QUANTITATIVE ANALYSIS OF COORDINATED EFFECTS

WILLIAM E. KOVACIC
ROBERT C. MARSHALL
LESLIE M. MARX
STEVEN P. SCHULENBERG*

Mergers involving rival firms in concentrated markets tend to increase opportunities for coordinated behavior.[1] This phenomenon is a long-

* William E. Kovacic, Commissioner, Federal Trade Commission, and Professor, George Washington University Law School (on leave); Robert C. Marshall, Professor of Economics, Penn State University; Leslie M. Marx, Professor of Economics, Duke University; Steven P. Schulenberg, Partner, Bates White, LLC. The authors thank the Human Capital Foundation (http://www.hcfoundation.ru) for support. The authors thank William Adkinson, Malcolm Coate, Pat DeGraba, Jonathan Gleklen, Paul Johnson, George Rozanski, Michael Salinger, four anonymous referees, seminar participants at the Federal Trade Commission and the 2006 Bates White Antitrust Conference for valuable comments, and the participants at the 2006 Fordham Conference on International Antitrust Law and Policy (where the companion piece to this article, William E. Kovacic, Robert C. Marshall, Leslie M. Marx, & Steven P. Schulenberg, *Coordinated Effects in Merger Review: Quantifying the Incentives to Collude*, *in* 2006 FORDHAM COMPETITION L. INST. 271 (Barry Hawk ed., 2007) was presented). The views expressed are those of the authors and do not necessarily reflect the views of the Federal Trade Commission or other individual Commissioners. Although this research continued while Marx was on leave from Duke University and serving as Chief Economist at the Federal Communications Commission, the views expressed are those of the authors and do not necessarily reflect the views of the Federal Communications Commission, its staff, or Commissioners.

[1] The early literature in industrial organization discusses how, in industries with small numbers of firms, firms might be expected to recognize their mutual interdependence and that one might expect relatively more collusive outcomes in industries with relatively fewer firms. *See* EDWARD H. CHAMBERLIN, THE THEORY OF MONOPOLISTIC COMPETITION (1933); Joseph S. Bain, *Relation of Profit Rates to Industry Concentration: American Manufacturing, 1936–1940*, 65 Q.J. ECON. 293 (1951); George J. Stigler, *A Theory of Oligopoly*, 72 J. POL. ECON. 44 (1964). Later work provides support for the idea that the competitiveness of an industry with a small number of firms can be expected to be increasing in the number of firms. *See* Reinhard Selten, *A Simple Model of Imperfect Competition, Where 4 Are Few and 6 Are Many*, 2 INT'L J. GAME THEORY 141 (1973); Steffen Huck, Hans-Theo Normann & Jörg Oechssler, *Two Are Few and Four Are Many: Number Effects in Experimental Oligopolies*, 53 J. ECON. BEHAVIOR & ORG. 435 (2004); William E. Kovacic, Robert C. Marshall, Leslie M. Marx & Matthew E. Raiff, *Lessons for Competition Policy from the Vitamins Cartel*, *in* THE POLITICAL ECONOMY OF ANTITRUST ch. 6 (Vivek Ghosal & Johann Stennek

standing focus of attention for merger control policy.[2] The Horizontal Merger Guidelines of the Federal Trade Commission and the Department of Justice recognize this possibility as a central concern.[3] The Merger Guidelines point to a need to understand the effects of a merger on the incentives for, payoffs from, and feasibility of coordinated behavior.[4] They also point to a need to understand the effects of coordinated behavior on the deadweight loss associated with a merger and, perhaps more relevant from the perspective of social policy, the decrease in consumer surplus associated with a merger.[5]

The Merger Guidelines' treatment of coordinated effects focuses on the capacity of a merger to increase coordination by firms that remain in the relevant market with respect to price, quality, or other dimensions of competition.[6] Section 2.1 of the Merger Guidelines states that "[c]oordinated interaction is comprised of actions by a group of firms that are profitable for each of them only as a result of the accommodating reactions of the others."[7] Successful coordination requires "reaching terms of coordination that are profitable to the firms involved and an ability to detect and punish deviations that would undermine the coordinated interaction."[8]

The Merger Guidelines' analysis of coordinated effects focuses chiefly on industry conditions that would facilitate the completion of three tasks—the formulation of a consensus, the detection of deviations from the consensus, and the punishment of cheaters—that are ingredients to

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eds., 2007). For details of modern cartel structures, see the European Commission decisions in price-fixing (Article 81) cases, such as those cited in note 13 *infra*. For older case studies, see, for example, GEORGE W. STOCKING & MYRON W. WATKINS, CARTELS IN ACTION: CASE STUDIES IN INTERNATIONAL BUSINESS DIPLOMACY (1946).

[2] *See* ANDREW I. GAVIL, WILLIAM E. KOVACIC & JONATHAN B. BAKER, ANTITRUST LAW IN PERSPECTIVE: CASES, CONCEPTS AND PROBLEMS 518–35 (2d ed. 2008) (discussing merger policy's concern with coordinated effects); Marc Ivaldi, Bruno Jullien, Patrick Rey, Paul Seabright & Jean Tirole, *The Economics of Tacit Collusion: Implications for Merger Control*, *in* THE POLITICAL ECONOMY OF ANTITRUST, *supra* note 1, ch. 8 (reviewing how merger policy accounts for possibilities of tacit collusion in post-merger period); *see generally* U.S. Dep't of Justice, 1968 Merger Guidelines (using four-firm concentration ratio as a guide to policy and identifying one goal of enforcement policy as "preventing any company or small group of companies from obtaining a position of dominance in a market"), *available at* http://www.usdoj.gov/atr/hmerger/11247.pdf.

[3] U.S. Dep't of Justice & Federal Trade Comm'n, Horizontal Merger Guidelines § 2.1 (1992, rev. 1997) [hereinafter Merger Guidelines], *available at* http://www.ftc.gov/bc/docs/horizmer.htm.

[4] *Id.*

[5] *Id.* § 0.1 (saying "the result of the exercise of market power is a transfer of wealth from buyers to sellers or a misallocation of resources").

[6] *Id.* § 2.1.

[7] *Id.*

[8] *Id.*

successful coordination.[9] To this end, the U.S. antitrust agencies "not only assess whether the market conditions for viable coordination are present, but also ascertain specifically whether and how the merger would affect market conditions to make successful coordination after the merger significantly more likely."[10] The assessment of post-merger performance outcomes "includes an assessment of whether a merger is likely to foster a set of common incentives among remaining rivals, as well as to foster their ability to coordinate successfully on price, output, or other dimensions of competition."[11]

Like the Merger Guidelines, our analysis is concerned with the incentives of firms, but with a somewhat different emphasis. Our approach focuses on how a merger affects the profitability of collusion, which affects firms' incentives to solve the tasks (consensus building, detection, and punishment) that are ingredients for successful coordination. Our approach assumes that firms will try harder to solve the coordination tasks if the incremental profits from coordination are higher and if the incremental profits from deviations are lower, so that attempts to coordinate are more likely to succeed.

Firm behavior in an industry can range from the uncoordinated behavior associated with one-shot noncooperative interaction to explicit collusion where all the firms essentially function as one entity. Much of the economics literature on collusion focuses on collusion among all of the firms in an industry.[12] Intermediate behavior can involve collusion only among a subset of the firms. Despite the theoretical focus on all-inclusive collusion, there are many significant real-world examples of cartels that include only a subset of the firms in the industry.[13] In addi-

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[9] *See* U.S. Dep't of Justice & Federal Trade Comm'n, *Commentary on the Horizontal Merger Guidelines* 18–25 (2006) [hereinafter *Commentary on Merger Guidelines*], *available at* http://www.ftc.gov/os/2006/03/CommentaryontheHorizontalMergerGuidelinesMarch2006.pdf.

[10] *Id.* at 18.

[11] *Id.*

[12] Notable exceptions include Daniel A. Graham & Robert C. Marshall, *Collusive Bidder Behavior at Single-Object Second Price and English Auctions*, 95 J. POL. ECON. 1217 (1987); Daniel A. Graham, Robert C. Marshall & Jean-Francois Richard, *Differential Payments Within a Bidder Coalition and the Shapley Value*, 80 AM. ECON. REV. 493 (1990); Robert C. Marshall, Michael J. Meurer, Jean-Francois Richard & William Stromquist, *Numerical Analysis of Asymmetric First Price Auctions*, 7 GAMES & ECON. BEHAV. 193 (1994); and Robert C. Marshall & Leslie M. Marx, *Bidder Collusion*, 133 J. ECON. THEORY 374 (2007) (analyzing collusion among subsets of bidders at an auction). The emphasis on all-inclusive collusion may stem from the theoretical economics literature, which largely emphasizes the all-inclusive cartel since in the equilibrium of simple models there are often no reasons for a cartel to be less than all-inclusive.

[13] For example, the International Vitamins Cartel was not all-inclusive for many vitamins. *See* Case COMP/E-1/37.512—Vitamins, Comm'n Decision, 2001 O.J. (L 6) 1, ¶¶ 27,

tion, colluding firms may be more or less successful at suppressing rivalry among themselves and so cartels can have varying degrees of effectiveness. The probability and extent of collusion among a particular subset of firms will depend on features of the firms, the industry, and the market.[14] For example, a merger that eliminates a "maverick" may increase the probability of collusion among all the firms in the market.[15] The Merger Guidelines' concern regarding coordinated effects reflects the fact that when a merger changes the configuration of an industry, it can affect the probability of collusion among various subsets of firms in the industry.[16]

Current merger analysis of coordinated effects tends to focus on questions such as: Will the merger cause the Herfindahl-Hirschman Index (HHI) to rise substantially? Will the merger absorb a "maverick" firm or otherwise negatively affect a "maverick" firm? Will the merger allow conspirators to detect deviations by other conspirators more easily? Will the punishment of deviators be easier or more effective?[17] Although the

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30, 34, 38, 46, 123. Other examples include the following cartels—carbonless paper, choline chloride, citric acid, copper plumbing tubes, carbon brushes, food flavor enhancers, industrial tubes, methionine, rubber chemicals, and sorbates. With the exception of copper plumbing tubes and carbon brushes, the European Commission's decisions identify significant players in the market that are not included in the conspiracy. *See* Case COMP/E-1/36.212—Carbonless Paper, Comm'n Decision, 2004 O.J. (L 115) 1, ¶¶ 16–18; Case COMP/E-2/37.533—Choline Chloride, Comm'n Decision, ¶¶ 27–29, 42 (Sept. 12, 2004), *available at* http://ec.europa.eu/competition/antitrust/cases/decisions/37533/en.pdf; Case COMP/E-1/36.604—Citric Acid, Comm'n Decision, 2002 O.J. (L 239) 18, ¶¶ 35–36, 45; COMP/E-1/38.069 Copper Plumbing Tubes, Comm'n Decision, ¶¶ 25, 68 (Sept. 3, 2004) (summary at 2006 O.J. (L 192) 21), *available at* http://ec.europa.eu/competition/antitrust/cases/decisions/38069/en.pdf; Case C.38.359—Electrical and Mechanical Carbon and Graphite Products, Comm'n Decision, ¶ 37 (Dec. 3, 2003), *available at* http://ec.europa.eu/competition/antitrust/cases/decisions/38359/en.pdf; Case COMP/C.37.671—Food Flavour Enhancers, Comm'n Decision, 2004 O.J. (L 75) 1, ¶ 21; Case COMP/E-1/38.240—Industrial Tubes, Comm'n Decision, ¶¶ 43–52 (Dec. 16, 2003) (summary at 2004 O.J. (L 125) 50), *available at* http://ec.europa.eu/competition/antitrust/cases/decisions/38240/en.pdf; Case C.37.519—Methionine, Comm'n Decision, 2002 O.J. (L 255) 1, ¶¶ 36–40; Case COMP/F/38.443—Rubber Chemicals, Comm'n Decision, ¶ 33 (Dec. 21, 2005) (summary at 2006 (L 353) 50), *available at* http://ec.europa.eu/competition/antitrust/cases/decisions/38443/en.pdf; Case COMP/E-1/37.370—Sorbates, Comm'n Decision, ¶ 63 (Oct. 1, 2003), *available at* http://ec.europa.eu/competition/antitrust/cases/decisions/37370/en.pdf. In addition, the Merger Guidelines recognize the importance of maverick firms, which are portrayed as firms not wanting to join cartels. Merger Guidelines, *supra* note 3, § 2.12. *See also* Jonathan B. Baker, *Mavericks, Mergers, and Exclusion: Proving Coordinated Competitive Effects Under the Antitrust Laws*, 77 N.Y.U. L. REV. 135, 166–73 (2002) (describing how Northwest Airlines acted as a maverick against coordinated airline pricing in 2000).

[14] See, for example, the discussion and references in MASSIMO MOTTA, COMPETITION POLICY: THEORY AND PRACTICE 142–66 (2004).

[15] Baker, *supra* note 13, at 177–79.

[16] Merger Guidelines, *supra* note 3, § 2.1.

[17] *See generally id.*; *Commentary on Merger Guidelines*, *supra* note 9, at 18–25.

HHI is easy to calculate, the change in the Herfindahl from pre-merger to post-merger merely suggests the potential for incremental coordinated and unilateral effects issues. Since there is no direct and unambiguous definition, empirical or otherwise, for a "maverick" firm in the Merger Guidelines,[18] the second question can be largely ambiguous. The last two questions, although rooted in the Folk Theorem and the repeated game literature, result in "dinner party" stories, where qualitative conclusions, such as "fewer firms make coordinated interaction more likely," are the norm.[19]

Coordinated effects analysis could benefit from further development of a systematic framework with quantifiable content that provides a foundation for predicting post-merger conduct. The economics literature on cartel formation and success, like the enforcement policies it informs, does not focus on the changes in incremental incentives for coordinated behavior as a result of a merger, but rather concentrates attention on the factors affecting the difficulty of reaching collusive agreements, detecting deviations, and punishing them."[20] However, there is some literature that is directly applicable to merger analysis. Compte, Jenny, and Rey analyze how a merger's impact on the distribution of firms' capacities can affect whether tacitly collusive equilibria are feasible.[21] Vasconcelos analyzes how mergers increase or reduce cost asymmetries and thereby, respectively, inhibit or promote coordination.[22] Each of these papers focuses on a discrete shift in the feasibility of tacit collusion associated with a merger. In this article, we start from the

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[18] The Merger Guidelines define "maverick" firms as "firms that have a greater economic incentive to deviate from the terms of coordination than do most of their rivals (e.g., firms that are unusually disruptive and competitive influences in the market)." Merger Guidelines, *supra* note 3, § 2.12. It is unclear how one would formulate a statistical test for the null hypothesis that a given firm was a "maverick." One aspect of a "maverick" is clear: if not part of the merger, the participation of such firms in post-merger coordinated interaction will be relatively low. The explicit mention of mavericks in the Merger Guidelines suggests an explicit recognition that all-inclusive explicit collusion is far from the leading concern regarding post-merger coordinated interaction.

[19] *See* Baker, *supra* note 15, at 139 (describing the "dinner party story"). The early literature in industrial organization discusses how, in industries with small numbers of firms, firms might be expected to recognize their mutual interdependence and that one might expect relatively more collusive outcomes in industries with relatively fewer firms. *See supra* note 1.

[20] *See generally* Stigler, *supra* note 1 (providing the seminal analysis of the problems a successful cartel must overcome); DENNIS W. CARLTON & JEFFERY M. PERLOFF, MODERN INDUSTRIAL ORGANIZATION 123–44 (4th ed. 2005) (discussing the factors influencing cartel success).

[21] Olivier Compte, Frédéric Jenny & Patrick Rey, *Capacity Constraints, Mergers and Collusion*, 46 EUR. ECON. REV. 1 (2002).

[22] Helder Vasconcelos, *Tacit Collusion, Cost Asymmetries, and Mergers*, 36 RAND J. ECON. 39 (2005).

premise that firms respond to incentives. Payoffs drive behavior. The larger are the payoffs from coordinated behavior, the more likely are firms to incur the costs and risks associated with coordinating their behavior. From this perspective, quantifying the payoffs associated with post-merger collusion provides an important input into predicting the likelihood of coordinated effects.

There are difficulties in assessing the likely effectiveness of post-merger collusion. In the framework proposed in this article, we focus on the potential profits associated with collusion, where those potential profits are the profits from a maximally effective post-merger cartel. Thus, we evaluate the profits for a cartel that is able to maximize the total profits of all of its members. Our calculation of the potential profits from collusion provides a measure of the incentive for collusion.

Furthermore, we can calculate firms' payoffs associated with deviations from "perfect" collusion, which provides a measure of the stability of a post-merger cartel. These calculations allow us to assess the likelihood and stability of collusion among various subsets of firms in an industry, both before and after a merger. Thus, the calculations we suggest provide information that is potentially valuable in assessing whether post-merger coordination is likely and which post-merger firms have the greatest incentive to coordinate.

Our presentation proceeds in three parts. In Part I, we set the proposed analysis within the context of the merger enforcement under the Merger Guidelines. In Part II, we illustrate how this proposed analysis could have been applied in a past merger case, *Hospital Corporation of America v. FTC*.[23] We conclude in Part III with some observations about the future development of merger policy.

I. OVERVIEW OF PROPOSED ANALYSIS

Our analysis uses the techniques employed in standard unilateral effects analyses of proposed mergers. Such analyses investigate, in a static context, the impact of the proposed decrease in the number of industry participants on interfirm interaction. As the Merger Guidelines observe, "A merger may diminish competition even if it does not lead to increased likelihood of successful coordinated interaction, because merging firms may find it profitable to alter their behavior unilaterally following the acquisition by elevating price and suppressing output."[24]

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[23] 807 F.2d 1381 (7th Cir. 1986).

[24] Merger Guidelines, *supra* note 3, § 2.2.

Typical unilateral effect analyses investigate the impact on pricing of the reduction in the number of market participants by combining two participants (A and B).[25] If the standard unilateral effects analyses are extended to investigate the impact of combining A and B to form A+B, then they can be used to analyze how the merger affects the incentives of any of the post-merger firms to collude, e.g., by estimating the impact of combining the newly combined A+B firm with another firm, C. The analysis can consider all possible pairs of firms (e.g., C and D) in the post-merger market, and assess for any two firms the payoff from collusion. Extending this approach further, we can estimate the payoffs from collusion among any subset of firms in the market (e.g., A+B, C, and D). Collusion among larger groups of firms can be investigated as well. A comparison of these payoffs can inform authorities as to which combinations of firms in the post-merger market pose the greatest threat of coordination. As we show, we can obtain measures of the stability of various cartels and evaluate efficiency claims associated with a merger.

The process we propose in this article involves three steps. The first step is to select an appropriate model of competition. This might be quantity competition, differentiated products price competition, bidder competition within an auction or procurement, a discrete choice model, or some other model of competition that incorporates the salient features of a given industry. We do not mean to diminish the potential difficulty of this task, but the variety of well-studied models in the economics literature provides a range of choices,[26] and in many cases a subset of these will provide a reasonable fit with the reality of the market in question.

The second step is to fit and/or calibrate the model to the pre-merger market and the relevant features of the pre-merger firms, such as their market shares. Firms' market shares will be endogenous to a market model, and so the ability to fit a model to market shares provides a check on the overall usefulness of the model. In the application pro-

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[25] There can be exceptions. In *FTC v. Arch Coal, Inc.*, 329 F. Supp. 2d 109 (D.D.C. 2004), the proposed merger was coupled with a proposed divestiture. For this reason, the district court assumed that the proposed merger would not alter the number of firms in the relevant market. *Id.* at 114–15.

[26] *See, e.g.*, Patrick Bajari & Matt Kahn, *Estimating Housing Demand with an Application to Explaining Racial Segregation in Cities*, 23 J. BUS. ECON. STAT. 20 (2005) (estimating housing demand using a non-parametric hedonic home price function); Patrick Bajari, Jeremy T. Fox & Stephen P. Ryan, *Evaluating Wireless Carrier Consolidation Using Semiparametric Demand Estimation*, 6 QUANTITATIVE MKTG. & ECON. 299 (2008) (estimating demand for national wireless coverage using data on market share ranks and a semiparametric maximum score estimator); Steven Berry, James Levinsohn & Ariel Pakes, *Automobile Prices in Market Equilibrium*, 63 ECONOMETRICA 841 (1995) (estimating demand and supply for automobiles in a differentiated products model).

vided in Part II, we use a model of differentiated products price competition that generates linear demand functions. We then calibrate the model using the limited set of data available to us. Given more extensive data, one could work with relatively more sophisticated models involving more parameters and be more demanding as to the set of real-world data that the model is asked to replicate.

Within the fitted and/or calibrated competitive framework, the final step is to assess the merger's effects and the effects of various post-merger explicit collusion scenarios. Estimates for post-merger prices, output, revenue, profits, margins, market shares, etc., can be calculated. The profitability of perfect collusion among various subsets of firms can be evaluated, and within each potential cartel, the profitability of deviations from collusion can be calculated. Measures of consumer surplus and overall welfare can be calculated. Bounds on the efficiency improvements required to offset unilateral and coordinated effects can be estimated.

We do not intend our approach to displace any existing analysis. Instead, we envision it as a complement to existing unilateral effects analyses and non-quantitative coordinated effects analyses. The modeling choices and data required for our approach are not meaningfully different from those required for a competent unilateral effects analysis. Thus, once a unilateral effects analysis is in place, the calculations we suggest can be conducted with little incremental effort. An exception would be if the unilateral effects model does not adequately capture how collusion would occur, such as the case where bid rigging at procurements would be a central feature of a collusive arrangement, but where the details of procurement procedures and their effects on the implementation of collusion are not adequately captured by the unilateral effects analysis. In this case, other modeling issues would need to be addressed for the coordinated effects analysis.

The value to merger analysis from quantifying coordinated effects is potentially large. As we show, a basic quantification of how incentives of post-merger firms to collude and to cheat on a collusive agreement change following a merger can be achieved without extensive additional economic modeling beyond that required for a quantitative unilateral effects analysis. The calculations we propose may reveal that coordinated effects are a significant concern, or they may reveal that there is little concern. In cases where coordinated effects are a significant concern, the calculations may point to a specific subset of firms that pose the greatest risk for coordination.

Although the proposed analysis does not directly calculate a probability of collusion, it does quantify the potential incremental payoff to firms from collusion, which gives an indirect measure of the probability of collusion. Similarly, we propose calculations of the payoffs to firms from unilateral deviations from collusion, which provide an indirect measure of the sustainability of collusion. In providing these measures, this approach can help satisfy the greater evidentiary demands that various courts have placed upon competition agencies which seek to block mergers based on coordinated effects theories.[27]

Our analysis calculates the "potential" profits from collusion, which are the profits that would obtain if the firms involved behaved so as to maximize their joint profits. Such "perfect" collusion may be far from what the firms can achieve through tacit means. Since the profits from tacit collusion tend to be large exactly when the profits from "perfect" collusion are large, our measure of "potential" profits provides a relevant benchmark for evaluating the importance of coordinated effects. Even in cases where the profits from tacit and explicit collusion diverge, the calculations we propose offer upper bounds on the profitability of tacit collusion among various subsets of firms. In cases where those bounds are small, one can have greater confidence that coordinated effects are not a significant issue.

Our approach focuses on incentives. Because our approach identifies cases in which the potential profits from collusion are large, it identifies cases in which firms have a strong incentive to find solutions to the difficulties that firms face in achieving successful coordination. Firms often face formidable challenges not only in setting and monitoring fidelity to the terms of their plan, but also in coping with phenomena—such as defections by participants in the collaboration, competitive moves by non-participants, new entry, expansion by fringe firms, countermeasures by customers—that can place pressure on a collusive arrangement. The recitation of these obstacles obscures the willingness and diligence of firms to surmount them if the rewards are enticing. Moreover, recently published studies and other information about the operation of cartels has demonstrated that the enormous energy and creativity that firms devote to solving coordination problems associated with the legal forms of cooperation (e.g., joint ventures) can be applied to solving coordina-

[27] Notable cases in which courts have rejected government efforts to use coordinated effects theories to block mergers include *FTC v. Arch Coal, Inc.*, 329 F. Supp. 2d 109 (D.D.C. 2004), and *Airtours v. Commission*, Case T-342/99, 2002 E.C.R. II-2585 (Ct. First Instance).

tion problems that arise in illegal collaborative endeavors (e.g., price-fixing agreements).[28]

When using the measure of potential profitability to gauge the incentives of firms to collude, one must also consider the stability of the cartel in question. A merger that increases the potential profitability of collusion may simultaneously increase the incentives for firms to cheat on the collusive arrangement, implying that although collusion is potentially profitable, it may be unstable. For example, in an industry with four firms A, B, C, and D, although firm C may have an increased incentive to collude with the combined firm A+B than with A or B alone, it may also have an increased incentive to cheat on such a cartel. We show that some rigor can be introduced into this analysis as well. To the extent that a unilateral effects analysis of a hypothetical merger of A+B with C provides robust demand and cost estimates for a market consisting of firms A+B, C, and D, then one can use these estimates to calculate the change in profit to firm C if it colludes with A+B versus if it agrees to collude but then cheats by behaving competitively while A+B acts according to the collusive agreement. As with the calculation of the potential profits from collusion, this analysis requires the usual inputs and assumptions required of a quantitative unilateral effects analysis, but one must extend that analysis to a hypothetical merger of A+B with C rather than applying that analysis only to the merger at issue between A and B.[29]

This article demonstrates how economic analysis can be applied to guide an analysis of coordinated effects under the Merger Guidelines. However, the analyst will face difficult choices along the way. It can be difficult to identify the most appropriate model and assumptions. Whenever such difficulties arise in unilateral effects analysis, they will also arise in our proposed extension of unilateral effects analysis to hypothetical mergers beyond the true merger being considered.[30]

Thus, our proposed analysis is subject to all the usual caveats related to quantitative models of unilateral effects. Those are not problems we

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[28] *See generally* Joseph E. Harrington, Jr., *How Do Cartels Operate?*, *in* 2 FOUNDATIONS & TRENDS IN MICROECONOMICS (SERIES), Vol. 1, No. 2 (2006); Margaret C. Levenstein & Valerie Y. Suslow, *What Determines Cartel Success?*, 44 J. ECON. LIT. 43 (2006).

[29] Given demand and cost estimates from a quantitative unilateral effects analysis, one can estimate the potential profit of firm C if it colludes with A+B, its profit if it competes with A+B, and its potential profit if it agrees to collude with A+B but then cheats on the agreement. See *infra* Table 6 for an example of such calculations.

[30] Malcolm B. Coate, Unilateral Effects Under the Guidelines: Models, Merits, and Merger Policy 3–14 (Oct. 2008) (describing unilateral effects models and issues raised by certain of their underlying assumptions), *available at* http://ssrn.com/abstract=1263474

attempt to solve in this article. In our approach to coordinated effects, the requirements for the appropriateness of assumptions are the same as those currently applied to a quantitative unilateral effects analysis.[31] Because our approach is, at its heart, an extension of existing unilateral effects analysis, the burden of defending the underlying assumptions required for our proposed coordinated effects analysis should, to a large extent, be relieved by the robustness checks offered by the complementary unilateral effects analysis.

II. APPLICATION: QUANTIFYING COORDINATED EFFECTS USING A MODEL OF DIFFERENTIATED PRODUCTS PRICE COMPETITION WITH AN APPLICATION TO *HOSPITAL CORPORATION*

A significant coordinated effects case, *Hospital Corporation of America v. FTC*,[32] provides a context within which we can illustrate our approach to quantifying coordinated effects by extending unilateral effects analysis.

The model within which the calculations are made should be appropriate for the application being considered. For the *Hospital Corporation* case, we base our analysis on a model of differentiated products price competition.[33] This model allows us to capture interactions in a market where firms produce heterogeneous products and consumers make their purchase decisions based on the firms' prices and quality levels. Other models that allow the calculation of the equilibrium outcomes associated with various configurations of competition and cooperation among firms can be used in other cases as appropriate. The full range of models used in examining unilateral effects are candidates for use in the type of analysis we propose.[34]

In Part II.A, we provide some background on the *Hospital Corporation* case. In Part II.B, we show how one can calibrate a model of differenti-

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[31] Given data and acceptable simplifying assumptions, one can use statistical (econometric) and analytic (economic theory) techniques to develop a quantitative model that is flexible enough to give estimates of prices, quantities, consumer welfare, and profits both before and after a proposed merger. *See, e.g.*, Gregory J. Werden & Luke M. Froeb, *The Effects of Mergers in Differentiated Products Industries: Logit Demand and Merger Policy*, 10 J.L. ECON. & ORG. 407 (1994) (analyzing the effects of hypothetical mergers among U.S. long-distance carriers); Luke M. Froeb, Steven Tschantz & Philip Crooke, *Bertrand Competition with Capacity Constraints: Mergers Among Parking Lots*, 113 J. ECONOMETRICS 49 (2003) (analyzing the effects of mergers in the parking industry).

[32] 807 F.2d 1381 (7th Cir. 1986).

[33] Daniel P. Kessler & Jeffrey J. Geppert, *The Effects of Competition on Variation in the Quality and Cost of Medical Care*, 14 J. ECON. & MGMT. STRATEGY 575 (2005) (estimating the effects of hospital competition on the quality of care and hospital expenditures).

[34] See, for example, the models described in MOTTA, *supra* note 14, at 243–55.

ated products price competition to the relevant market in the *Hospital Corporation* case. In Part II.C, we show how one can use the model to quantify the impact of coordinated effects. The results of this section take the appropriateness of the model as given, but of course, all the usual robustness checks that would be applied to the market models used in a unilateral effects analysis would be required.[35] In Part II.D, we consider three extensions of the model and analysis. First, we allow for the possibility that the proposed merger results in quality improvements among the merging firms—in *Hospital Corporation* one issue was whether the merger of lower quality hospitals with higher quality hospitals might improve the quality of the lower quality ones. Second, we extend the model of Part II.B, which for simplicity ignores possible differences in operating costs among the hospitals, to allow for differential costs. Third, we extend the model of Part II.B, which for simplicity ignores capacity constraints, to allow for differential capacity constraints among the hospitals.

A. BACKGROUND ON *HOSPITAL CORPORATION*

As presented in the court of appeals decision in *Hospital Corporation*,[36] Hospital Corporation of America (HCA) acquired Hospital Affiliates International, Inc. and Health Care Corporation in the early 1980s.[37] Before these acquisitions took place, HCA had owned one hospital in Chattanooga, Tennessee, and the acquisitions thus gave it ownership of two more.[38] Pursuant to the terms of the acquisitions, HCA also assumed contracts that Hospital Affiliates International had made to manage two other Chattanooga-area hospitals.[39] After the acquisitions, HCA owned or managed five of the eleven hospitals in the area.[40] The FTC challenged the acquisitions as a violation of Section 7 of the Clayton Act. In particular, the FTC expressed concerns about the potential for post-ac-

[35] In *United States v. Oracle*, 331 F. Supp. 2d 1098 (N.D. Cal. 2004), the court rejected the government's unilateral effects claim because plaintiffs had failed to show localized competition between the parties. *Id.* at 1172–73. In addition, the court cited Oracle's contention that the plaintiff's modeling efforts were "'simplistic' and 'spurious'" because the English auction model used did not properly reflect the existence of powerful buyers and was inconsistent with the fact that customers actually conducted prolonged negotiations. *Id.* at 1172.

[36] 807 F.2d 1381 (7th Cir. 1986).

[37] *Id.* at 1383.

[38] *Id.*

[39] *Id.* at 1383–84.

[40] *Id.* at 1384.

quisition coordination between HCA and the other three large hospitals in the area.[41]

The acquisitions raised Hospital Corporation's market share in the Chattanooga area from 14 percent to 26 percent. This made it the second-largest provider of hospital services in a market where the four largest hospitals together had a post-acquisition market share of 91 percent (as compared to 79 percent before the acquisitions).[42] The FTC concluded that the acquisitions created a danger that the largest Chattanooga hospitals would collude.[43]

Judge Richard Posner's opinion for the U.S. Court of Appeals for the Seventh Circuit upheld the FTC's decision to condemn the merger. The court first focused on the importance of reducing to four the number of major players in the relevant market:

> The reduction in the number of competitors is significant in assessing the competitive vitality of the Chattanooga hospital market. The fewer competitors there are in a market, the easier it is for them to coordinate their pricing without committing detectable violations of section 1 of the Sherman Act, which forbids price fixing. This would not be very important if the four competitors eliminated by the acquisitions in this case had been insignificant, but they were not; they accounted in the aggregate for 12 percent of the sales of the market. As a result of the acquisitions the four largest firms came to control virtually the whole market, and the problem of coordination was therefore reduced to one of coordination among these four.[44]

Judge Posner then addressed how other actual or potential market participants might respond to efforts by the four leading Chattanooga area hospitals to restrict output.[45] An increase in price caused by the efforts of the four hospitals to curtail their own output might induce other firms to build new hospitals in the region. An important factor would be the degree to which the application of Tennessee's certificate of need law might inhibit the expansion of hospital capacity in Chattanooga. Even though there was no evidence in the case that the Tennessee certificate of need law previously had prevented a hospital from carrying out an expansion program, Judge Posner observed that the "law might have some effect under the conditions that would obtain if

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[41] Hospital Corp. of Am., 106 F.T.C. 361, 496–511 (1985), *aff'd*, Hospital Corp. of Am. v. FTC, 807 F.2d 1381 (7th Cir. 1986).

[42] *Hospital Corp.*, 807 F.2d at 1384.

[43] *Id.*; *see also Hospital Corp.*, 106 F.T.C. at 511.

[44] Hospital Corp., 807 F.2d at 1387.

[45] *Id.*

the challenged acquisitions enabled collusive pricing of hospital services."[46] Judge Posner explained:

> Should the leading hospitals in Chattanooga collude, a natural consequence would be the creation of excess hospital capacity, for the higher prices resulting from collusion would drive some patients to shorten their hospital stays and others to postpone or reject elective surgery. If a noncolluding hospital wanted to expand its capacity so that it could serve patients driven off by the high prices charged by the colluding hospitals, the colluders would have not only a strong incentive to oppose the grant of a certificate of need but also substantial evidence with which to oppose it—the excess capacity (in the market considered as a whole) created by their own collusive efforts. At least the certificate of need law would enable them to delay any competitive sally by a noncolluding competitor.[47]

In two ways, the certificate of need law would serve as a useful tripwire for the colluding incumbent hospitals. First, the "certificate of need law forces hospitals to give public notice, well in advance, of any plans to add capacity."[48] This would enable the incumbents to mobilize to repel threats by cartel outsiders. Second, "[t]he requirement of notice makes it harder for the member of a hospital cartel to 'cheat' on the cartel by adding capacity in advance of other members; its attempt to cheat will be known in advance, and countermeasures taken."[49] Thus, the colluding hospitals would be alerted to an apparent defection by a member of its own ranks. Of course, the requirement of notice would not help the cartel to monitor cheating based on increases in the level or quality of service.

The court of appeals went on to note that, to justify its prediction of probable anticompetitive effects, the FTC had emphasized three other factors beyond structural considerations and the availability of mechanisms to forestall supply responses to the cartel's output restrictions. The court observed that (1) "demand for hospital services is . . . highly inelastic"; (2) "there is a tradition, well documented in the Commission's opinion, of cooperation between competing hospitals in Chattanooga"; and (3) hospitals benefit by "presenting a united front in negotiations with third-party payors," particularly since "hospitals are under great pressure from the federal government and insurance companies to cut costs."[50]

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[46] *Id.*
[47] *Id.*
[48] *Id.*
[49] *Id.*
[50] Id. at 1388–89.

B. MODEL OF DIFFERENTIATED PRODUCTS PRICE COMPETITION FOR *HOSPITAL CORPORATION*

We present a model that allows us to quantify the potential benefits of coordination between HCA and the three other large Chattanooga-area hospitals, both before and after the acquisitions. This allows us to quantify the increase in incentives for coordination as a result of the acquisitions.

We consider a model of differentiated products price competition with eleven hospitals, where the services of the hospitals are assumed to be imperfect substitutes for one another. We consider a one-period version of the model for our basic analysis and then the more dynamic repeated-game version of the model to analyze incentives for cheating. We assume consumers choose the quantity of healthcare to purchase from each hospital based on the prices and characteristics of the hospitals. We can view the model as assigning each hospital i an overall quality level a_i and fixing the degree of substitutability s_{ij} between the services of hospitals i and j. Specifically, consumers are assumed to maximize their utility from hospital services minus their cost to purchase those services. In this formulation, which is based on Singh and Vives' 1984 work, each hospital faces demand for its services that depends on its quality and price and the qualities and prices of its rivals.[51] We assume firm i has marginal cost c_i.

To elaborate, the model provides parameterized demand curves for each firm giving a firm's quantity as a function of its price and the prices of the other firms in the market. The extent to which a firm's quantity is affected by its price and the other firms' prices depends on the model's parameters, $a_1,\ldots,a_{11}$, which can be interpreted as the qualities of the

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[51] Consistent with Singh and Vives' 1984 work, we assume a representative consumer that maximizes $U(q_1,\ldots,q_{11})-\sum_{i=1}^{11} p_i q_i$, where

$$U(q_1,\ldots,q_{11}) = \sum_{i=1}^{11} \left(a_i q_i - \frac{1}{2} q_i^2 - \sum_{j>i} s_{ij} q_i q_j \right).$$

Nirvikar Singh & Xavier Vives, *Price and Quantity Competition in a Differentiated Duopoly*, 15 RAND J. ECON. 546 (1984). This utility function gives rise to a linear demand structure with inverse demands given by, for i=1,...,11,

$$p_i = a_i - q_i - \sum_{j \neq i} s_{ij} q_j.$$

We assume firm i has constant marginal cost marginal cost c_i and zero fixed costs. We assume each firm chooses its price to maximize its profits given the prices of its rivals. Thus, we use the concept of Nash equilibrium to solve for equilibrium prices. These prices determine equilibrium quantities, profits, consumer surplus, and welfare. In this model, consumer surplus is $U(q_1,\ldots,q_{11})-\sum_{i=1}^{11} q_i p_i$, and welfare is consumer surplus plus the sum of the firms' profits. Part A of the Appendix provides a more formal presentation of the basics of the model.

firms' offerings. Given demand, a firm's profit is thus determined by its choice of price together with the other firms' price choices and the firm's costs (and capacity limits if relevant). To determine the prices that would result from noncooperative price setting in this market, we solve for the Nash equilibrium of the price-setting game, assuming firms maximize profits.

To obtain data with which to calibrate the model, we refer to the Seventh Circuit's opinion for information about the market shares of the Chattanooga hospitals.[52] There were eleven hospitals in the market. HCA's original hospital had a share of 14 percent. It acquired or took over management of four hospitals with a combined share of 12 percent. The largest hospital had a share greater than 26 percent. HCA's hospitals, with their aggregate share of 26 percent, when combined with the three other large hospitals, had a total share of 91 percent. Consistent with this information, we establish target market shares as show in Table 1. We calibrate the model by choosing the parameters so that these market shares are generated as an equilibrium outcome of the model.

TABLE 1: TARGET MARKET SHARES

Hospital	Description	Target market share
1	HCA	14%
2, 3, 4, and 5	HCA acquired	3%
6	Largest	30%
7 and 8	Large	17.5%
9, 10, and 11	Small	3%

The parameters available in our model are the 11 cost parameters c_i, the 11 quality measures a_i, and the 55 substitutability parameters s_{ij}. The values to which we calibrate the model are the market shares given in Table 1. Given the number of parameters relative to the number of calibration values, we make some simplifying assumptions for the cost and substitutability parameters. In particular, we begin by considering a model in which marginal costs are the same for all hospitals and set to zero, i.e., for all i, $c_i = 0$. We relax this assumption in Part II.D.2. Consistent with a model of differentiated products, we allow for substantial, but not perfect, substitutability among the hospitals. We assume that for all i and j, $s_{ij} = 0.9$ (s_{ij} equal to zero corresponds to independent products and s_{ij} equal to one corresponds to perfect substitutes). Given more

[52] Hospital Corp., 807 F.2d at 1384.

detailed data on firms' costs and substitutability, which might be informed, for example, by relative driving distances among the firms' physical locations or the similarity or differences in services offered, one would want to use that data in setting these parameters.

We then choose the quality measures a_i so that the hospitals' revenue shares in the model are equal to the target market shares shown in Table 1 up to the first decimal place. We perform a simple grid search to find a set of parameters that satisfy our criteria. The parameters produced by this calibration are: $a_1 = 0.887$, $a_2 = a_3 = a_4 = a_5 = a_9 = a_{10} = a_{11} = 0.874$, $a_6 = 0.898$, $a_7 = a_8 = 0.890$. Given more detailed data on firm performance, such as relative prices, output, revenue, margins, or profits, one could include matching those data as criteria for the calibration of the parameters.

C. QUANTITATIVE COORDINATED EFFECTS ANALYSIS FOR *HOSPITAL CORPORATION*

With this parameterized model that mimics the market share characteristics of the *Hospital Corporation* opinion, we can calculate the hospitals' profits and consumers' surplus under a variety of scenarios designed to capture the impact of cooperation between HCA and its three largest rivals before and after the acquisitions. The scenarios we consider are:

- *Pre-acquisition noncooperative*: all eleven hospitals behave noncooperatively;
- *Post-acquisition noncooperative*: hospitals 1–5 (HCA and its acquisitions) act as a single firm, but that combined firm and the other six hospitals behave noncooperatively with respect to one another;
- *Pre-acquisition cooperative*: the four largest hospitals in the pre-acquisition market, hospitals 1, 6, 7, 8 (HCA and its three largest rivals), act as a single firm, but that firm and the other seven hospitals behave noncooperatively with respect to one another; and
- *Post-acquisition cooperative*: hospitals 1–8 (HCA together with its acquisitions and three largest rivals) act as a single firm, but that firm and the remaining three hospitals behave noncooperatively with respect to one another.

For each scenario we calculate the profit of each hospital and the combined profit of hospitals acting as a single firm. See the Appendix for the technical details of this and other calculations described in this section.

Table 2 shows how various hospitals' (and groups' of hospitals) profits change as a result of the acquisitions and as a result of a shift to cooperative behavior. If HCA cooperates with the large hospitals without first making the acquisitions, the combined profit of those four hospitals increases by only 9 percent. But if HCA first acquires hospitals 2, 3, 4, and 5, then cooperation with the large hospitals increases the combined profits of HCA and the large hospitals by 65 percent, and it increases the combined profits of HCA, its acquired hospitals, and the other large hospitals by 67 percent relative to pre-acquisition noncooperative behavior.

TABLE 2: CHANGE IN PROFIT RELATIVE TO PRE-ACQUISITION NONCOOPERATIVE

Individual firm(s) or group of firms (if joined by "+")	Post-acquisition noncooperative (1–5 as single firm)	Pre-acquisition cooperative (1, 6, 7, 8 as single firm)	Post-acquisition cooperative (1–8 as single firm)
1	12%	9%	73%
2, 3, 4, and 5	18%	38%	83%
6	10%	8%	57%
7 and 8	13%	9%	68%
9, 10, and 11	34%	38%	345%
1+2+3+4+5	15%	23%	78%
1+6+7+8	12%	9%	65%
1+2+3+4+5+6+7+8	13%	13%	67%
1+...+11	15%	15%	92%

The model can be used not only to estimate the potential profits from collusion, but also to estimate the impact of collusion on prices, output, consumer welfare, and other market variables. These calculations may be useful as evidence of the potential magnitude of the harm to competition resulting from the coordinated effects.

The profit increases shown in Table 2 occur because colluding hospitals increase their prices relative to their noncooperative levels. Specifically, Table 3 shows that the acquisition itself induces HCA and the acquired hospitals to increase prices, but by less than 50 percent relative to the pre-acquisition noncooperative prices. However, the acquisition together with cooperation with the other large hospitals induces HCA to more than double its price and induces the acquired hospitals to more than triple their prices, which increase by 256 percent relative to the pre-acquisition noncooperative prices.

TABLE 3: CHANGE IN PRICES RELATIVE TO PRE-ACQUISITION NONCOOPERATIVE

Firm	Post-acquisition noncooperative (1–5 as single firm)	Pre-acquisition cooperative (1, 6, 7, 8 as single firm)	Post-acquisition cooperative (1–8 as single firm)
1	20%	30%	116%
2, 3, 4, and 5	49%	17%	256%
6	5%	19%	78%
7 and 8	7%	26%	103%
9, 10, and 11	16%	17%	111%

As a result of these price increases, the equilibrium output of the colluding hospitals decrease as shown in Table 4. In response to the quantity restrictions of the colluding hospitals, the quantities of the noncolluding hospitals increase. In some cases, the quantities of the independent hospitals more than double relative to their pre-acquisition noncooperative levels.

TABLE 4: CHANGE IN QUANTITIES RELATIVE TO PRE-ACQUISITION NONCOOPERATIVE

Individual firm(s) or group of firms (if joined by "+")	Post-acquisition noncooperative (1–5 as single firm)	Pre-acquisition cooperative (1, 6, 7, 8 as single firm)	Post-acquisition cooperative (1–8 as single firm)
1	–7%	–16%	–20%
2, 3, 4, and 5	–21%	17%	–49%
6	5%	–9%	–12%
7 and 8	7%	–13%	–17%
9, 10, and 11	16%	17%	111%
1+2+3+4+5	–16%	6%	–39%
1+6+7+8	3%	–12%	–16%
1+2+3+4+5+6+7+8	–4%	–4%	–25%
1+...+11	–0.2%	–0.2%	–1.5%

As shown in the last row of Table 4, the total quantity produced in the market decreases in each of the scenarios shown relative to the pre-acquisition noncooperative case. However, these overall decreases are not large because the quantity increases of the independent hospitals largely offset the quantity decreases of the cooperating hospitals. In contrast to a coarser analysis, such as one based only on market share statistics like the Herfindahl Index, this approach allows us to quantify the response of non-cartel firms to the cartel's action.

In reality, regulation and capacity constraints may limit the ability of the independent hospitals to expand their output. To address this, we incorporate capacity constraints into the model in Part II.D.3 and to a lesser extent in Table 6.

Given the equilibrium prices and quantities in the various scenarios, we can calculate the change in consumer surplus as a result of the acquisition and subsequent coordination. Because we assume zero costs (we relax this assumption in Part II.D.2), the change in total profit for all the hospitals is equal to the change in total consumer expenditures, so the last row in Table 2 shows how consumer expenditures are affected in the different scenarios. The acquisitions alone result in a 15 percent increase in consumer expenditures; however, when combined with coordination among the acquired hospitals and the three large hospitals (and responses by the other hospitals), the result is a 92 percent increase in consumer expenditures—more than eight times as high.

Although the analysis above has focused on a particular hypothetical cartel in the post-acquisition market, namely the one consisting of hospitals 1–8, the approach can also provide insights into whether that is, in fact, the group of firms that is at greatest risk for cooperation. For example, Table 5 shows that the commonly-owned hospitals 1–5 benefit from collusion with any of the other hospitals, but only the large hospitals 6, 7, and 8 find the coordination mutually beneficial. Specifically, adding hospital 7 or 8 to a cartel of 1–6, and adding hospital 8 to a cartel of 1–7 generate additional profits for both the original cartel and for the added hospital. In contrast, the smallest hospitals, hospitals 9, 10, and 11, have higher profits if they remain outside the cartel (assuming the cartel still functions). This suggests that it was appropriate for the FTC to focus on the post-acquisition cartel of hospitals 1–8, with the three smallest hospitals remaining outside the cartel.[53] One might have expected that it would be appropriate for the FTC to focus on the possibility of post-acquisition collusion among the large hospitals since it is a typical theoretical conclusion that the small firms benefit most if they stay outside the cartel. However, the quantification we suggest provides a more rigorous path to this conclusion and one that is tailored to the particulars of the market at issue rather than being based on a general theoretical understanding. Furthermore, our analysis provides a measure of how

[53] *Hospital Corp.*, 807 F.2d at 1384, 1387.

much greater the incentives for collusion are among the various large hospitals and, as we now discuss, allows quantitative measures of the stability of various collusive attempts.

TABLE 5: EFFECTS OF INCREMENTAL EXPANSION OF THE HYPOTHETICAL CARTEL

Base market structure	Firm to add to cartel	Change in profit of original cartel	Change in profit of added firm
1–5 collude	6	11%	7%
1–5 collude	7 or 8	11%	7%
1–5 collude	9, 10, or 11	9%	–2%
1–6 collude	7 or 8	13%	7%
1–7 collude	8	20%	6%
1–8 collude	9, 10, or 11	31%	–43%

Although Table 5 shows that the large hospitals 6, 7, and 8 would profit from collusion with HCA and the hospitals it acquired in the merger, it is also important to consider whether such a cartel would be stable over time. In particular, this can be assessed by exploring whether these hospitals would have strong incentives to cheat on such a cartel if it were formed.[54] We can do this within the context of our model by calculating the increase in each hospital's profit if it were to choose its price to maximize its profit while holding fixed the other cartel members' prices at their collusive levels. Secret price cuts by a cartel member can potentially allow it to capture a short-term gain. However, such deviations from the cartel agreement run the risk of detection, and retaliation from the other cartel members.[55] One common approach to modeling such retaliation is to assume that once a deviation from collusive behavior is detected, the other cartel members will return to noncooperative pricing.[56]

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[54] *See* Stigler, *supra* note 1 (providing the seminal discussion of the central issue of the incentive for cheating on the cartel agreement by member firms).

[55] *See id.* at 46 (discussing the importance of cartels' ability to monitor and deter secret price cuts).

[56] There is support in the theoretical literature and in cartel case studies for this assumption. *See* Edward J. Green & Robert H. Porter, *Noncooperative Collusion Under Imperfect Price Information*, 52 ECONOMETRICA 87, 89–90 (1984) (assuming that firms revert to noncooperative behavior if the market price falls below a chosen level). The use of reversion to pre-collusive play as a punishment for deviations from collusion is explicitly mentioned in Congressional testimony involving dyestuffs manufacturers. The testimony includes a letter from a foreign sales manager of a dyestuffs manufacturer stating: "You and your contemporaries should be in a position to establish market prices based upon definite strength determination of color, which prices should be followed by you if such an under-

Thus, we can construct a measure of the sustainability of collusion by calculating the increase in profit to a firm from cheating on the cartel and also the loss in profit as a result of the abandonment of the collusive agreement. We show these calculations in Table 6. We assume one period is required for detection (one could calibrate this to a quarter or a year or some other length of time) and that the punishment involves reversion to noncooperative play for the remainder of an infinite time horizon.[57] We provide unconstrained calculations and also the calculations imposing the constraint that hospitals cannot (in the short run) increase their output beyond their pre-acquisition noncooperative levels. See Part B of the Appendix for the details of this calculation.

TABLE 6: EFFECTS ON PROFITS OF DEVIATIONS FROM COLLUSION

Firm	One time increase in profit from a unilateral deviation (relative to post-acquisition cooperative)	One time increase in profit from a unilateral deviation (relative to post-acquisition cooperative with capacity constraint)	Decrease in profit from reversion to post-acquisition noncooperative (relative to post-acquisiton cooperative)
6	14%	6%	–30%
7 and 8	22%	11%	–32%

As shown in Table 6, if we assume capacity constraints are binding for short-run deviations, as one might expect them to be, the one-shot gain from secret price cutting, 6 percent for hospital 6 and 11 percent for hospitals 7 and 8, are modest relative to the loss of approximately 30 percent per period for all future periods as a result of a return to noncooperative behavior. These calculations suggest that collusion among the large hospitals in this market remains a concern even when incentives for unilateral deviations from collusion are considered.

standing is reached. But, if you have any indication that a contemporary is not adhering to such prices, then immediately revert to the prices prevailing before any arrangements were established." *See* S. Comm. on Patents, Hearings before the Committee on Patents on S. 2303 and S. 2491, Part 5, at 2424, 77th Cong. 2d Sess. (May 13 & 16, 1942).

[57] Sensitivity analysis can easily be performed on both the length of time before detection and the length of punishment. To the extent that results are not sensitive to the details of the assumptions, their robustness can be established. The assumption on the length of time before detection can be informed by reporting practices in the industry. For example, the existence of a trade association providing quarterly feedback to its members on market activity would suggest one quarter as an assumption worth considering.

Let us review the assumptions we use in order to perform these calculations. First, as in a quantitative unilateral effects analysis, we need a model of the market. For our *Hospital Corporation* application, we use the differentiated products price competition model of Singh and Vives.[58] This model has a variety of demand and cost parameters, which we calibrate to the Chattanooga-area hospital market. We use general, publicly available information to calibrate the model, but in a litigation context one would expect access to much more detailed information, allowing for a more exacting calibration. Second, we need a conjecture as to the nature of collusion. Since we are focused on calculating the potential profits from collusion, we use the assumption that colluding firms act so as to maximize the joint profits of the colluding firms. Thus, given a set of colluding firms, we assume maximally effective collusion. (Note that the profit maximizing outcome for the cartel could potentially be achieved through either explicit or tacit collusion.) Third, in order to calculate the incentives for cheating on the cartel agreement, we need to make assumptions regarding the length of time before a deviation would be detected and the form and length of the punishment that would be triggered.

D. EXTENSIONS

We consider three extensions to our analysis above. In Part II.D.1, we show how one might use the model to investigate claims regarding post-acquisition quality improvements. One could analyze a claim of cost savings in a similar manner. In Part II.D.2, we recalculate the above model to allow for positive marginal costs. Finally, in Part II.D.3, we incorporate capacity constraints into the model.

1. *Incorporating Quality Improvements*

As an extension to the analysis described above, we can incorporate the potential for post-acquisition improvements in the quality of various hospitals into the analysis. In our model of the *Hospital Corporation* acquisitions, the hospitals are differentiated, with different hospitals receiving different weights in the representative consumer's utility function. We can view hospitals that get a higher weight in the utility function as offering higher quality. In this sense, in the model described above, HCA is medium quality, the hospitals it acquires (firms 2–5) are poor quality, and hospital 6 is high quality.

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[58] *See* Singh & Vives, *supra* note 50.

Consider a claim by HCA that, as a result of its acquisition of hospitals 2–5, the quality of those hospitals will increase. In general, it might be hard to evaluate and quantify such a claim, but the model offers a way to do this. See Part C of the Appendix for the details of how one would incorporate quality improvement as a result of the merger. If we just consider the merger and assume no coordinated effects, and if the quality of hospitals 2–5 increases up to the level of HCA, then the model shows that consumer surplus is higher than the pre-acquisition noncooperative level. So, in the absence of coordinated effects, this type of quality improvement would offset the price increases associated with greater concentration. However, one can show that even if the quality of the four acquired hospitals increases to the level of the high-quality hospital 6, consumer surplus still falls as a result of the acquisitions plus coordinated effects (i.e., coordination among hospitals 1–8).

In our original analysis, the profits of the hospitals not involved in the acquisition increase as a result of the acquisition and the associated decrease in interfirm rivalry (see Table 2). However, if we assume that the acquisition results in an increase in the quality of hospitals 2–5 to the level of HCA or greater, then the acquisition results in a decrease in profits for the remaining firms. In this case, the increased competitiveness of hospitals 2–5 dominates any reduction in rivalry. This is a case in which one might expect the hospitals not involved in the acquisition to oppose it.[59]

2. *Incorporating Cost Differences*

Although the published opinions in the *Hospital Corporation* matter do not contain data on hospital costs or margins, we can illustrate how one might incorporate that information if it were available.

We show how one can recalibrate the model allowing the hospitals to have different marginal costs. We again choose parameters so that the equilibrium revenue shares match the target market shares, and we choose costs so that relative to HCA, the marginal cost of hospitals 2–5 and 9–11 is 5 percent higher, the marginal cost of hospital 6 is 10 percent lower, and the marginal cost of hospitals 7–8 is 5 percent lower.[60] This captures the idea that the largest hospital 6 has the lowest cost, and

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[59] *See* Tomaso Duso, Klaus Gugler & Burcin Yurtoglu, *EU Merger Remedies: An Empirical Assessment*, *in* THE POLITICAL ECONOMY OF ANTITRUST, *supra* note 1, ch. 12 (showing how the impact of a merger on the stock price of rival firms can be informative as to whether the merger is pro-collusive or pro-competitive).

[60] In contrast to the previous calibration, we assume $c_1 = .07$, $c_2 = c_3 = c_4 = c_5 = c_9 = c_{10} = c_{11} = .0735$, $c_6 = .063$, $c_7 = c_8 = .0665$, and obtain $a_1 = .9073$, $a_2 = a_3 = a_4 = a_5 = a_9 = a_{10} = a_{11} = .8905$, $a_6 = .9264$, $a_7 = a_8 = .9104$ using a grid search designed to mimic the market shares.

the small hospitals 2–5 and 9–11 have the highest costs. Given our calibration, equilibrium price-cost margins in the pre-acquisition noncooperative case range from 4 percent to 30 percent, with HCA's margin equal to 17 percent and hospitals 7 and 8's margins equal to 21 percent.

In this version of the model, changes in the hospitals' profit levels relative to pre-acquisition noncooperative profits are similar to those in the version of the model with zero costs, except that the profits of hospitals 2–5 decrease significantly and the profits of hospitals 9–11 increase dramatically in the post-acquisition cooperative case. As shown in Table 7, the price increases as a result of the acquisition and cooperation are more modest than in the version of the model with zero costs.

TABLE 7: CHANGE IN PRICES RELATIVE TO PRE-ACQUISITION NONCOOPERATIVE WITH POSITIVE COSTS

Firm	Post-acquisition noncooperative (1–5 as single firm)	Pre-acquisition cooperative (1, 6, 7, 8 as single firm)	Post-acquisition cooperative (1–8 as single firm)
1	2%	6%	19%
2, 3, 4, and 5	3%	2%	21%
6	1%	5%	17%
7 and 8	1%	6%	19%
9, 10, and 11	1%	2%	9%

Perhaps the most interesting difference between the version of the model with positive costs and the version with zero costs is in the equilibrium quantities. As shown in Table 8, in the post-acquisition cooperative case, the colluding hospitals maximize their joint profits by essentially shutting down the high-cost members of the cartel, hospitals 2–5.[61] The output of those hospitals falls 98 percent relative to the pre-acquisition noncooperative case.

The results that equilibrium quantities differ when we incorporate cost information and that a cartel might want to shut down high-cost members are standard in the theoretical literature. However, without a specific quantitative analysis tailored to the market in question, one cannot assess whether in this particular market there would be incentives

[61] Hospitals 2–5 are assumed to have been acquired by HCA in the post-acquisition scenarios, so any transfer payments required to arrange the closure of hospitals 2–5 would be internal to the merged entity.

for a cartel to shut down its high-cost members. One must assess whether their costs are sufficiently high relative to their contributions to profits to warrant eliminating their productive capacity. As we show, even with general information about the market, a calibration can be performed that provides insights into the shut-down decision. But with the more detailed cost information available in a litigation context, these calculations could be made far more precise. For example, merging firms making claims about cost savings and scale or scope economies associated with the merger would have to provide estimates of the relevant costs. If the option is available, detailed cost information can be requested in discovery. This data can be used to calculate estimates of firms' marginal costs.

TABLE 8: CHANGE IN QUANTITIES RELATIVE TO PRE-ACQUISITION NONCOOPERATIVE WITH POSITIVE COSTS

Individual firm(s) or group of firms (if joined by "+")	Post-acquisition noncooperative (1–5 as single firm)	Pre-acquisition cooperative (1, 6, 7, 8 as single firm)	Post-acquisition cooperative (1–8 as single firm)
1	–3%	–19%	–19%
2, 3, 4, and 5	–30%	40%	–98%
6	3%	–7%	–7%
7 and 8	4%	–14%	–15%
9, 10, and 11	21%	40%	214%
1+2+3+4+5	–16%	10%	–58%
1+6+7+8	2%	–12%	–13%
1+2+3+4+5+6+7+8	–3%	–5%	–25%
1+...+11	–0.2%	–0.3%	–1.6%

As in our model with zero costs, the overall quantity reduction is modest because of the quantity increases by non-colluding firms. In this model, each of hospitals 9–11 increases its output 214 percent in the post-acquisition cooperative case.

Although consumer expenditures increased 92 percent in the model with zero costs as a result of the acquisition plus coordination, in the model with positive costs, the price increases are smaller, and so the increase in consumer expenditures is only 13 percent. Overall, the addition of positive costs to the model suggests that the impact of the acquisitions and any subsequent coordination may not be as great as suggested by the model with zero costs. However, the changes in quantities in the model with positive costs highlight the need to take into account capacity constraints, which the FTC argued were an important feature of the market in *Hospital Corporation* because of Tennessee's certificate of need law. In the next section, we incorporate capacity constraints.

TABLE 9: CHANGE IN QUANTITIES RELATIVE TO PRE-ACQUISITION NONCOOPERATIVE WITH POSITIVE COSTS AND CAPACITY CONSTRAINTS

Individual firm(s) or group of firms (if joined by "+")	Post-acquisition noncooperative (1–5 as single firm)	Pre-acquisition cooperative (1, 6, 7, 8 as single firm)	Post-acquisition cooperative (1–8 as single firm)
1	–3%	–13%	–4%
2, 3, 4, and 5	–30%	25%	–32%
6	3%	–4%	1%
7 and 8	4%	–9%	–2%
9, 10, and 11	21%	25%	25%
1+2+3+4+5	–16%	5%	–17%
1+6+7+8	2%	–8%	–1%
1+2+3+4+5+6+7+8	–3%	–3%	–6%
1+...+11	–0.2%	–0.5%	–2.8%

3. *Incorporating Capacity Constraints*

One might argue that the results of our previous models are not realistic because they allow hospitals to increase their output without bound. In this section, we amend the model with positive costs to include the constraint that a hospital's output can be no more than 125 percent of its equilibrium output in the pre-acquisition noncooperative case. See Part D of the Appendix for the details of the calculation. Our assumption of a 125 percent bound on output expansion is arbitrary and made for the purposes of demonstrating how the analysis would proceed. If one had information on the idle capacity held by various firms (in the case of hospitals, the number of unused beds and the ability to increase beds given the existing infrastructure), which should be readily available, one can tailor this assumption to the characteristics of the market in question.

When we add this constraint, the capacity limits bind on the non-colluding small hospitals in the two cooperative cases. One can see this from Table 9, which shows changes in equilibrium quantities for this version of the model. In the pre-acquisition cooperative case, hospitals 2–5 and 9–11 are not included in the cartel, and the capacity constraint binds for each of them. In the post-acquisition cooperative case, hospitals 9–11 are not included in the cartel, and the capacity constraint binds for each of them.

Because non-colluding hospitals can no longer increase their output by as much in response to the price increases of the colluding hospitals, the price increases are larger (in the post-acquisition cooperative case, firms increase prices between 25 percent and 30 percent relative to the pre-acquisition noncooperative case), and the profit increases are larger (see Table 10).

TABLE 10: CHANGE IN PROFIT RELATIVE TO PRE-ACQUISITION NONCOOPERATIVE WITH POSITIVE COSTS AND CAPACITY CONSTRAINTS

Individual firm(s) or group of firms (if joined by "+")	Post-acquisition noncooperative (1–5 as single firm)	Pre-acquisition cooperative (1, 6, 7, 8 as single firm)	Post-acquisition cooperative (1–8 as single firm)
1	9%	25%	155%
2, 3, 4, and 5	18%	165%	456%
6	5%	15%	82%
7 and 8	8%	21%	126%
9, 10, and 11	47%	165%	854%
1+2+3+4+5	10%	50%	209%
1+6+7+8	7%	18%	108%
1+2+3+4+5+6+7+8	7%	22%	117%
1+...+11	8%	25%	132%

In contrast to our first model with zero costs, where the cartel of hospitals 1–8 could increase its profits by 67 percent as a result of the acquisitions plus coordination, and in contrast to the model with positive costs but no capacity constraints, where they could increase their profits by only 51 percent, in the model with positive costs and capacity constraints, hospitals 1–8 can increase their profits by 117 percent. In addition, relative to the pre-acquisition noncooperative case, the acquisitions plus cooperation result in an increase in consumer expenditures of 23 percent and a decrease in the total quantity supplied of 2.8 percent. As a result, consumer surplus decreases by more than 5 percent.

III. CONCLUSION

Our analytic approach to coordinated effects allows a direct quantification of the incremental payoffs to post-merger collusion. The assumptions required are, for the most part, those already required for a quantitative unilateral effects analysis that may already be performed, with the data from that analysis available for use. Features not relevant for a unilateral effects analysis of a particular market are less likely to be relevant for the analysis we propose.[62] Any disquiet about the assumptions or modeling environment is not specific to the coordinated effects analysis and, thus, a single debate for both unilateral effects and coordinated effects modeling can take place. Other assumptions can be informed by theory and data and evaluated using sensitivity analysis.

The quantification presented here displaces nothing that is currently being done with coordinated effects analysis. It is a strict augmentation. There are issues associated with the Merger Guidelines, such as a direct quantification of the increased probability of coordination among remaining firms, that our proposed analysis does not address, but this just means, unsurprisingly, that the analysis does not accomplish everything that the Merger Guidelines prescribe, which is the case for all existing coordinated effects analyses.

Various levels of collusion can be investigated and specific firms, which might be mavericks, can be isolated. Calibration and estimation can be undertaken with guidance from pre-merger data so that the post-merger simulations are appropriately benchmarked. The analysis may flag specific subsets of firms that may earn extraordinary payoffs from post-merger collusion and, if the merger is approved, these subsets

[62] One can expect that among the relevant features will be: the characteristics of demand (e.g., overall size and elasticity), cost characteristics of the firms in the market, capacities of the firms in the market and the extent to which they are capacity constrained, and information flow among market participants. One can also bring in to the analysis information about firms' past propensities for collusion and the possible maverick status of certain firms.

could be monitored for suspicious activities,[63] or they could be enjoined ex ante from certain actions as part of merger approval.[64]

The case study provided in this article contributes in a number of ways. First, the analysis is a direct outgrowth of a standard unilateral effects analysis. The models and estimation that have already been conducted for a unilateral effects analysis can be extended, at low cost, to address aspects of coordinated effects. The incremental analysis is low cost in the sense that the heavy lifting in terms of developing a sound model of the market and defending the underlying assumptions associated with a model must be done for a quantitative unilateral effects analysis. Our approach relies on using that same machinery to perform incremental calculations that can then inform authorities as to the level of concern they should attached to coordinated effects among various subsets of post-merger firms.

Overall, the analysis we propose for coordinated effects is, in our opinion, a strict improvement and should become part of standard practice for the economic review of all merger cases.

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[63] Many examples of such activities are possible, but to give a few: coordinated price announcements (see, e.g., Robert C. Marshall, Leslie M. Marx & Matthew E. Raiff, *Cartel Price Announcements: The Vitamins Industry*, 26 INT'L J. INDUS. ORG. 762 (2008)); the expansion of the trade association to include special working groups or increased monitoring and/or reporting (see, e.g., Case IV/C/33.833—Cartonboard, Comm'n Decision, 1994 O.J. (L 243) 1, ¶¶ 31–32 (1994) (broadly confirmed by the Court of First Instance and the European Court of Justice in a series of decisions. *See, e.g.*, Case T-327/94, SCA Holding Ltd. v. Comm'n, 1998 E.C.R. II-1373 (Ct. First Instance); Case C-297/98 P, SCA Holding Ltd. v. Comm'n, 2000 E.C.R. I-10101 (Eur. Ct. Justice)).

[64] For example, firms could be enjoined from announcing price increases in advance of their effective dates. Such a prohibition was imposed on an association of sugar refiners in 1934, but the Supreme Court reversed that portion of the district court order. *See* United States v. Sugar Inst., 15 F. Supp. 817, 830, 908 (S.D.N.Y. 1934)), *rev'd in relevant part*, 297 U.S. 553, 603 (1936)). Decades later, a prohibition on advance price announcements was included in the 1967 consent agreement in *United States v. Pennsalt Chemical Corp.,* 1967 Trade Cas. (CCH) ¶ 71,982 at 83,475 (E.D. Pa. 1967).

APPENDIX

A. MODEL BASICS

We consider a model of differentiated products price competition with 11 firms, where the products of the firms are assumed to be imperfect substitutes for one another. Consistent with Singh and Vives (1984), we assume a representative consumer that maximizes

$$U(q_1,\ldots,q_{11}) - \sum_{i=1}^{11} p_i q_i\,,$$

where

$$U(q_1,\ldots,q_{11}) = \sum_{i=1}^{11}\left(a_i q_i - \frac{1}{2}q_i^2 - \sum_{j>i} s_{ij} q_i q_j\right).$$

This utility function gives rise to a linear demand structure with inverse demands given by, for i=1,...,11,

$$p_i = a_i - q_i - \sum_{j\neq i} s_{ij} q_j.$$

In this model, consumer surplus is

$$U(q_1,\ldots,q_{11}) - \sum_{i=1}^{11} q_i p_i\,,$$

and welfare is consumer surplus plus the sum of the firms' profits. We assume firm i has constant marginal cost c_i and zero fixed costs.

We seek a parameterization that delivers equilibrium market shares equal to those shown in Table 1. As our initial parameterization, we assume that for all i and j, $c_i = 0$, $b_i = 1$, and $s_{ij} = 0.9$, and we choose the intercept terms a_i using a grid search to match the Table 1 market shares (up to the first decimal place): $a_1 = 0.887$, $a_2 = a_3 = a_4 = a_5 = a_9 = a_{10} = a_{11} = 0.874$, $a_6 = 0.898$, $a_7 = a_8 = 0.890$.

The model implies inverse demand functions

$$P_i(\mathrm{q}) = a_i - b_i q_i - \sum_{j\neq i} s_{ij} q_j.$$

Using the system of inverse demand functions, we can solve for the firms' demand functions as a function of the vector of prices $Q(\mathrm{p})$. Profits are given by $\pi_i(\mathrm{p}) = Q_i(\mathrm{p})\,(p_i - c_i)$. Consumer surplus is

$$CS(\mathrm{p}) = U(Q(\mathrm{p})) - \sum_{i=1}^{11} Q_i(\mathrm{p})\,p_i$$

and welfare is

$$W(\mathrm{p}) = U(Q(\mathrm{p})) - \sum_{i=1}^{11} Q_i(\mathrm{p})\, c_i.$$

For each of the four scenarios described in Part II.C, we can solve for equilibrium prices as described below.

Pre-acquisition noncooperative: The noncooperative equilibrium prices satisfy for all $i \in \{1,...,11\}$,

$$p_i^{nc} \in \underset{p_i}{\operatorname{argmax}}\, Q_i(p_i, p_{-i}^{nc})\,(p_i - c_i)\,.$$

Post-acquisition noncooperative: In this scenario, equilibrium prices satisfy

$$(p_1^{pnc},...,p_5^{pnc}) \in \underset{p_1,...,p_5}{\operatorname{argmax}} \sum_{i=1}^{5} Q_i(p_1,...,p_5, p_6^{pnc},...,p_{11}^{pnc})\,(p_i - c_i)$$

and for $i \in \{6,...,11\}$,

$$p_i^{pnc} \in \underset{p_i}{\operatorname{argmax}}\, Q_i(p_i, p_{-i}^{pnc})\,(p_i - c_i)\,.$$

Pre-acquisition cooperative: In this scenario, equilibrium prices satisfy

$$(p_1^c, p_6^c, p_7^c, p_8^c) \in \underset{p_1, p_6, p_7, p_8}{\operatorname{argmax}} \sum_{i \in \{1,6,7,8\}} Q_i\,(p_1, p_2^c, p_3^c, p_4^c, p_5^c, p_6, p_7, p_8, p_9^c, p_{10}^c, p_{11}^c)\,(p_i - c_i)$$

and for $i \in \{2,3,4,5,9,10,11\}$,

$$p_i^c \in \underset{p_i}{\operatorname{argmax}}\, Q_i(p_i, p_{-i}^c)\,(p_i - c_i)\,.$$

Post-acquisition cooperative: In this scenario, equilibrium prices satisfy

$$(p_1^{pc},...,p_8^{pc}) \in \underset{p_1,...,p_8}{\operatorname{argmax}} \sum_{i=1}^{8} Q_i(p_1,...,p_8, p_9^{pc}, p_{10}^{pc}, p_{11}^{pc})\,(p_i - c_i)$$

and for $i \in \{9,10,11\}$,

$$p_i^{pc} \in \underset{p_i}{\operatorname{argmax}}\, Q_i(p_i, p_{-i}^{pc})\,(p_i - c_i)\,.$$

Given the equilibrium prices, we can calculate noncooperative quantities, revenue, and profit for each firm or combination of firms, as well as consumer surplus and welfare, as described above.

For the analysis on the effect of incremental expansion of cartels, we use a similar approach to calculate the new equilibrium prices once an additional firm or firms is added to the cartel. Given those prices, we can calculate noncooperative quantities, revenue, and profit for each firm or combination of firms, as well as consumer surplus and welfare, as described above.

B. DEVIATIONS FROM COLLUSION

For the analysis of the effects on profits of deviations from collusion, we perform the following calculations. As a benchmark, we use the equilibrium prices for the post-acquisition cooperative scenario described above. To calculate the one-period profit for firm $i \in \{6,7,8\}$ from a unilateral deviation, we fix prices for firms other than i at their values p^{pc}, and we choose firm i's price as

$$p_i' \in \operatorname*{argmax}_{p_i} Q_i(p_i, p_{-i}^{pc})(p_i - c_i)\,.$$

These prices determine the firm's one-period profits from the deviation. To include a capacity constraint equal to the equilibrium output in the pre-acquisition noncooperative scenario, we continue to take prices for firms other than i at their values in p^{pc}, and we choose firm i's price as

$$p_i' \in \operatorname*{argmax}_{p_i \text{ s.t. } Q_i(p_i, p_{-i}^{pc}) \leq Q_i(\mathrm{p}^{nc})} Q_i(p_i, p_{-i}^{pc})(p_i - c_i)\,.$$

To calculate the decrease in profit from a reversion to post-acquisition noncooperative, we compare profits in the post-acquisition noncooperative scenario with those in the post-acquisition cooperative scenario.

C. INCORPORATING QUALITY IMPROVEMENTS

As described in the body of the paper, one can view the parameters $a_1,\ldots,a_{11}$ as measures of consumer perception of the quality of the hospitals. Recalling the parameter values $a_1 = 0.887$, $a_2 = a_3 = a_4 = a_5 = a_9 = a_{10} = a_{11} = 0.874$, $a_6 = 0.898$, $a_7 = a_8 = 0.890$, it follows that firm 1 is medium quality, the firms it acquires (firms 2–5) are poor quality, and firm 6 is high quality.

To see how one could model a claim by firm 1 that, as a result of its acquisitions of firms 2–5, the quality of those firms will increase to the level of the acquiring firm, take the post-acquisition noncooperative scenario as an example. In that scenario, one would first recalculate the demand functions assuming $a_2,\ldots,a_5$ are instead equal to the value for firm 1 of 0.887. Denote these new demand functions as $\hat{Q}_i$. Second, one would calculate equilibrium prices for the post-acquisition noncooperative scenario as described above, but substituting the new demand functions $\hat{Q}_i$, which reflect the improved quality of the acquired firms.

As above, given the equilibrium prices, calculations of consumer surplus and other values follow.

D. Incorporating Capacity Constraints

To incorporate a capacity constraint, one need only revise equilibrium price calculations to include the constraint that p_i be such that $Q_i(p_i, p_{-i})$ does not exceed the constraint. For example, for the post-acquisition noncooperative scenario with capacity constraints **k**, equilibrium prices satisfy

$$(p_1^{pnc},\ldots,p_5^{pnc}) \in \underset{p_1,\ldots,p_5 \text{ s.t. } p_1 \le k_1,\ldots,p_5 \le k_5}{\operatorname{argmax}} \sum_{i=1}^{5} Q_i(p_1,\ldots,p_5,p_6^{pnc},\ldots,p_{11}^{pnc})\ (p_i - c_i)$$

and for $i \in \{6,\ldots,11\}$,

$$p_i^{pnc} \in \underset{p_i \text{ s.t. } p_i \le k_i}{\operatorname{argmax}}\ Q_i(p_i, p_{-i}^{pnc})\,(p_i - c_i)\,.$$

In Part II.D.3, the capacity constraint for firm i is taken to be $1.25Q_i(\mathrm{p}^{nc})$.