than inflation would penalize and therefore limit price increases in the non-Medicare drug market. Finally, the discretion of the Secretary to "negotiate" further reductions if prices remained "unreasonable" suggests that the purpose

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[57] *Id.* at 27.

[58] Sara Fisher Ellison, What Prices Can Tell Us about the Market for Antibiotics (unpublished manuscript, Massachusetts Inst. Tech. 1998).

[59] WHDPC, *supra* note 51, at 216 & 221. After a $250 deductible, beneficiaries would pay 20 percent of their drug costs, up to an $1,000 annual cap on out-of-pocket expenditures.

[60] See *id.* at 223–24.

[61] Robert Pear, Clinton Will Seek a Medicare Change on Drug Coverage, N.Y. Times, June 8, 1999, at A1.

of these provisions was not simply to limit opportunistic price increases but to drive prices down.

Another part of the Clinton plan was the creation of a Breakthrough Drug Committee. "The committee would have no authority to set or control drug prices."[62] But the committee's mission would be to study and issue reports on the "reasonableness" of prices of new breakthrough drugs. The political pressure generated by an unfavorable report might limit prices, but that would make its effects akin to direct regulation. Indeed, Ellison and Catherine Wolfram[63] find that pharmaceutical companies restrained their prices during the period of the health care reform debate, with the more politically vulnerable firms engaging in greater constraint. So political pressure can restrain prices even absent direct regulation.

Moreover, Thomas[64] warned that this committee would "presumably target for implicit regulation precisely the products that are the current basis of U.S. global competitive success—blockbuster products." Moreover, he noted that in ascertaining the "reasonableness" of a drug's price, the committee would "consider the discovery costs of each drug in isolation" and ignore "the multiplicity of dead ends inescapably reached in the process of discovering any one particular drug."[65] Thus this would provide implicit regulation that would be very harmful to U.S. pharmaceutical companies.

So this was the Clinton plan as it was finally revealed in September of 1993. As we have emphasized, it was not suddenly unveiled as a complete surprise. We now let our results tell us when the information about the Clinton plan was incorporated into stock prices. From what we do know about the evolution of the Clinton plan, we are able to interpret the results to sketch how some changes in the Clinton plan's emphasis were judged to be harmful to the pharmaceutical industry.

IV. RESULTS

In this section we highlight the main result of our article, the estimated expected price path of the pharmaceutical portfolio over our event period, which we interpret in light of the preceding chronology and analysis. We also compare that estimate with various other more common methodologies. Finally, we conduct a "reverse event study" to support that our estimated price path is due to gradual incorporation of information about health care reform, rather than other events.

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[62] WHDPC, *supra* note 51, at 46.

[63] Sara Fisher Ellison & Catherine Wolfram. Pharmaceutical Prices and Political Activity (unpublished manuscript, Massachusetts Inst. Tech., April 2000).

[64] See Thomas, *supra* note 8.

[65] *Id.* at 126.

A.   Estimated Expected Price Path

For estimating and interpreting the isotonic regression, we need to focus on a period in which a single "large event" of interest unfolds. The large event in whose effect we are interested is the revelation of the Clinton health care reform plan. By the time the plan was officially unveiled before Congress on September 22, 1993, the public had a lot of information about its content. When did the information start to be revealed? There are different starting dates that one could justify on various grounds. One possibility is the day on which the HCTF disbanded. We presume it was only at that point that the plan was set. After that time, information about it could have leaked out and been incorporated into stock prices. Many facets of the plan, however, were leaked before the final plan was set, so one could, instead, go back to the formation of the task force and the naming of Hillary Rodham Clinton as its head. Indeed, information on Clinton's position on health care issues was revealed throughout the primary and general campaigns leading up to his election. We will, therefore, go back as far as January 19, 1992, a few weeks prior to the New Hampshire primary, and also the day on which Bill Clinton issued his white paper on health care reform.

We choose as an ending point 2 weeks after the plan was officially unveiled. We extended the period beyond the official presentation to account for learning about facets of the plan in subsequent congressional hearings. Also, note that our ending point is identified by observers as the Clinton plan's political high point. We could have extended the event period even further to include additional learning about the plan, but we thought that doing so would have obscured the effect of the unveiling of the Clinton plan. Additional learning, presumably having a small adverse effect at that point, would have been swamped by the falling political prospects, presumably having a larger positive effect.

A couple of remarks about the choice of the event period are necessary. First, the event period was, and should be, chosen on the basis fo the chronology of events rather than the movement of stock prices. Second, our choice of event period defines the large event in which we are interested. We do not dismiss the idea that other researchers could have chosen an event period different than ours, perhaps a subset or superset of it, to answer different questions of economic interest. We do, however, believe that our choice of event period is reasonable given that we care about the effect of health care reform on pharmaceutical stock prices, and we have chosen a period in which (1) it became clear that Bill Clinton's biggest campaign issue would be health care, (2) he was elected, and (3) his health care reform plan was formulated and revealed.

Figure 3 summarizes the isotonic regression by graphing the expected path of market-adjusted pharmaceutical prices over this time.[66] For ease of interpretation, we have rescaled the values to begin with 1. Note first that pharmaceutical

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[66] We omitted pointwise confidence bands on this figure to make it easier to read. Ninety-five percent pointwise confidence bands obtained through bootstrapping are quite narrow, .0070 on average.

companies lost a considerable amount of (market-adjusted) value. The expected market-adjusted price fell from 1.000 to .476 in less than 2 years, a fall of 52.4 percent.[67]

A different choice of endpoints would have, of course, given us a different percentage decline, independent of the technique we use to obtain the expected price path. What the isotonic regression really affords us is a clear picture of what happens in the middle. This picture tells us when and how much persistent information was incorporated at various points in time. The expected price path is particularly interesting in light of the coinciding political developments and the evolution of the Clinton plan.

The earliest period that sees dramatic information incorporation is the time over which Clinton solidifies his nomination (after Super Tuesday) until his shift in emphasis toward "managed competition." The estimated price path declines from .931 to .829 over this period. In other words, about 20 percent of the total decline occurs then. Much of this decline probably reflects Clinton's growing political success. But strikingly, this period also coincides with a shift in Clinton's thinking and rhetoric on health care policy. The candidate's initial position was "pay or play," a form of employer mandate. Each employer would have the choice of either providing health insurance to its workers or paying into a government fund to cover the otherwise uninsured. This proposal did not emphasize controlling health care costs. So even if there was some market anticipation that cost containment would be included in reform, the beneficial demand expansion effects of reform may have received considerable weight. In contrast, by June 19, 1992, Clinton uses the language of managed competition, arguing that it "would really do a lot more to hold costs within inflation."[68] Although the particulars remained unspecified, the decline in the estimated price path suggests that the stock market viewed "cost containment" as a threat to pharmaceutical company profitability. And the subsequent details of the plan lend support to that view.

This interpretation is reinforced by the next dramatic period, the 3 weeks leading up to nominee Clinton's speech at Merck on September 24, 1992, outlining his health care agenda for the fall campaign. The expected price path falls from .815 to .762 over these 3 weeks. Since the expected price path falls *before* the Merck speech, it suggests significant market anticipation of the speech's content. But the pattern does not reflect a single, credible leak about the speech, since that would lead only to a single fall in the expected price path. The speech itself brought some information; the expected price path fell a further .020 the day after.

The significance of the speech was in cementing Clinton's move away from "pay or play" toward a particular version of "managed competition." While Clinton still promised universal coverage, he now offered two elements to control

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[67] This is slightly more than the decline in market-adjusted prices.

[68] Johnson & Broder, *supra* note 30, at 80.

costs. First was the reorganization of the health care market. Second was state-by-state health care budgets. These were the two cost containment approaches that were fleshed out in his legislative proposal 1 year later. As Governor Clinton promised at Merck, "I want to keep consumers with a variety of choices, including access to local health care networks put together by insurers, hospitals, clinics and doctors—managed care networks that will receive the money they need to meet a consumer's health care needs over a lifetime. By limiting a network's total spending, without interfering at all with its practices, the state-by-state budgets that I recommend will create real incentives for hospitals, clinics, doctors and consumers to reduce bureaucracy, eliminate unnecessary duplicative technology and practices and cut waste on their own."[69]

Once again, the pattern of expected stock prices may also reflect gradual incorporation of information about Clinton's likely political success against President Bush, which would make health care reform more likely. But it is the emphasis on cost containment that likely made such reform bad news for pharmaceutical companies. As an account shortly after the Merck speech noted, "Drug companies are especially vulnerable because they have a huge line of products whose prices can be easily measured—and forced down."[70] And Clinton's insistence that health care expenditures should not be allowed to exceed some limit foreshadowed the regulatory or quasi-regulatory requirements necessary to meet that goal.

But some very important details remained unspecified at that stage, particularly about the nature and therefore conduct of the vertically integrated networks of insurers and health care providers. As Lacy Glenn Thomas[71] noted, if such networks came to favor high-quality, but cost-effective, care, it could even benefit the U.S. pharmaceutical industry abroad: "Under those optimistic circumstances, the imprimatur 'sold in America' . . . will signal that new drugs have passed a brutal but fair test of cost-effectiveness in the U.S. market and that they are thus worthy of consumption abroad."[72] But subsequent Clinton plan details supported Thomas's pessimistic scenario, that these networks would choose products primarily on the basis of cost, rather than cost-effectiveness.

The third dramatic period of information incorporation is after Clinton's election and before the HCTF is formed. The expected price path experiences a further .12 decline, over 20 percent of the total decline. Most of that occurs in a cluster of steps in December and January. This exemplifies gradual incorporation of leaks and small events as the Clinton presidency and its approach to health care took shape. Significantly, the health care policy group formed for the presidential transition concluded that assuring universal coverage would be much costlier than Clinton had anticipated, and so either larger budget deficits

[69] The 1992 Campaign; In His Own Words, N.Y. Times, September 25, 1992, at A19.

[70] News You Can Use; On Money, U.S. News & World Rep., October 12, 1992, at 86.

[71] See Thomas, *supra* note 8.

[72] See *id.* at 125.

or health care price controls would be required.[73] Although President-Elect Clinton rejected this assessment, stock market participants apparently recognized the adverse implications for the pharmaceutical industry.

Another interesting result is that relatively little information was incorporated at other times. For example, one development that received a lot of contemporary attention was the Clintons' attacks on the drug companies in February 1993, closely followed by rumors that drug price controls would be proposed. The expected price path declines by almost .005 in the aftermath of these attacks. Compared to the information incorporated in other periods, the isotonic regression suggests that although those attacks added news, the news confirmed a suspicion already largely reflected by the stock market. Thus the stock market may have already reflected a high probability that the Clinton plan would include explicit drug price controls. Of course, these were not in the final plan. Given subsequent developments, a more likely interpretation is that the stock market judged that the Clinton plan would be very effective in driving down drug prices, even without resort to explicit price controls. So the combination of "managed competition" coupled with the caps on health plan premiums would significantly reduce drug prices.

Later developments also brought relatively little news. The middle of the graph displays a lengthy flat period that roughly corresponds to the latter period of the operation of the HCTF. When the HCTF disbanded at the end of May 1993, the decline in prices resumed, but at a slower rate than before.

One striking feature of this graph is that the information incorporation does not seem to be closely clustered around identifiable events. First, there is no movement specifically associated with Bill Clinton's acceptance of the Democratic nomination for president and only a .0038 decline associated with his election. This is as it should be, since both developments were heavily anticipated by market participants and thus already reflected in prices. It is nonetheless reassuring that the expected price path reflects this anticipation. Second, and of greater interest, there is very little information incorporation near the end of the event period, when the plan is actually unveiled. Given that Clinton's health care reform plan was reviled by and considered quite bad news for pharmaceutical companies, it is a striking finding that the actual unveiling of the plan had so little effect but one consistent with our notion that the information had already been revealed and incorporated through the lengthy political process. In fact, according to our estimate, 82 percent of the information had already been incorporated by February 22, 7 months before the plan was actually unveiled.

One might wonder about the robustness of these results to our choice of event period. We have defended our choice of event period as reasonable in light of the coinciding developments. But one may disagree with our judgment and wish to focus on a shorter subperiod. One can do so simply by performing the isotonic regression over these shorter time periods. The resulting graphs for the individual

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[73] Johnson & Broder, *supra* note 30, at 109–10.

subperiods are very close to the corresponding portion of the graph we obtain for the entire period, with small exceptions at the endpoints.[74]

We offer the following caveat in interpreting our results. In estimating an expected price path, we isolate the persistent effect of information on pharmaceutical prices over this 21-month period. The period included events relevant to the pharmaceutical industry that were not related to health care reform, such as earnings reports, drug approvals by the Food and Drug Administration (FDA), and drug discoveries or failures. It is possible that the persistent information we estimate includes developments other than health care reform. Such other events are very unlikely to be driving these results, however. First, news such as an earnings announcement by a single firm should not have a large effect on an entire pharmaceutical portfolio. Bad news about one firm's prospects would often be "no news" or "good news" for its competitors. Second, any industry-relevant news would affect the estimated expected price path only if the effect were persistent; otherwise it would be treated as "noise." So news that is idiosyncratic to a particular firm or time period is unlikely to account for the results.

Moreover, corroborating evidence indicates that health care reform was the major systematic factor affecting the pharmaceutical industry over this period. Surveying annual reports for firms in our sample, several mentioned ongoing litigation and the commercial success or failure of specific drugs. Such statements were, of course, idiosyncratic to firms and also not treated with the same gravity as potential health care reform. Despite the normal boilerplate expected in annual reports, Merck's 1993 annual report describes health care reform proposals as "highly regulatory," and Pfizer's 1993 annual report admits that proposals could have "an adverse impact on the Company's pharmaceutical business in the United States."

Of course, there were other trends affecting the pharmaceutical industry besides health care reform. But on closer examination, these other trends are not likely to account for our results. For example, the early 1990s saw rising interest in biotechnology firms, which potentially posed a competitive threat to the traditional pharmaceutical companies. This interest was reflected in contemporaneous stock market gains for biotechnology firms. In 1989–91 the Fidelity Select Biotechnology Portfolio experienced annual returns of 43.93 percent, 44.35 percent, and 99.05 percent. Strikingly, the years of the Clinton proposals brought sharp reversals to the biotechnology sector. The Fidelity Select Biotechnology Portfolio experienced losses of 10.34 percent in 1992 and 18.8 percent in 1994, with a paltry gain of .70 percent in 1993.[75] This was despite modest gains experienced in the broader stock market over these 3 years. Of course, the biotechnology

[74] This is a statement about our particular application of isotonic regression. It need not be true in general.

[75] Fidelity Investments Prospectus, Fidelity Select Portfolios, April 29, 1999, at P-19. These calculations do not include the fund's front-end sales charge, which was 3 percent. This Fidelity fund received Morningstar's highest rating for its performance over the 10 years ending 1999.

sector's prospects may have been downgraded by investors worried about the Clinton plan's increasing emphasis on cost containment.[76] But the poor performance in biotechnology stocks in 1991–94 makes it doubtful that our estimated decline in the value of traditional pharmaceutical firms is due to a competitive shift toward biotechnology rather than to political developments.

Another trend was the growth of pharmacy benefit management (PBMs), which negotiated substantial price discounts for pharmaceuticals. To the extent that PBMs were a contemporaneous concern, their impact would be reflected in pharmaceutical company earnings. We looked at the effects of the adverse earnings announcements of March 24, 1993, which did prompt a stock market reaction. There was no corresponding movement in the estimated expected price path, which illustrates that these extraneous developments were of minimal persistent importance.

In order to address the issue of possible alternative explanations, at the end of this section we conduct a "reverse event study" to see if major movements of the market-adjusted pharmaceutical portfolio are due to factors we have overlooked. The reverse event study does not uncover any news events other than health care reform.

Final corroboration of the anticipated adverse impact of health care reform comes from Ellison and Wolfram.[77] They examine whether pharmaceutical firms acted to preempt imminent regulation by distorting their prices downward and find evidence that they did. Looking at industry pricing over time seems to suggest this, but they uncover even more powerful cross-sectional evidence: more politically sensitive firms distorted their prices more. In other words, firms were willing to take costly steps to reduce the probability of major health care reform, and those with more to lose were more willing. These costly actions reveal that the Clinton plan must have been considered undesirable. Moreover the cross-sectional evidence supports the view that health care reform, rather than some extraneous causes, was important for the decline in pharmaceutical stocks.

Taken as a whole, these various strands of evidence support our view that health care reform was the driving factor in the estimated price path.

B.   Comparison of Impact on Branded and Generic Portfolios

So health care reform was viewed by stock market participants as having an adverse effect on pharmaceutical industry profitability, and this effect can in part be attributed to the growing emphasis on cost containment as a goal of reform.

One of the interesting positive and policy questions is whether this wealth loss by pharmaceutical companies would be accompanied by changes in firm behavior, such as reduced R&D investments, which would reduce welfare. The

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[76] Biotechnology may have been particularly vulnerable to this, since even those products successfully brought to market had dramatic costs per treatment.

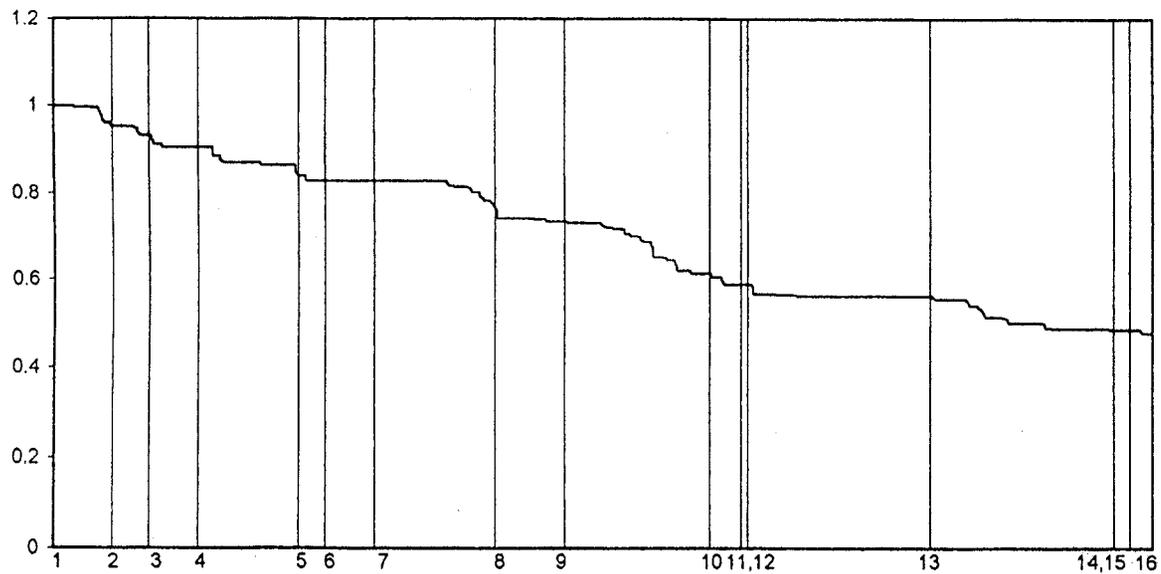[77] See Ellison & Wolfram, *supra* note 63.

FIGURE 3.—Expected price path, market-adjusted pharmaceutical portfolio, January 17, 1992–October 4, 1993. (1) Bill Clinton issues health care white paper outlining reform proposal, January 19, 1992. (2) New Hampshire primary, February 18, 1992. (3) Super Tuesday, March 10, 1992. (4) New York primary, April 7, 1992. (5) House Republican health care proposal advanced, June 4, 1992. (6) Bill Clinton shifts reform emphasis toward managed competition, June 19, 1992. (7) Bill Clinton accepts Democratic nomination, July 16, 1992. (8) Bill Clinton gives speech at Merck, September 24, 1992. (9) Bill Clinton is elected, November 3, 1992. (10) Hillary Rodham Clinton is named head of the Healthcare Task Force (HCTF), January 25, 1993. (11) Bill Clinton attacks pharmaceutical manufacturers for high prices, February 12, 1993. (12) New York Times reports HCTF is leaning toward regulating drug prices, February 16, 1993. (13) Healthcare Task Force disbands, May 31, 1993. (14) New York Times analyzes a leaked Clinton plan, September 11, 1993. (15) Bill Clinton unveils health care reform proposal, September 22, 1993. (16) Possible political high point of plan, October 3, 1993.
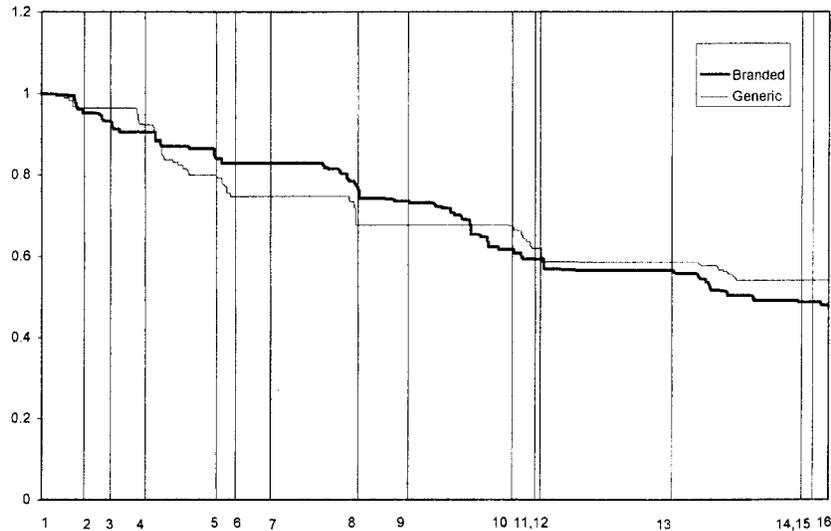
FIGURE 4.—Isotonic regression of branded and generic portfolios

most optimistic scenario is that health care reform would transfer wealth away from pharmaceutical shareholders but not distort R&D decisions. For this to occur, health care reform would have to act as if it were a (nondistortionary) tax on the value of pharmaceutical firms. The alternative is that health care reform would operate more like a tax on the value of firms' R&D capital, and that would reduce the incentives to engage in R&D.

As an indirect attempt to address this issue, we will compare the isotonic regression results from the previous section with that for a comparison portfolio composed of six generic drug manufacturers. Since generic manufacturers are much less R&D intensive than branded producers, this comparison may shed some light on the extent to which health care reform was seen as a tax on the value of R&D capital.

The comparison is summarized in Figure 4. The branded isotonic regression is reproduced from Figure 3. The starting values have been normalized to 1.00, and the ending value for the generic portfolio is .541, as opposed to .476 for the branded portfolio. The branded portfolio does lose more value, but not much more. Moreover, the expected price paths, while not identical, are similar and cross at a number of points. For example, the estimated price path for the generic portfolio gradually declines from .747 to .677 in the 3 weeks before the Merck speech (event 8), paralleling a similar decline in the branded portfolio. While the pointwise confidence intervals for the two expected price paths often are nonoverlapping, meaning we can reject equality at many dates, we cannot reject

TABLE 2

TRADITIONAL EVENT STUDY

Event Number	1-Day Window	t-Statistic	7-Day Window	t-Statistic
1	.005	.549	−.009	−2.711
2	−.004	−.410	−.003	−.957
3	−.003	−.362	−.003	−.964
4	.004	.494	.003	.949
5	−.003	−.349	−.008	−2.455
6	−.006	−.660	.001	.217
7	.002	.270	−.000	−.122
8	−.011	−1.260	−.008	−2.482
9	.003	.383	−.002	−.465
10	−.018	−1.978	.001	.335
11	.007	.746	.020	3.084
12	−.028	−3.184	−.023	−3.588
13	−.003	−.369	−.006	−1.929
14	−.014	−1.605	−.003	−.831
15	−.005	−.599	.001	.291
16	−.007	−.798	−.000	−.080

NOTE.—See Figure 3 for the list of events.

equality of the price paths. We would therefore say that the pattern of information incorporation is similar for the branded and generic portfolios.

The extent of wealth loss, therefore, is not sensitive to our measure of research intensity. One interpretation of this result is that health care reform was in fact expected to affect R&D activity but was also expected to hurt generic manufacturers in other ways. For example, if health care reform effectively limited the prices branded manufacturers could charge, that should also hurt firms who manufacture generic substitutes for those branded products. This scenario, of course, implies that the generic portfolio is not an appropriate comparison group for ascertaining the impact of health care reform on R&D. Although we offered the generic manufacturers as a comparison group, we are aware of the possible problems, and so we are hesitant to draw sweeping policy conclusions based on this evidence. Nonetheless, we could find no evidence that health care reform would have adversely affected R&D.

Since the branded and generic portfolios display similar patterns, in the remainder of this article we will concentrate on the branded results.

C.   Traditional Event Study

Given that we can identify this series of potentially important events from contemporary news accounts, a natural alternative to the isotonic regression would be to perform a series of traditional event studies, cumulate the resulting estimated effects on stock prices, and compare that total effect and pattern of incorporation to what we estimate from the isotonic regression.

Table 2 presents results for the 16 events listed in the legend to Figure 3,

using 1-day and 7-day event windows.[78] When we cumulate the effects of these individual events, allowing for compounding, we obtain a total loss of 7.9 percent (with a standard error of 3.3 percent) for 1-day windows. The reported coefficients for the 7-day window are interpreted as the average effect for each of the 7 days, and so to obtain a total effect we multiply each coefficient by seven and then compound. The total loss implied by the 7-day window is 27.1 percent (with a standard error of 8.5 percent).

Compare these results with the estimated loss from the isotonic regression of 52.4 percent. Even the 7-day window misses much of the information incorporation. In other words, this gradual leakage of information does not seem to be merely the result of 1- or 2-day market anticipation of formal announcements. Rather, there are a multitude of events—subtle shifts in public perception, gradual filling in of plan details, and unveiling of political positions—that the traditional event study is not well equipped to capture. The traditional event study not only misses this multitude of small events, but in the case of the 1-day windows, the identified events were not even jointly significant in their impact.

Note also that the event study identifies some events as having a positive effect.[79] The isotonic regression, however, constrains the expected price path to be monotonic and so would treat such movements as noise.

To facilitate comparison of the two methods, especially the patterns of information incorporation over time that they imply, we constructed price paths based on the event study results (see Figure 5). The cumulative effect is smaller than that of the isotonic regression, of course, but the patterns—rates of decline in various periods—are also quite different. This result is not surprising given that so much of the information incorporation occurs away from our 16 identifiable events.

D.   Cumulative Abnormal Returns

Another alternative would be simply to plot the CARs over time. This method is used extensively for detecting broad patterns in stock price movements, one of our main goals. Our analysis differs from such a plot in three ways. First, by using market-adjusted prices, not CARs, as the basis for our estimated expected price path, we take care of the well-known problem that adding returns does not compound losses and gains appropriately. Therefore, unlike a CAR plot, one can measure the percentage decline in the market-adjusted pharmaceutical portfolio by simply referring to the endpoints of the isotonic regression (or market-adjusted price series). Second, we restrict all movements in the expected price to be in one direction, negative in this case. This restriction is consistent with our notion that since ex post the evolution of the Clinton plan was bad news for pharma-

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[78] The 7-day window is centered on the event date.

[79] One event, President Clinton attacking pharmaceutical companies for high prices, is positive and significant with the 7-day window. All other positive movements are not significant.
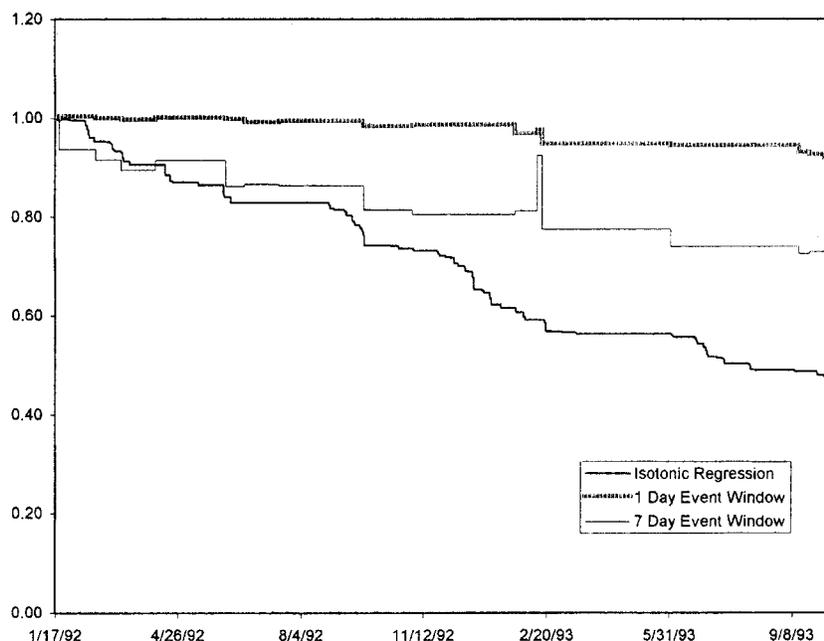
FIGURE 5.—Isotonic regression and traditional event study

ceutical stocks, we are interested only in when that information was incorporated into prices. By imposing monotonicity and conducting an isotonic regression, we extract fundamentally different information from the data than a CAR plot can reveal. Third, the estimated expected price path is smoother than the CAR plot, so, like any nonparametric estimator, we have distilled out some noise and produced a smoothed plot, which is easier to interpret visually. Moreover, our approach produces the correct standard errors for inference.[80]

These three differences are illustrated quite clearly in Figure 6. Figure 6 presents our expected price path, the market-adjusted prices we used to estimate it, and the CAR plot. The effect of compounding, especially, is quite evident. The largest discrepancy between the market-adjusted prices and the estimated expected price path is approximately March through May of 1993. One might feel that the isotonic regression distills out too much here, treating interesting stock price movements as noise. In particular, the ups and downs of the market-adjusted prices could be due to changes in the perceived composition and political prospects of the Clinton plan, as viewed by contemporary market participants. John-

[80] Applied researchers may select the estimation period after having looked at some initial CAR plots. Researchers Stephen J. Brown and Jerold B. Warner (Measuring Security Price Performance, 8 J. Fin. Econ. 205 (1980)), noted the dangers of conducting inference by "eyeballing" CAR plots.
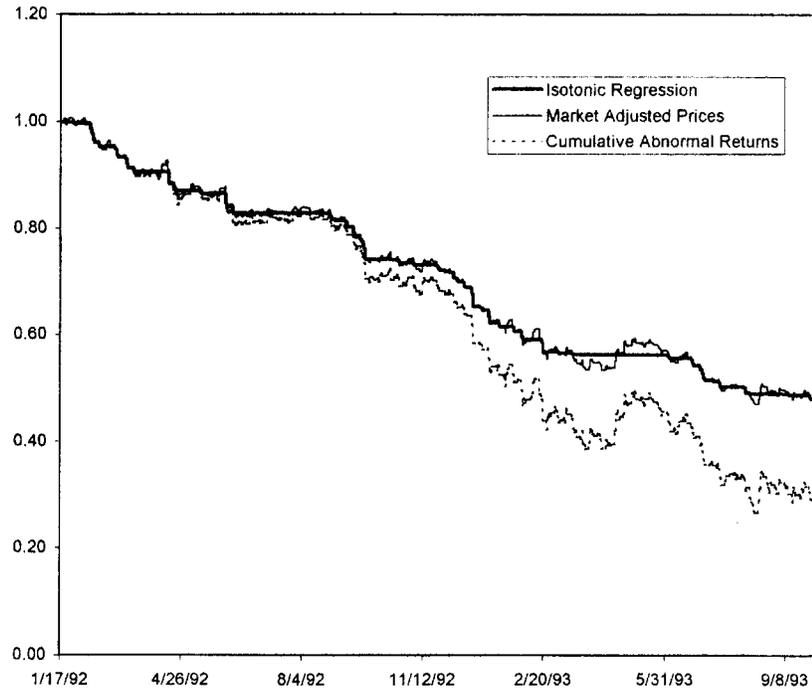
FIGURE 6.—Isotonic regression and CAR plot

son and Broder[81] note that April and May 1993 were marked by politically damaging (and often erroneous) leaks about details of the HCTF's plan, distractions of political energy from health care to the budget battle, and adverse press as the HCTF missed President Clinton's original 100-day deadline for producing a plan.[82] These developments could account for the rise in market-adjusted prices from April 8 to May 21. Nonetheless, the information content of those developments turned out to be transitory, as reflected in the subsequent continued downturn in prices.[83]

E.   Reverse Event Study

When comparing our estimation and a traditional event study, we noted that an event study performed with our set of identifiable intermediate events still

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[81] See Johnson & Broder, *supra* note 30.

[82] See *id.* at 135–46.

[83] Thus for our purposes it is appropriate to treat these movements as noise, although for other purposes they could be of interest.

TABLE 3

REVERSE EVENT STUDY

Date	Movement in Market-Adjusted Price (%)	Event
June 2, 1992	−3.41	Bristol-Myers Squibb earnings forecast
December 23, 1992	−3.54	None
February 19, 1993	−3.97	Expanded Accupril use; Glaxo profits up
April 20, 1993	3.15	Joint AIDS research; free Paxil
April 27, 1993	3.63	Shift in thinking of Healthcare Task Force[a]
August 18, 1993	3.15	None

[a] Event associated with health care reform.

missed much of the information incorporation. One possibility is that it was incorporated through a series of leaks, shifts in perception, events so small that they are ex post unidentifiable. Another possibility is that we could have done a more thorough job of identifying events. What we did to address this concern was to find large movements in the pharmaceutical portfolio price during this period and see if we can link them with relevant events, either connected with health care reform or not.[84] This exercise can also help demonstrate that the declines that we estimate are due to health care reform, as opposed to other news events during this period. Most alternate explanations for the decline in pharmaceutical prices should be captured in particular events. For example, major FDA regulatory decisions are closely guarded secrets until they are publicly released, as are material news about a company's prospects, such as its quarterly earnings announcements. So gradual incorporation of information is unlikely to be important for these developments.

We first identified all of the dates for which the market-adjusted price of the branded pharmaceutical portfolio rose or fell more than 3 percent. There were 6 such days between January 19, 1992, and October 4, 1993 (see Table 3). Interestingly, three of the six large movements were increases despite the precipitous decline of market-adjusted prices over this period. Note that we have identified large movements in market-adjusted prices, not actual prices. There certainly were other days that saw large movements in pharmaceutical stock prices that were correlated with market movements and, therefore, were not large in a market-adjusted sense.

We then looked back at contemporary news stories to see if we could find events that could account for the large movements we observed. We looked only for news stories appearing on the day of and the day after each large movement. All six big movements occurred on days that were preceded by trading days, so

[84] This exercise is in the spirit of David M. Cutler, James M. Poterba, & Lawrence H. Summers (What Moves Stock Prices? 15 J. Portfolio Mgmt. 4 (1989)), which identifies the 50 largest postwar stock market movements and notes that a minority of them seemed to be precipitated by news events.

any big stories appearing in newspapers on earlier days would have been traded on already. We looked at the day after each large movement because news could have been reported publicly during the day of the large movement, traded on, and then only appeared in print the next morning.

In summary, we found that most of the large movements were attributed to some cause in press accounts the following day but that these accounts were largely unconvincing, either because no news had been reported or because the news seemed to be of a magnitude unlikely to account for a 3 percent change in an entire pharmaceutical portfolio. For only one movement did we find a press report of relevant news on the day of the movement as well as an account the following day verifying the news' effect. That event was related to health care reform.

1. *Reported on June 2 and 3, 1992.*   After the large drop on June 2, it was reported that an announcement by Bristol-Myers Squibb revising downward earnings expectations was the cause.[85]

2. *Reported on December 23 and 24, 1992.*   The large stock price decrease was described as being caused by drug companies not responding quickly enough to stop the erosion of sales growth and profit margins.[86] We interpret this as a proffered explanation rather than reporting of precipitating news.[87]

3. *Reported on February 19 and 20, 1993.*   An advisory panel of the FDA recommended expanded use of Warner-Lambert's blood pressure drug Accupril.[88] Glaxo reported "surprisingly buoyant" first-half pretax profit.[89] Both of these reports would have caused movement opposite to the one we observed.

4. *Reported on April 20 and 21, 1993.*   Fifteen major pharmaceutical companies agreed to conduct joint research on AIDS drugs. This move is applauded by AIDS activists and public health officials.[90] Smithkline Beecham said it would provide free doses of its antidepressant Paxil to poor patients.[91]

5. *Reported on April 27 and 28, 1993.*   The *Wall Street Journal* reported that "[t]he Clinton Administration is thinking increasingly about entering into cost-control agreements with the health industry instead of dictating how much

[85] Craig S. Smith, Industrial Average Declines 17.11 Due to Bad News for Drug Stocks, Wall St. J., June 3, 1992, at C2.

[86] Craig S. Smith, Stocks Drift as Christmas Nears; Drug Sector Sees Heavy Selling, Wall St. J., December 24, 1992, at 14.

[87] Even if we were to consider it news completely unrelated to health care reform, such as the growth of PBMs, that still accounts for only a 3.5 percentage point decline in the market-adjusted price of the pharmaceutical portfolio.

[88] Warner-Lambert Co.: FDA Panel Recommends Expanded Use for Product, Wall St. J., February 19, 1993, at B4 (Technology Brief).

[89] Stephen D. Moore, Glaxo Posts Strong 1st-Half Results, Denies Strategy Shift Is Contemplated, Wall St. J., February 19, 1993, at A10.

[90] Michael Waldholz, Medicine: Top Firms Plan Joint Testing of AIDS Drugs, Wall St. J. (Europe), April 20, 1993, at B1.

[91] SmithKline to Provide Anti-depressant Drug for Needy Patients, Wall St. J. (Europe), April 21, 1993, at 12.

doctors, hospitals and drug companies can charge."[92] A report of such a shift in thinking was likely to be good news for pharmaceutical stocks. In fact it was reported the following day that a burst of stock buying was "fueled in part by health care reform news out of Washington."[93] Here, a piece of news with a potentially large effect on pharmaceutical stocks was reported on the day in which we observed a large movement of pharmaceutical stocks (in the expected direction) and was also cited the following day as a reason for that large movement. This is the one case of the six where we feel fairly confident in attributing the price movement to a particular event.

6. *Reported on August 18 and 19, 1993.*   Nothing.

Note that the one information-related movement involved the Clinton administration's shift in the focus of their cost-containment strategy. This reinforces our conclusion that the goals and evolving details of cost containment were significant factors affecting pharmaceutical stockholder wealth over this period. Although this particular shift was reported in the newspaper, and so perhaps could have been identified by a researcher, we should point out that it is not an event in the traditional sense but rather the reporting of a shift in focus. This is precisely the type of subtle information leakage we would hope to capture were it persistent and in the correct direction.

V.   CONCLUSION

Much of the dramatic decline in the estimated price path of pharmaceutical stocks coincided with the Clinton plan's gradual inclusion of strategies to contain health care costs. Pharmaceutical stocks were harmed by health care reform developments that emphasized cost containment. Moreover, further declines accompanied details about the Clinton plan's system of "managed competition," even absent direct controls on pharmaceutical prices. The stock market judged that the bargaining between cost-conscious health insurance purchasing cooperatives and health care providers would result in much lower prices for pharmaceutical companies than those prevailing previously.

Interestingly, similar concerns may be operating as pharmaceutical companies react warily to President Clinton's June 1999 proposal to extend prescription drug coverage to Medicare recipients. Price controls are not part of the proposal and have been explicitly ruled out by White House officials. Instead, costs would be held down by having the government hire private "pharmacy benefit managers" to negotiate discounts from drug manufacturers.[94] Nonetheless, pharmaceutical companies apparently believe that price controls would eventually be imple-

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[92] Rick Waltzman & Hilary Stout, Voluntary Pacts on Health Care Costs Are Considered: White House Doesn't Want to Set Fees, but Seeks Powers for Compliance, Wall St. J., April 27, 1993, at A2.

[93] Doug Pettit, Health-Care Reform News Sends Drug Stocks Up; Industrials Rise, Wall St. J., April 28, 1993, at C2.

[94] Pear, *supra* note 61.

mented or that "negotiated" discounts on a major portion of their sales would hurt their profits as much as direct price controls.[95]

Through our approach, researchers interested in a policy issue can better assess the timing and impact of a policy change on stock prices. Although we have not emphasized it in this application, a researcher might instead be interested in the legislative or regulatory process itself. So a researcher studying the important veto points in the legislative process could use isotonic regression to examine the information impact on relevant firms of different parts of the legislative process, such as the submission of a bill, the assignment of it to a committee, and the movement of the bill from the committee to the floor.

Finally, although we have emphasized the application of isotonic regression to evaluating public policy changes, in principle this technique could be applied to any environment in which gradual incorporation of information is an important feature. In particular, in settings such as corporate control contests, information often leaks out before a formal announcement by private parties. We intend to explore these issues in future work.

APPENDIX

ISOTONIC REGRESSION

Our data consist of stock prices measured at discrete intervals. There is a true, unobserved, continuous, monotonic process of information revelation about a larger event. This information is incorporated into stock prices at discrete intervals (although different discrete intervals than ones at which we observe the stock prices). Stock prices reflect both this discrete incorporation of the continuous information flow as well as a random (serially correlated) error, containing effects of noise traders, information about other unrelated events, misinformation about the large event in question, and so forth. It is that continuous process of information revelation that we would like to estimate using isotonic regression. Isotonic regression is a least-squares estimation method that does not impose functional form restrictions on the regression function but does impose more general shape restrictions: that the function be nondecreasing and that the function take a step form. The true model is $y = f(x) + \varepsilon$, where, in our context, y is a stock price (or market-adjusted price or price of a portfolio of stocks, and so forth) and x is time. Observations occur at $\{x_1, x_2, \ldots, x_n\}$, for us, daily intervals. Isotonic regression gives us the regression function $\hat{f}(x)$ such that

$$\hat{f}(x) = \mathrm{argmin}_{f(x)} \sum_{i=1}^{n} [y_i - f(x_i)]^2,$$

subject to

$$\hat{f}(x_j) \geq \hat{f}(x_k) \quad \text{for } x_j < x_k$$

and

$$\hat{f}(x) = 0 \quad \forall\, x \notin \{x_1, x_2, x_3, \ldots, x_n\}.$$

[95] Robin Toner, Prescription Drug Coverage Dominates Fight Brewing on Medicare Overhaul, N.Y. Times, June 16, 1999, at A1.

The second restriction, that $\hat{f}$ be constant between observations, exists only to ensure uniqueness. The restriction, however, has an interesting interpretation in a finance context because the actual price series does, of course, follow a (nonmonotonic) step pattern. Antitonic regression is defined similarly, but where the regression function is constrained to be nonincreasing.[96] Like other nonparametric estimators, such as kernel regression estimators, the form of the regression function $\hat{f}(x)$ is unspecified. Unlike other nonparametric estimators, one does not choose a smoothing parameter in order to perform the estimation. Since a principle output of this and other nonparametric estimators is a graphical representation of the relationship, smoothness matters because the presence of a lot of "bumps" masks the overall shape. The restrictions placed on $\hat{f}(x)$ produce an automatically smoothed regression function in the sense that it has no "bumps" (up and down or down and up movements). It may still have a lot of steps (potentially one for each data point, but typically many fewer) but will still look smooth and easily reveal overall shape. Implementation is through a simple algorithm:[97] Denote "pools" of observations l_j, and define $\hat{y}_j = (1/|l_j|)\sum_{y_i \in l_j} y_i$, where $|\cdot|$ is the number of elements in a set. Place each observation in its own pool initially, so the $\hat{y}_j$ terms are simply the y_i terms. These initial pools will, of course, be ordered by time (or, more generally, the regressor). Compare the pool associated with the earliest time with that associated with the second-earliest time. If $\hat{y}_1 < \hat{y}_2$, then leave the pools intact and compare the second pool to the third. Otherwise, combine the two pools and compute a new $\hat{y}_1$, which will then be used in the next comparison. Continue sequentially comparing pools in this fashion until all neighboring pools have been compared. If, on the last pass through the pools, any pools were combined, repeat the process. If not, the estimation is complete. The isotonic regression of y on x is then given by the $\hat{y}_j = \hat{f}(x_j)$ generated by the final pass through of the pools. Note that for a continuous and nonincreasing true conditional mean function $f(x)$ (along with some regularity conditions involving the x terms), $\hat{f}(x)$ is pointwise consistent for $f(x)$.[98] A question arises, perhaps particular to our empirical setting, of how to interpret the location and magnitude of the steps. In particular, we implicitly attach meaning to each step as an incorporation into a stock price of partial information about a larger event. Such an interpretation is valid because pointwise consistency of $\hat{f}$ implies that $\hat{f}(x_k) - \hat{f}(x_j)$ is converging in probability to $f(x_k) - f(x_j)$. In other words, if f is very steep in a particular interval, then so will $\hat{f}$ be asymptotically. Computing standard errors analytically, instead of through some simulation or bootstrap procedure, for isotonic regression is not simple. Interested readers can refer to results that we summarize and reference below. H. D. Brunk[99] showed that as the number of observation points n on a closed interval goes to infinity, then

$$n^{1/3}[\hat{f}(x_0) - f(x_0)]$$

has a nondegenerate distribution. This result allows for heteroskedasticity (but not serial correlation) of the errors and holds only when $(\partial f/\partial x)(x_0)$ is positive. (The rate of convergence is actually faster for points at which f is flat.)[100] While norming by $n^{1/3}$ gives a

[96] In the text of the paper we use the more familiar term "isotonic regression" to describe our technique, although we actually perform an antitonic regression.

[97] The description is of the "up-and-down blocks" algorithm. R. E. Barlow *et al.*, Statistical Inference under Order Restrictions 72 (1972).

[98] See *id.* at 112, for a precise statement of the relevant theorem and other details.

[99] H. D. Brunk, Estimation of Isotonic Regression, in Nonparametric Techniques in Statistical Inference 177 (M. L. Puri ed. 1970).

[100] See F. T. Wright, The Asymptotic Behavior of Monotone Regression Estimates, 9 Annals Stat. 433 (1981).

nondegenerate distribution, it does not give a normal distribution. In particular, if $\sigma^2(\cdot)$ is the conditional variance of y, then

$$\left[\frac{2n}{\sigma^2(x_0)f'(x_0)}\right]^{1/3} [\hat{f}(x_0) - f(x_0)]$$

converges in distribution to $V/2$, where V is the random value at which $W(t) - t^2$ attains its maximum. ($W(t)$ is a standard Wiener process with $W(0) = 0$.)[101] The last piece one needs comes from Herman Chernoff,[102] who shows that V has density

$$g(v) = \frac{1}{2}u_x(v^2, v)u_x(v^2, -v),$$

where u_x is a partial derivative of the function

$$u(x, t) = P\{W(v) > v^2 \quad \text{for some } v > t | W(t) = x\}.$$

In other words, the difference between an isotonic regression estimate at point x_0 and the true value of the regression function at x_0 converges to a distribution at rate $n^{1/3}$ (compared with $n^{1/2}$ for most parametric estimators). Its limiting distribution, while symmetric, is not normal, does not have a closed form, and is not tabulated (as far as we know). Computing analytical confidence intervals would involve estimating integrals of this distribution through simulation, for instance. Note also that these theoretical results do not allow for serial correlation in the error. For these various reasons, we suggest bootstrapping standard errors. Our bootstrapping procedure, which we describe below, is based on the assumption of first-order serial correlation (which nests the case of no serial correlation, of course) but could be modified to allow for other error structures. The assumption of first-order serial correlation gives us the following relationship among errors, ε_i: $\varepsilon_i = \rho\varepsilon_{i-1} + \eta_i$, where $|\rho| < 1$ and η_i are independent and identically distributed with $E(\eta_i) = 0$ and $\text{var}(\eta_i) = \sigma_\eta^2$. Our first step is estimating the isotonic regression $\hat{f}(x_i)$ and obtaining residuals $\hat{\varepsilon}_i$. We regress $\hat{\varepsilon}_i$ on $\hat{\varepsilon}_{i-1}$ to obtain $\hat{\rho}$. Then we let $\hat{\eta}_i = \hat{\varepsilon}_i - \hat{\rho}\hat{\varepsilon}_{i-1}$. We then have $n - 1$ $\hat{\eta}_i$ terms from which we will bootstrap. We draw one $\hat{\eta}_i$, call it $\hat{\eta}_{ib}$, with replacement for each observation, form the $\hat{\varepsilon}_{ib} = \hat{\eta}_{ib} + \hat{\rho}\hat{\varepsilon}_{i-1b}$, and finally form the $y_{ib} = \hat{f}(x_i) + \hat{\varepsilon}_{ib}$. We performed this exercise 5,000 times, estimated the isotonic regression on each of those 5,000 "new" data sets, and then calculated pointwise 95 percent confidence intervals by using the 2.5 and 97.5 percentiles of the distributions of isotonic regression estimates for each point. In our application, y is the market-adjusted price, x is time, and f is the continuous, monotonic process of information revelation about the larger event. The estimated expected price path is then given by $\hat{f}(x)$.

BIBLIOGRAPHY

Aaron, Henry J. "The Problem That Won't Go Away." In *The Problem That Won't Go Away: Reforming U.S. Health Care Financing*, edited by Henry J. Aaron, pp. 1–12. Washington, D.C.: Brookings Institution, 1996.

Ball, Clifford A., and Torous, Walter N. "Investigating Security-Price Performance in the Presence of Event-Date Uncertainty." *Journal of Financial Economics* 22 (1988): 123–53.

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[101] See Sue Leurgans, Asymptotic Distributions of Slope-of-Greatest-Convex-Minorant Estimators, 10 Annals Stat. 287 (1982).

[102] Herman Chernoff, Estimation of the Mode, 16 Annals Inst. Stat. & Math. 31 (1964).

Barlow, Richard E., *et al. Statistical Inference under Order Restrictions.* New York: John Wiley and Sons, 1972.

Bizjak, John M., and Coles, Jeffrey L. "The Effect of Private Antitrust Litigation on the Stock-Market Valuation of the Firm." *American Economic Review* 85 (1995): 436–61.

Brown, Stephen J., and Warner, Jerold B. "Measuring Security Price Performance." *Journal of Financial Economics* 8 (1980): 205–58.

Brunk, H. D. "Estimation of Isotonic Regression." In *Nonparametric Techniques in Statistical Inference,* edited by M. L. Puri, pp. 177–95. Cambridge: Cambridge University Press, 1970.

Campbell, John Y.; Lo, Andrew W.; and MacKinlay, A. Craig. *The Econometrics of Financial Markets.* Princeton, N.J.: Princeton University Press, 1997.

Chernoff, Herman. "Estimation of the Mode." *Annals of the Institute of Statistics and Mathematics* 16 (1964): 31–41.

Cutler, David M. "Tax Reform and the Stock Market: An Asset Price Approach." *American Economic Review* 78 (1988): 1107–17.

Cutler, David M.; Poterba, James M.; and Summers, Lawrence H. "What Moves Stock Prices?" *Journal of Portfolio Management* 15 (1989): 4–12.

Ellison, Sara Fisher. "What Prices Can Tell Us about the Market for Antibiotics." Unpublished manuscript. Cambridge: Massachusetts Institute of Technology, 1998.

Ellison, Sara Fisher, and Mullin, Wallace P. "Economics and Politics: The Case of Sugar Tariff Reform." *Journal of Law and Economics* 38 (1995): 335–66.

Ellison, Sara Fisher, and Wolfram, Catherine. "Pharmaceutical Prices and Political Activity." Unpublished manuscript. Cambridge: Massachusetts Institute of Technology and Harvard University, April 2000.

Fidelity Investments Prospectus, Fidelity Select Portfolios, April 29, 1999, p. P-19.

Fuchs, Victor R. "The Future of Health Economics." *Journal of Health Economics* 19 (2000): 141–57.

Grossman, Gene M., and Levinsohn, James A. "Import Competition and the Stock Market Return to Capital." *American Economic Review* 79 (1989): 1065–87.

Hausman, J. A.; Abrevaya, Jason; and Scott-Morton, F. M. "Misclassification of the Dependent Variable in a Discrete-Response Setting." *Journal of Econometrics* 87 (1998): 239-269.

Johnson, Haynes, and Broder, David. *The System: The American Way of Politics at the Breaking Point.* New York: Little, Brown & Company, 1997.

Leurgans, Sue. "Asymptotic Distributions of Slope-of-Greatest-Convex-Minorant Estimators." *Annals of Statistics* 10 (1982): 287–96.

MacKinlay, A. Craig. "Event Studies in Economics and Finance." *Journal of Economic Literature* 35 (1997): 13–39.

Malatesta, Paul H. "The Wealth Effect of Merger Activity and the Objective

Functions of Merging Firms." *Journal of Financial Economics* 11 (1983): 155–81.

Malatesta, Paul H., and Thompson, Rex. "Partially Anticipated Events." *Journal of Financial Economics* 14 (1985): 237–50.

Mitchell, Mark L., and Stafford, Erik. "Managerial Decisions and Long-Term Stock Price Performance." Unpublished manuscript. Chicago: University of Chicago, 1997.

Pakes, Ariel. "On Patents, R&D, and the Stock Market Rate of Return." *Journal of Political Economy* 93 (1985): 390–409.

Rose, Nancy L. "The Incidence of Regulatory Rents in the Motor Carrier Industry." *Rand Journal of Economics* 16 (1985): 299–318.

Salinger, Michael. "Standard Errors in Event Studies." *Journal of Financial and Quantitative Analysis* 27 (1992): 39–53.

Salinger, Michael. "Value Event Studies." *Review of Economics and Statistics* 74 (1992): 671–77.

Salinger, Michael. "When Do Peeping Toms See Something (Statistically) Significant?" Unpublished manuscript. Boston: Boston University School of Management, 1994.

Schweitzer, Stuart O. *Pharmaceutical Economics and Policy.* New York: Oxford University Press, 1997.

Schwert, G. William. "Using Financial Data to Measure Effects of Regulation." *Journal of Law and Economics* 24 (1981): 121–58.

Thomas, Lacy Glenn. "Industrial Policy and International Competitiveness in the Pharmaceutical Industry." In *Competitive Strategies in the Pharmaceutical Industry,* edited by Robert B. Helms, pp. 107–29. Washington, D.C.: American Enterprise Institute Press, 1996.

Weisbrod, Burton A. "The Health Care Quadrilemma: An Essay on Technological Change, Insurance, Quality of Care, and Cost Containment." *Journal of Economic Literature* 29 (1991): 523–52.

Willard, Kristen L.; Guinnane, Timothy W.; and Rosen, Harvey S. "Turning Points in the Civil War: Views from the Greenback Market." *American Economic Review* 86 (1996): 1001–18.

White House Domestic Policy Council. *The President's Health Security Plan.* New York: Times Books, 1993.

Wright, F. T. "The Asymptotic Behavior of Monotone Regression Estimates." *Annals of Statistics* 9 (1981): 443–48.