Quantitative Methods for Evaluating the Unilateral Effects of Mergers*

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FIRST DRAFT—COMMENTS WELCOME

Abstract

We describe the quantitative modeling techniques that are used in horizontal merger review for the evaluation of unilateral effects, and discuss how the 2010 Horizontal Merger Guidelines helped legitimize these methods and motivate scholarly research. We cover markets that feature differentiated-products pricing, auctions and negotiations, and homogeneous products, in turn. We also develop connections between quantitative modeling and market concentration screens based on the Herfindahl-Hirschman Index (HHI).

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1 Introduction

In this article, we describe what we view as the state-of-the-art quantitative modeling techniques for horizontal merger review. We discuss how the 2010 Horizontal Merger Guidelines of the U.S. Department of Justice (DOJ) and the Federal Trade Commission (FTC) have helped legitimize these methods within the antitrust community and motivate scholarly research. As best we can discern, the notion that formal models could inform merger review emerged from the game-theoretical revolution in industrial organization during the 1980s. Initially, this research was mostly theoretical (e.g., Tirole (1988)), but soon thereafter empirical tools were devised to apply these models to data (e.g., Berry et al. (1995)). The modeling techniques we describe here are the result of an ongoing interplay between current academic research and antitrust practice.

Our particular focus is on models that seek to capture the *unilateral effects* of mergers. We find it helpful to conceptualize unilateral effects as those arising because mergers alter firms' equilibrium strategies in one-shot oligopoly games.[1] As a general matter, competition between firms creates strategic externalities because, by maximizing profit, firms take actions that reduce the profits of rivals. Mergers internalize these externalities by allowing the merging firms to pursue joint profit maximization. In most models, this increases prices, lowers output, and reduces consumer surplus and total welfare, unless the change in strategic incentives is offset by merger efficiencies. Unilateral effects can be contrasted to *coordinated effects*, which arise if a merger shifts the market to a supracompetitive equilibrium in a repeated game.[2]

Quantitative modeling plays multiple roles in merger review. It clarifies the mechanisms through which the merger is likely to affect market outcomes, and thereby provides an economic rationale for any enforcement action. Models also inform the types of evidence that should be sought in an investigation. Finally, models provide a way to evaluate the net effects of potentially countervailing forces, with the classic example being cost efficiencies versus a loss of competition. This ability of models to balance possibly offsetting forces is particularly important in the context of litigation, in helping courts wade through plaintiffs' and defendants' various arguments to decide whether a merger is net harmful.

Perhaps ironically, one thing that quantitative modeling does *not* typically accomplish is a precise quantification of merger effects. Models by their nature are simplified

[1] For a formal definition of unilateral effects, see Werden (2008).

[2] The quantitative modeling of coordinated effects is nascent, but recent research has made progress (e.g., Igami and Sugaya (2019); Miller et al. (2019)).

representations of the world. Their purpose is to isolate the key ways that mergers affect economic incentives, and they need not account for secondary and tertiary details. Furthermore, as assumptions are necessary to make predictions, some uncertainty is inevitable. Thus, modeling should not be expected to provide precise estimates of merger effects, but rather should be used to form an assessment of countervailing forces and an overall sense of magnitudes.

We come now to the Horizontal Merger Guidelines (hereafter, the "Guidelines") and their role in promoting unilateral effects analysis. The Guidelines were first promulgated in 1968. Major revisions were issued in 1982, 1992, and 2010, with minor revisions in 1984 and 1997.[3] Unilateral effects first appeared in the 1992 version. Reflecting the state of research at the time, the theoretical basis for unilateral effects was sketched, but scant empirical direction was provided. As research and antitrust practice evolved over the 1990s and 2000s, further revision became increasingly necessary. Carl Shapiro, a principle author of the 2010 Guidelines, describes this history as follows:

> The biggest shift in merger enforcement between 1992 and 2010 has been the ascendancy of unilateral effects as the theory of adverse competitive effects most often pursued by the Agencies. Prior to 1992, merger enforcement focused primarily on coordinated effects. In recent years, a sizeable majority of DOJ merger investigations have focused on unilateral effects. Along with this pronounced shift in practice has come considerable new economic learning about unilateral effects. This shift in practice and advance in learning regarding unilateral effects was one of the chief reasons we at the DOJ felt that the time had come to update the Guidelines.[4]

The 2010 Guidelines update and improve the treatment of unilateral effects along multiple dimensions. They explicitly state that the antitrust agencies may rely on quantitative models to inform enforcement decisions, which has in turn helped legitimize modeling in the broader antitrust community. The 2010 Guidelines also provide more complete discussions about the theoretical considerations and empirical evidence that amplify or diminish concerns about unilateral effects, given the specific institutional details of the market in question. Shapiro (2010) describes these changes as part of the continued evolution of the Guidelines "from hedgehog to fox." Further, by accurately characterizing the state of antitrust practice, the 2010 Guidelines have spurred

[3]The DOJ and FTC also released a helpful discussion document in 2006, the Commentary on the Horizontal Merger Guidelines (henceforth, the "Commentary").

[4]Shapiro (2010), p. 712. The "Agencies" refers to the DOJ and FTC.

ongoing research into unilateral effects.

We organize the remainder of this article as follows. We begin with three sections that, in turn, cover differentiated price competition, auctions and negotiation, and homogeneous products quantity competition. This parallels the material in Section §6 ("Unilateral Effects") of the 2010 Guidelines. In each section, we sketch the typically used theoretical frameworks, describe what we view as the state-of-the-art quantitative modeling techniques, and discuss the interplay of research and antitrust practice. We hope the material is useful for practitioners seeking to apply modeling in merger review, and to academics seeking to make practical contributions to antitrust economics.

We then develop links between game-theoretical analyses of unilateral effects and market concentration screens based on the Herfindahl-Hirschman Index (HHI). Our objective is to correct any misconception that market concentration screens are not theoretically justified by unilateral effects models. We draw on recent research and generate numerical results to provide a visualization. The 2010 Guidelines state that a merger will be presumed anticompetitive if the post-merger HHI exceeds 2,500 and the change in HHI (ΔHHI) exceeds 200.[5] Our analysis suggests that a simple tweak might better align merger review with economic theory: a presumption that applies if the post-merger HHI exceeds 2,500 <u>or</u> the ΔHHI exceeds 200.

We conclude with a short discussion of two thought-provoking early-stage research projects. One of these proposes an entirely different empirical framework for the analyses of unilateral effects (Magnolfi and McLeod (2020)). The other suggests that the current reliance of unilateral effects pricing models on Bertrand-Nash equilibrium may be misplaced if firms employ pricing algorithms, as increasingly is the case in online markets (Brown and MacKay (2019)). We wish to leave the reader with a sense that antitrust economics continues to be a fruitful area for intellectual inquiry. The 2010 Guidelines—for all their improvements and accomplishments—provide a snapshot of how merger review was practiced at a fixed point in time. As economic understanding improves and market realities change, antitrust practice will inevitably shift as well.

In the discussions that follow, we draw upon an incredibly rich literature that has been produced over multiple decades by academics, agency economists, and antitrust consultants alike. We have found it impossible to do justice to all of the relevant contributions, and we offer our sincerest apologies to any whose research has been omitted. Complementary literature reviews can be found in other articles (e.g., Willig (1991);

[5]The HHI equals the sum of squared market shares, with the shares being measured on a scale from zero to 100. The ΔHHI is calculated as twice the product of the merging firms' market shares.

Werden (2008); Shapiro (2010)).

2 Differentiated Products Pricing

The area in which empirical methods for horizontal merger analysis have seen the most work is in cases of differentiated products in Bertrand oligopoly settings. Many of these approaches have their roots in the 1992 Guidelines and contemporaneous academic research, but their use has become more widespread since the release of the 2010 Guidelines.

2.1 Analytical Framework

The typical analysis emerges from the Bertrand model of oligopoly competition. Let each firm set prices that maximize its profit, conditional on the prices of its competitors. Firms face the standard trade-off that higher prices improve the profit margin per unit but reduce the quantity demanded by consumers. These effects balance if the following first-order condition is satisfied:

$$p_i + \left[\frac{\partial q_i(p)}{\partial p_i}^T\right]^{-1} q_i(p) = mc_i(p), \tag{1}$$

where p_i, q_i, and mc_i are vectors for firm i's prices, quantities, and marginal costs, respectively, and p is a vector of all firms' prices.[6] The left-hand side of the equation is marginal revenue; thus, profit maximization in this setting requires that marginal revenue equals marginal cost. For simplicity, and because our experience suggests that marginal costs tend to be approximately constant over the relevant range with differentiated products, we assume $mc_i(p) = mc_i$ hereafter.[7]

In this setting, if any firm lowers its prices, it gains some consumers that otherwise would have purchased from competitors. These pricing externalities—the product of competition—push equilibrium prices toward marginal cost, benefiting consumers and increasing welfare. Mergers internalize the pricing externalities and create profit incentives for firms to raise prices. Absent countervailing efficiencies, this results in adverse

[6] Throughout this article, we use the superscript T to refer to the vector/matrix transpose operation. Further, we assume products are substitutes, i.e., that $\partial q_j / \partial p_k > 0$ for any products $j \neq k$.

[7] See also Werden and Froeb (1998), p. 532: "A stylized fact of US industry is that marginal costs are typically constant...." We revisit this subject in our discussion of homogeneous products (Section 4).

consequences for consumers and welfare.

Formally, if a merger occurs between firms j and k, then post-merger first order conditions for the products initially owned by j take the form:

$$p_j + \left[\frac{\partial q_j(p)}{\partial p_j}^T\right]^{-1} q_j(p) = mc_j - \left[\frac{\partial q_j(p)^T}{\partial p_j}\right]^{-1} \left(\frac{\partial q_k(p)^T}{\partial p_j}\right)(p_k - mc_k). \tag{2}$$

Comparing to the equation (1), the left-hand-side is identical, but the right-hand-side is greater due to the addition of a new term that represents the merger effect ($\partial q_j / \partial p_j < 0$ with downward-sloping demand). There are two equivalent intuitions. The first is that a merging firm may find higher prices to be profitable post-merger because some of the lost sales are recaptured by the merging partner. The second is that the merger creates an opportunity cost because if a merging firm increases its quantity (e.g., by lowering price), it cannibalizes some profit that otherwise would have been obtained by the merging partner. This latter intuition is bolstered by the fact that the new term enters the first order conditions in the same way as marginal cost.

The analysis to this point is straight-forward and follows from a simple game-theoretical analysis of pricing incentives. Much of the guiding research was conducted in the 1980s and was known at the time the 1992 Guidelines were drafted.[8] Thus it is that the 1992 and 2010 Guidelines use virtually identical language to describe how mergers affect pricing incentives in differentiated products markets. The 1992 Guidelines state:

> A merger between firms in a market for differentiated products may diminish competition by enabling the merged firm to profit by unilaterally raising the price of one or both products above the premerger level. Some of the sales loss due to the price rise merely will be diverted to the product of the merger partner and, depending on relative margins, capturing such sales loss through merger may make the price increase profitable even though it would not have been profitable premerger.[9]

Next, the 2010 Guidelines:

> A merger between firms selling differentiated products may diminish competition by enabling the merged firm to profit by unilaterally raising the

[8] Robert Willig, a primary author of the 1992 Guidelines, provides a description of the modeling framework in Willig (1991).

[9] 1992 Guidelines, §2.21.

price of one or both products above the pre-merger level. Some of the sales lost due to the price rise will merely be diverted to the product of the merger partner and, depending on relative margins, capturing such sales through merger may make the price increase profitable even though it would not have been profitable prior to the merger.[10]

At this point, the 1992 and 2010 Guidelines diverge, with the former focusing on the conditions under which market shares correlate with the magnitude of unilateral effects, and the latter providing an in-depth discussion about how the opportunity costs created by the merger can be quantified and translated into price effects in specific market settings. In doing so, the 2010 Guidelines draw on knowledge embedded in the antitrust agencies, accumulated from decades of merger review, and also on insights developed in the academic literature. The 2010 Guidelines, in turn, have spurred academic research that extends and improves the modeling of unilateral effects in differentiated products markets in various and useful ways.

2.2 Upward Pricing Pressure

One interpretation of the first order conditions in equation (2) is that the merger creates *upward pricing pressure* by imposing opportunity costs on the merging firms (Farrell and Shapiro (2010)).[11] For simplicity, consider the case of single-product terms. Then the opportunity cost—the magnitude of upward pricing pressure or "UPP"—imposed by the merger on merging firm j is given by

$$UPP_j = \underbrace{d_{jk}}_{\text{Diversion}} \times \underbrace{(p_k - mc_k)}_{\text{Markup}}. \tag{3}$$

The first term in this formula, $d_{jk} \equiv \frac{\partial q_k/\partial p_j}{\partial q_j/\partial p_j}$, is the *diversion ratio* that governs substitution from firm j to firm k. It provides the fraction of sales lost by firm j due to an increase in its price that would be recaptured by firm k.[12] Such recapture matters for pricing incentives only to the extent that profit is earned on the diverted sales. Thus,

[10] 2010 Guidelines, §6.1.

[11] The upward pricing pressure approach of Farrell and Shapiro (2010) draws on preceding research on merger price effects (e.g., Werden (1996); O'Brien and Salop (2000)) that we review later.

[12] As best we can discern, the term "diversion ratio" was coined by Carl Shapiro (Shapiro (1995, 1996)), though the concept dates at least to Willig (1991). Empirical articles in industrial organization continue to focus more on demand elasticities; however, see Conlon and Mortimer (2019) for a detailed discussion of how diversion can be estimated from data on prices and shares.

the relevant notion of UPP for firm j is constructed as the multiplicative product of diversion from j to k and the markup of firm k—neither diversion nor markups in isolation are sufficient to capture the pricing incentives of the merged firm.

In practice, UPP often is converted to an index in order to provide a unit-free measure of the merger's impact on pricing incentives. Let the gross upward pricing pressure index ("GUPPI") be given by

$$GUPPI_j = \underbrace{d_{jk}}_{\text{Diversion}} \times \underbrace{m_k}_{\text{Margin}} \times \underbrace{\frac{p_k}{p_j}}_{\text{Relative Prices}} \tag{4}$$

where $m_k = (p_k - mc_k)/p_k$ is the price-cost margin of firm k.[13] The 2010 Guidelines describe the GUPPI as providing an important diagnostic for unilateral effects in markets with differentiated products. In doing so, it first defines the *value of diverted sales* in terms that track precisely the formulation for the GUPPI provided in equation (4):

> The value of sales diverted to a product is equal to the number of units diverted to that product multiplied by the margin between price and incremental cost on that product. . . . For the this purpose, the value of diverted sales is measured in proportion to the reduction in unit sales resulting from the price increase. Those lost revenues equal the reduction in the number of units sold of that product multiplied by that product's price.[14]

The Guidelines then state:

> The Agencies rely much more on the value of diverted sales than on the level of the HHI for diagnosing unilateral price effects in markets with differentiated products.[15]

An important insight that emerges from UPP analysis is that the effect of a merger on unilateral pricing incentives depends on two main objects: diversion and margins. Firms typically have a strong incentive to understand both their costs and the substitution patterns of their consumers, so information on these objects often becomes available to agencies during the course of merger investigations. The 2010 Guidelines

[13]For more on the development of upward pricing pressure indices, see Moresi (2010) and the other contributions cited in footnote 90 of Farrell and Shapiro (2010).

[14]2010 Guidelines, §6.1.

[15]2010 Guidelines, §6.1. Notably, the Guidelines do not state that the Agencies rely on UPP-style analysis more than on the *change* in HHI for diagnosing unilateral effects. As we develop in Section 5, the change in HHI often can be quite informative of unilateral effects in differentiated-products markets.

specifically mention documentary and testimonial evidence, "win/loss" reports, reports on consumer switching, and customer surveys as among the evidence that may support inferences about diversion. The Guidelines provide less guidance on margins but, in our experience, reasonable estimates often can be culled from documents, testimony, and normal-course pricing analyses. Accounting data also can be informative, especially if supplementary evidence helps distinguish fixed and variable costs.[16]

If reasonable estimates of diversion and margins can be obtained, then the UPP framework allows for a micro-founded analysis of post-merger pricing incentives without the complete understanding of demand elasticities and margins that is often obtained in sophisticated academic research on mergers in particular settings. We return to this subject in our later discussion of merger simulation.

First Order Approximation and Cost Pass-Through

Farrell and Shapiro (2010) introduce UPP as a simple measure of post-merger pricing incentives but caution against interpreting it as a predictor of actual price changes.[17] Yet they also suggest a methodology by which UPP analysis might provide a price prediction: because UPP represents an opportunity cost, and enters the post-merger first order conditions in the same manner as marginal cost, the multiplicative product of UPP and cost pass-through might be informative of unilateral price effects.

This idea is formalized in the subsequent research of Jaffe and Weyl (2013). In deriving the main result, it is convenient to rewrite the pre-merger first order conditions of equation (1) as follows:

$$f_i(p) \equiv -\left(\frac{\partial q_i(p)}{\partial p_i}^T\right)^{-1} q_i(p) - (p_i - mc_i) = 0. \tag{5}$$

We first develop a formulation of pre-merger pass-through. Stack the first order conditions of each firm, $f(p) = [f_1(p)', f_2(p)', \dots]'$, and consider a vector of taxes, t, such that the post-tax equilibrium is characterized by

$$f(p) + t = 0.$$

[16]The 2010 Guidelines at §4.1.3 state that "The Agencies often estimate incremental costs, for example, using merging parties' documents or data the merging parties use to make business decisions."

[17]Referring to UPP and concentration analysis, Farrell and Shapiro (2010, p. 3) state that "neither approach purports to quantify the likely equilibrium effect (e.g., the price change) of the merger...."

Then, by the implicit function theorem,

$$\frac{\partial p}{\partial t}\frac{\partial f(p)}{\partial p} = -I,$$

and pre-merger pass-through is given by

$$\rho \equiv \frac{\partial p}{\partial t} = - \left[\frac{\partial f(p)}{\partial p}\right]^{-1}\Bigg|_{p=p^0}, \tag{6}$$

where p^0 is the vector of prices in the pre-merger equilibrium. As the function $f(p)$ depends on the first derivatives of demand, pass-through depends on both the first and second derivatives of demand (the demand elasticities and curvatures, respectively).

Returning to the effect of the merger between firms j and k, the post-merger first order conditions of any firm i can be expressed as

$$h_i(p) = f_i(p) + g_i(p),$$

where $g_i(p) = 0$ if $i \neq j, k$, and if $i = j$ (symmetrically, if $i = k$) then

$$g_j(p) = - \left[\frac{\partial q_j(p)^T}{\partial p_j}\right]^{-1} \left(\frac{\partial q_k(p)^T}{\partial p_j}\right)(p_k - mc_k).$$

Here $g_j(p)$ and $g_k(p)$ represent the multi-product formulations of UPP. See also equation (2). Jaffe and Weyl prove that, to a first order approximation, the vector of merger price effects is

$$\Delta p = - \left(\frac{\partial h(p)}{\partial p}\right)^{-1}\Bigg|_{p=p^0} g(p^0), \tag{7}$$

where $h(p)$ and $g(p)$ again stack the firm-specific vectors. Thus, a price prediction can be obtained by multiplying UPP by pass-through. However, if one is being precise, the relevant notion of pass-through is not the pre-merger cost pass-through matrix given in equation (6). Rather, observing that the expression contains the Jacobian of $h(p)$ rather than the Jacobian of $f(p)$, the expression uses post-merger pass-through evaluated at pre-merger prices; Jaffe and Weyl refer to this matrix as *merger pass-through*.

The methodology of first order approximation can be interpreted as substituting pass-through for the parametric assumptions common in merger simulation models (which we discuss below). Adding to the theoretical appeal is that the objects within the price prediction of equation (7)—pass-through and UPP—are evaluated at pre-merger prices and thus conceptually should be possible to estimate from data.

Reduced-form regressions of price on marginal cost can obtain estimates of the pre-merger cost pass-through matrix. With known demand elasticities, Slutsky symmetry, and a horizontality assumption, this can allow demand curvatures to be obtained, and merger pass-through then can be calculated. Miller et al. (2016) provide Monte Carlo evidence demonstrating that this procedure is quite accurate in predicting merger price effects under a variety of different demand structures.

But how often are reliable estimates of pass-through available in practice? The results of Jaffe and Weyl (2013), along with those of a related article (Weyl and Fabinger (2013)), have motivated a small renaissance in the empirical literature on pass-through estimation and incidence.[18] Our reading of that literature makes us pessimistic about the exact application of equation (7) in merger review. Consider the case of a three-firm oligopoly. The reduced-form regression equations typically would take the form

$$\begin{bmatrix} p_{1t} \\ p_{2t} \\ p_{3t} \end{bmatrix} = \begin{bmatrix} \rho_{11} & \rho_{12} & \rho_{13} \\ \rho_{21} & \rho_{22} & \rho_{23} \\ \rho_{31} & \rho_{32} & \rho_{33} \end{bmatrix} \begin{bmatrix} c_{1t} \\ c_{2t} \\ c_{3t} \end{bmatrix} + \begin{bmatrix} \epsilon_{1t} \\ \epsilon_{2t} \\ \epsilon_{3t} \end{bmatrix},$$

where c_{it} is some cost-shifter (in dollars per unit sold) associated with firm i and period t, and ϵ_{it} is a reduced-form error term. Because firms producing similar goods tend to have similar production technologies, often there is insufficient empirical variation to separately identify the nine pass-through parameters—the cost terms are too collinear. More frequently, a notion of market pass-through can be estimated based on common cost shocks (e.g., defining market pass-through as $\rho_1^M \equiv \rho_{11} + \rho_{13} + \rho_{13}$).[19] While market pass-through informs many policy questions, it falls short of the merger pass-through matrix needed for the exact application of equation (7).

An entirely different critique of the empirical pass-through literature is developed in the Conlon and Rao (2019) study of the distilled spirits market. They observe that 80% to 90% of prices end in 99 cents (e.g., \$9.99) and that price changes predominately occur in one dollar increments (e.g., \$9.99 to \$10.99). A retailer operating under these constraints might not raise price at all in response to small cost increases but, in the

[18] See also Miklos-Thal and Shaffer (2019).

[19] This was the case in our own attempts to estimate pass-through for the cement industry in Miller et al. (2014). For an exception that may prove the rule, see Muehlegger and Sweeney (2019). MacKay et al. (2014) provide a more formal treatment of econometric bias in cost pass-through regressions.

event that a price rise is warranted, the magnitude of the price increase is likely to far exceed that of the cost increase. Thus, Conlon and Rao demonstrate that a naive estimator suggests pass-through that is alternately implausibly small or implausibly large, depending on the sample. They also provide an estimator based on the ordered logit model that gives a more robust path forward in such settings.

The broad point we take from this discussion is that collinearity and various pricing frictions can interfere with pass-through estimation, even in markets that appear to be a good match for the methodology of first order approximation. Thus, there are few actual examples of first order approximation being used in a merger investigation or litigation. In the trial for *General Electric/Electrolux* (2015), the expert testifying on behalf of the DOJ used calibrated pass-through rates implied by several different demand systems in order to construct price predictions.[20] This seems like a sensible approach when consistent pass-through estimates are unavailable.

UPP as a Predictor of Merger Price Effects

Miller et al. (2017) suggest that the value of UPP itself provides a good approximation for merger price effects. In light of equation (7), this amounts to an argument that using the identity matrix to proxy for merger pass-through may sacrifice little predictive accuracy. Consider a simple numerical example with three symmetric firms. Consumers select between the firms and an outside good in accordance with a logit demand system. Each firm has a margin of 0.50 and a 30% market share. With a merger between the first two firms, equation (7) becomes

$$\begin{bmatrix} 0.204 \\ 0.204 \\ 0.052 \end{bmatrix} = \begin{bmatrix} 0.771 & 0.180 & 0.297 \\ 0.180 & 0.771 & 0.297 \\ 0.122 & 0.122 & 0.776 \end{bmatrix} \begin{bmatrix} .214 \\ .214 \\ 0 \end{bmatrix}.$$

The value of UPP (0.214) nearly equals the first order approximation (0.204) for the merging firms. This happens because the diagonal elements of the merger pass-through matrix are somewhat below one, while the off-diagonal elements are positive. Thus, replacing merger pass-through with an identity matrix overstates some effects and understates others; the balance is that UPP is close to the first order approximation. The

[20] See the slides used by Michael Whinston as part of his testimony, at page 59, available at `https://www.justice.gov/atr/file/ge-px02015/download`. The merger was abandoned before the trial concluded.

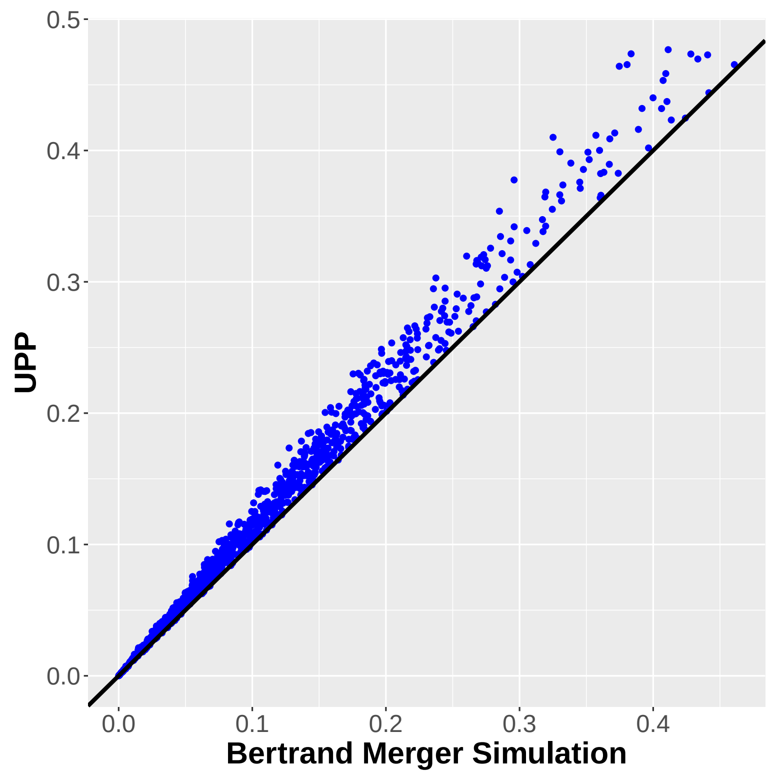

Figure 1: UPP and Merger Price Effects

Notes: The figure presents the results of a Monte Carlo experiment in which models of Bertrand competition with logit demand are calibrated to match 500 randomly drawn data sets. A merger between two firms is considered. Each dot provides the value of UPP for one merging firm (on the vertical axis) and the corresponding price increase implied by Bertrand merger simulation (on the horizontal axis).

same countervailing biases arise in many of the differentiated-products demand systems used in industrial organization, though see Miller et al. (2017) for exceptions.

We conduct a short Monte Carlo exercise to allow for visualization. We take random draws on a market with four firms and an outside good. Demand is logit. Each market is calibrated using (1) a random assignment of market share and (2) a margin for the fourth firm that is drawn from a uniform distribution over [0.25,0.75]. Prices are normalized to one. Consider a merger between the first two firms. We calculate UPP and also compute the "true" price effect with merger simulation.[21] Figure 1 summarizes the results. As shown, the dots cluster around the $45°$-line, indicating that UPP and the price increases implied by merger simulation are quite similar.

As part of the investigation into the proposed *Reynolds American/Lorillard* (2015) merger, the FTC used UPP to predict price effects, prior to negotiating a divestiture.

[21]The exercise is similar in spirit to that of Miller et al. (2017), which also considers linear demand, the Almost Ideal Demand System, and log-linear demand. See that article for details on the calibration.

The analysis is described in Hanner et al. (2016).[22] On the other hand, in our experience, economists engaged in merger review sometimes propose multiplying UPP by 0.50 to obtain a price prediction, with the rationale that this is the pass-through of a monopolist with linear demand. This risks understating price increases for two reasons: First, it ignores the equilibrium feedback effects that increase pass-through in oligopoly models. Second, if demand is convex then pass-through can be much higher than with linear demands, all else equal. Thus it is that the Miller et al. (2017) results indicate that UPP approximates merger price effects reasonably well for linear demands, and provides conservative price predictions if demand is Almost Ideal or log-linear.

2.3 Merger Simulation

Merger simulation provides an alternative methodology for capturing post-merger pricing incentives and predicting price effects. Start again with equation (1) and stack the first order conditions of each firm. The formulation of Bertrand equilibrium typically used in the empirical industrial organization literature (e.g., Nevo (2001)) obtains:

$$p + \left[\Omega \circ \frac{\partial q(p)}{\partial p}^{T}\right]^{-1} q(p) = mc, \tag{8}$$

where the (j,k) element of the symmetric "ownership matrix," Ω, equals 1 if products j and k are owned by the same firm, and zero otherwise, and where $\circ$ refers to element-by-element multiplication. This provides a system of equations that can be used both for inference about the pre-merger equilibrium (the "imputation step") and for prediction about merger effects (the "simulation step").

In academic research, the imputation step typically involves demand estimation to obtain the derivatives, $\partial q(p)/\partial p$. With prices and quantities, and letting Ω reflect pre-merger product ownership, marginal cost then is identified from equation (8). In merger review, the direction of inference can be reversed: data on marginal costs and diversion are used to the recover the demand derivatives, and this in turn allows demand to be calibrated. The agencies often rely on simple demand functional forms, such as the logit (e.g., Werden and Froeb (1994, 2002)), the Almost Ideal Demand

[22] Although it predates the formal development of UPP in the economics literature, the analysis presented by the FTC in *Swedish Match/National Tobacco* (2000) also included similar calculations. See the FTC Proposed Findings of Fact at pages 125-126, which describe testimony by John Simpson, available at https://www.ftc.gov/sites/default/files/documents/cases/2000/06/swedishmatchpublic.pdf.

System (e.g., Epstein and Rubinfeld (2001)), or linear demands, rather than the more sophisticated random-coefficients logit demand system (Berry et al. (1995)) that is popular in academic research. This difference reflects the resources available. In merger review, the time and data necessary for sophisticated demand estimation often are unavailable, but margins and diversion may be obtained from documents.[23]

In the simulation step, Ω is adjusted to account for post-merger product ownership. This has the effect of incorporating additional terms into the merging firms' first order conditions, just as in equation (2) and with the same intuitions. Post-merger prices that solve the new system of equations then can be computed numerically. Because the merger moves prices away from the pre-merger equilibrium, some parametric assumptions on demand are required. As one might expect given the first order approximation of equation (7), demand systems that generate greater pass-through tend to predict larger price effects (Crooke et al. (1999); Froeb et al. (2005); Miller et al. (2016)).

The two-step procedure for merger simulation emerged in the academic literature after the release of the 1992 Guidelines (e.g, Berry and Pakes (1993); Hausman et al. (1994); Werden and Froeb (1994)). Just as structural modeling gained traction in empirical industrial organization, simulation became more frequently used in merger review. For example, in *Maybelline/Cosmair* (1996), the DOJ estimated demand for mascara from available scanner data and then performed a merger simulation that indicated price effects would not be substantial.[24] Similarly, the FTC estimated demand in *General Mills/Pillsbury* (2001) and did a merger simulation.[25]

However, before the 2010 Guidelines, merger simulation was often perceived in the broader antitrust community as a "black box" analysis that could not readily be explained to non-economists. One major contribution of the 2010 Guidelines, then, has proven to be their inclusion of the following sentence:

> When sufficient data are available, the Agencies may construct economic models designed to quantify the unilateral price effects resulting from the merger.[26]

The effect has been to normalize the use of simulation and model-based inquiry in

[23] Articles in the academic literature have examined how merger simulation responds to the presence of consumer search costs or switching costs (e.g., Allen et al. (2013); MacKay and Remer (2019)). To our knowledge, these refinements have yet to be incorporated into simulation used in merger investigations.

[24] See 2006 Commentary, §2.

[25] See 2006 Commentary, §2. The commentary also mention Bertrand merger simulation in two other DOJ cases: *Interstate Bakeries/Continental* (1995) and *Vail Resorts/Ralston Resorts* (1997). In the latter instance, demand was measured using survey data.

[26] 2010 Guidelines, §6.1.

merger review. For example, a little over a year after the promulgation of the 2010 Guidelines, the DOJ presented a Bertrand merger simulation with linear demand in the litigation of *H&R Block/TaxACT* (2011).[27] In considering the simulation results, the District Court viewed it as a helpful complement to the other evidence in the trial,

> The Court finds that the merger simulation model used by the government's expert is an imprecise tool, but nonetheless has some probative value in predicting the likelihood of a potential price increase after the merger. The results of the merger simulation tend to confirm the Court's conclusions based upon the documents, testimony, and other evidence in this case ....[28]

Thus, it seems that courts may find some merger simulation results persuasive, especially if accompanied by corroborating evidence.

More recently, the agencies have relied on more sophisticated simulations, approaching the structures commonly seen in the scholarly literature, where complex demand and supply functions are the norm. In *AT&T/DirecTV* (2015), experts working on behalf of the FCC and those working on behalf of the merging firms both constructed simulation models with nested logit demands estimated using detailed, geographically disaggregated data.[29] Based in part of these results, the FCC decided to approve the transaction. During the litigation of *Aetna/Humana* (2016), the DOJ's expert also used a merger simulation with nested logit demand.[30] Similar to what was seen in *H&R Block/TaxACT*, the District Court put weight on the simulation results as additional support that complemented other evidence.[31]

An interesting question relates to the relative advantage of UPP analysis and merger simulation. As we see it, the two main benefits of UPP are that (1) only data from the merging firms are required, and (2) the mechanisms by which a merger affects prices are more transparent.[32] Only simulation obtains prices consistent with a post-merger equilibrium, but whether this generates more accurate predictions depends on the appropriateness of (often untestable) parametric assumptions. Simulation is better

[27] See the Memorandum Opinion at page 76, describing testimony by Frederick Warren-Boulton.

[28] Memorandum Opinion, page 78.

[29] See Appendix C to the FCC Memorandum Opinion and Order.

[30] See the demonstrative exhibit used by Aviv Nevo, at slides 63-66, available at `https://www.justice.gov/atr/page/file/918706/download`.

[31] See the Memorandum Opinion at page 66.

[32] The latter point can make UPP and simulation complements, as UPP can be used to explain intuition, and simulation can provide corroborating evidence. Both UPP and simulation have been presented together in a number of recent court cases. Hanner et al. (2016) note that the differing assumptions underlying the two approaches can make them complementary.

equipped to handle nonlinearities in costs/demand or other non-standard features. However, for the most part, UPP and merger simulation are broadly similar in their ability to assess post-merger pricing incentives and to predict merger price effects.

2.4 Merger Efficiencies with Differentiated Products

Some mergers make the firms involved more efficient. If these gains are sufficiently large then consumers can benefit from the merger despite a loss of competition. In principle, this trade-off can be accounted for in UPP-style analyses or merger simulation. We focus here on UPP because simulation is already more widely understood.

Efficiencies typically take the form of either marginal cost reductions or quality improvements. Consider marginal cost reductions first. Because UPP enters the post-merger first order conditions as an adverse (opportunity) cost shock, a cost reduction of the same magnitude "cancels out" UPP such that the post-merger first order condition is satisfied at the pre-merger price. Thus, in the case of a single-product firm, *net* UPP exists if and only if

$$d_{jk} \times (p_k - mc_k) > c_j^0 - c_j^1, \tag{9}$$

where c_j^0 and c_j^1 are pre-merger and post-merger costs, respectively. Equivalently, letting $\dot{c}_j \equiv (c_j^0 - c_j^1)/c_j^0$ be the percentage change in costs, and converting UPP to an index, we have net upward pricing pressure if and only if

$$d_{jk} m_k \frac{p_k}{p_j} > \dot{c}_j (1 - m_j) \tag{10}$$

Equations (9) and (10) provide simple diagnostic formulas that can help identify how likely it is for a given merger to produce net upward pricing pressure and hence lead to some increase in prices. Using this type of analysis, the DOJ presented evidence in *General Electric/Electrolux* (2015) that the efficiencies the merging firms claimed were not sufficiently large to overcome positive UPP.[33]

There is a shortcoming of this approach, however. Because the incentive of one merging firm (firm A) to raise price depends on the markup of its merging partner (firm B), if the costs of firm B decrease then the upward pricing pressure created for firm A is amplified. To capture this cross-firm effect, it is necessary to consider the firms' first order conditions simultaneously (Werden (1996)). Prices increase if, for

[33] See the demonstrative exhibit used by Michael Whinston at page 57, available at `https://www.justice.gov/atr/file/ge-px02015/download`.

both merging firms, the "compensating marginal cost reduction" (CMCR) is greater than the actual cost reduction:

$$\hat{c}_j \equiv \frac{m_j d_{jk} d_{kj} + m_k d_{kj} p_k / p_j}{(1-m_j)(1-d_{jk}d_{kj})} > \dot{c}_j. \tag{11}$$

The results of UPP and CMCR analysis usually align, but in close cases or if greater precision is desired, then the CMCR is more appropriate.[34] In the staff report issued for the proposed *AT&T/T-Mobile* (2011) merger, the FCC provided both UPP and CMCR calculations to show that efficiencies would have to be quite large in order to result in no incentives to raise price.[35]

We turn now to quality efficiencies, relying on the derivations of Willig (2011). Denote the willingness-to-pay ("quality") for product j as v_j, and assume that demand can be expressed in terms of quality-adjusted prices, $H_j = v_j - p_j$.[36] Let the pre-merger and post-merger qualities be v_j^0 and v_j^1, respectively. Then upward pressure exists on quality-adjusted prices if and only if

$$d_{jk} m_k \frac{p_k}{p_j} > \frac{v_j^1 - v_j^0}{p_j}. \tag{12}$$

which again provides a simple diagnostic formula. In our experience, the greatest challenge to evaluating quality efficiencies in application tends to arise in the quantification of the right-hand side of the inequality. To illustrate the difficulties, consider the case of logit demand. The (transformed) quantity-demanded of product j takes the form:

$$\tilde{q}_j = x_j' \beta - \alpha p_j + \xi_j$$

where x_j is a vector of product characteristics, ξ_j represents unobserved quality, and (β, α) are structural preference parameters. If the merger induces changes in the characteristics, $\Delta x_j \equiv x_j^1 - x_j^0$, then we have $v_j^1 - v_j^0 = \Delta x_j' \beta / \alpha$. Thus, it is necessary to

[34] Equation (11) applies to asymmetric single-product firms. With symmetry, a simplification yields $\hat{c}_j = (m/(1-m))(d/(1-d))$. See Werden (1996) for the case of multi-product firms. Nocke and Whinston (2019) provide an analogous equation that depends only on the market shares of the merging firms, for the specific case of logit demand.

[35] See the economic appendix to the Staff Report at pages C-9 to C-10, available at `https://docs.fcc.gov/public/attachments/DA-11-1955A2.pdf`. The transaction was subsequently abandoned.

[36] Willig (1978) establishes that demand is a function of quality-adjusted prices if and only if consumers' indirect utilities also can be expressed as a function of (the same) quality adjusted prices. This holds, for example, in logit and nested logit models of demand but not in richer random-coefficients logit models. See Israel et al. (2013) for an application of quality-adjusted prices to airline mergers.

know the change in characteristics (Δx), the responsiveness of demand to characteristics (β), and the responsiveness of demand to price (α). Academic studies in empirical industrial organization often obtain these objects with estimation—see especially Fan (2013), which endogenizes post-merger product characteristics—but, in merger review, data limitations and compressed schedules tend to make it difficult to recover β from data.[37] Further, it can be difficult to know Δx, in part because gun-jumping rules prohibit firms from coordinating prior to merger consummation. These obstacles make a formal balancing of UPP and quality efficiencies infeasible in most instances.

3 Auctions and Procurement

Compared to the amount of discussion devoted to Bertrand analysis, the Guidelines spend far less time on auctions. They are only mentioned in footnote 21 of the 1992 Guidelines and are covered in a single page in the 2010 Guidelines. This disparity in emphasis may either be a cause or a symptom of the fact that there are fewer analytical tools aimed at antitrust practitioners wishing to study auction settings. However, there have been some recent developments, likely due in part to the general increasing use of structural modeling and merger simulations since the release of the 2010 Guidelines.

3.1 Analytical Framework

Unilateral effects for differentiated products are frequently discussed using Bertrand models, as seen in the previous section. However, many merger investigations arise in "request for proposal" (RFP) or procurement settings, where prices are set by different mechanisms. A leading example is a firm that buys an input from an intermediate supplier. In these instances, the buyer may specify the way in which prices are determined and may sometimes negotiate with individual sellers. These types of markets are often modeled as auctions.

A common point of emphasis in examining mergers with auctions is how often the merging firms are likely to bid against each other, particularly when they are customers' first and second-most preferred choices. In an RFP setting, the buyer typically plays suppliers off one other, which resembles a descending price auction, where the first and second choices are of prime interest. This dynamic also appears in second-price and

[37] Notably, the responsiveness of demand to characteristics (β) differs from the responsiveness of demand to price (α) in that it cannot be inferred from a price-cost margin.

second-score auctions, which are strategically equivalent to descending price settings. A helpful baseline framework for analyzing these situations appears in Miller (2014, 2017), and uses a second-score auction that treats products as differentiated in terms of the value they give consumers. Waehrer and Perry (2003) derive a model in terms of firms that have different costs and capacity in delivering a homogeneous product, and find similar merger effects.

Assume that a consumer i is soliciting bids from a series of suppliers indexed by j, such that the payoff from supplier j is $u_{ij} = v_{ij} - p_j$, where v_{ij} is the gross value of the supplier's product to customer i, and p_j is the price paid. Each supplier observes its own value v_{ij} and its own marginal cost, but not those for competitors. Price is determined by a second-score auction, where the buyer purchases from the supplier whose bid gives the highest payoff, but the price is such that the realized payoff is equal to that offered by the second best bid. Given this auction mechanism, it is a weakly dominant strategy for each firm to set its bid equal to its marginal cost. Thus, if supplier j wins the auction we have that

$$p_j = v_{ij} - \max_{l \neq j}\{v_{il} - mc_l\}. \tag{13}$$

In equilibrium, the buyer's payoff is equal to the surplus generated by the runner-up product (that is, $\max_{l \neq j}\{v_{il} - mc_l\}$ if j is the winning product), while the winning supplier earns the incremental surplus it generates beyond its closest competitor ($v_{ij} - mc_j - \max_{l \neq j}\{v_{il} - mc_l\}$).

In this setting, price is determined by how narrow the gap is between the surplus generated by the buyer's most and second-most preferred suppliers. Therefore, insofar as a merger alters that relationship, it can cause prices to rise. Specifically, suppose that suppliers j and k merge. Then, if supplier j wins the auction we have that

$$p_j = v_{ij} - \max_{l \neq j,k}\{v_{il} - mc_l\}. \tag{14}$$

That is, the merged entities will not bid against each other, because they have perfect information on the amount of surplus each of their products can offer the customer. If product k was the second-best option for the buyer, the price will rise. In instances where the merging firms are not ranked first and second, nothing changes about the realized outcome. Therefore, in assessing the potential effects of a proposed merger, of key interest is how likely the merging firms are to be a buyer's first and second-most preferred suppliers.

The focus on customers' first and second choices is discussed both the 1992 and

2010 Guidelines. The 1992 Guidelines reference this issue in terms of supplier cost,

> In some markets sellers are primarily distinguished by their relative advantages in serving different buyers or groups of buyers, and buyers negotiate individually with sellers. Here, for example, sellers may formally bid against one another for the business of a buyer, or each buyer may elicit individual price quotes from multiple sellers. A seller may find it relatively inexpensive to meet the demands of particular buyers or types of buyers, and relatively expensive to meet others' demands. Competition, again, may be localized: sellers compete more directly with those rivals having similar relative advantages in serving particular buyers or buyer groups. For example, in open outcry auctions, price is determined by the cost of the second lowest cost seller. A merger involving the first and second lowest cost sellers could cause prices to rise to the constraining level of the next lowest cost seller.[38]

The 2010 Guidelines are more agnostic on what factors specifically determine the winner of an auction, but continue with the emphasis on first and second choices,

> Anticompetitive unilateral effects in these settings are likely in proportion to the frequency or probability with which, prior to the merger, one of the merging sellers had been the runner-up when the other won the business. These effects also are likely to be greater, the greater advantage the runner-up merging firm has over other suppliers in meeting customers' needs.[39]

Thus, a key question in the analysis of these types of mergers has been determining how likely the merging firms are to be first and second in consumers' eyes. Much of the empirical and structural work has focused on tackling that issue.

3.2 Reduced-Form Analysis and Merger Simulation

Although there are a number of empirical tools used in assessing unilateral effects, such as the UPP and merger simulation frameworks discussed in Section 2, the majority of them have appeared in the context of differentiated products sold via Bertrand competition. Analogous work on mergers with auctions is more scarce, particularly when considering tools aimed at practitioners. This may in part be due to a divergence between the focus of the academic literature on auctions, which has often emphasized

[38] 1992 Guidelines, §2.21.

[39] 2010 Guidelines, §6.2.

nonparametric identification or applications to specific contexts such as natural resource auctions or bid rigging, and that of the merger reviewing agencies. The existing work that does appear falls, broadly speaking, into two categories: (1) reduced-form analysis of win/loss data or bids, and (2) second-score or second-price merger simulations.

Win/Loss and Bid Analysis

The typical reduced-form analysis of mergers and auctions attempts to answer the questions as to whether the merging firms are likely to be the first and second-best options for buyers and, if so, how much of an advantage they have on the third-best. In effect, these types of exercises are loose attempts to mirror the UPP calculation but for auctions. Comparing equations (13) and (14), we see that the expected increase in price for product j is

$$pr_{jk}E[(v_{ik} - mc_k) - \max_{l \neq j,k}\{v_{il} - mc_l\} | j \text{ wins}, k \text{ is second}], \tag{15}$$

for a merger between suppliers j and k, where pr_{jk} is the probability that j is the first choice and k is the runner-up. The probability that the merging firms are first and second is a similar concept to diversion, while the gap in surplus between the second and third bidders is related to the markup, although these terms are not identical to their UPP counterparts. In merger review, one or both of these objects may be measured.

Procurement settings typically generate data on individual auctions or RFPs. Frequently these data list who the winner was, sometimes with the realized price, along with some subset of the following information: (1) for products or services that are purchased repeatedly, who the last supplier was, which is sometimes called "win/loss" data; (2) the identity of the non-winning bidders; or (3) more rarely, the value of the non-winning bids. Data sets of the first two types are used to form an assessment of the probability the merging firms are first and second, while data of the third type can be used to calculate sample values for expression (15) directly. In *Quest Diagnostics/Unilab* (2003), for example, the FTC had information sufficient to show that the merging firms were the first and second-lowest bidders for a significant percentage of customers and argued that prices would rise to the level dictated by the third-lowest supplier.[40] Experts testifying on behalf of the DOJ in the *Oracle/PeopleSoft* (2004) trial

[40] 2006 Commentary, §2.

proceedings showed data and regressions indicating that when PeopleSoft was present in an RFP, Oracle offered more discounts.[41] In the *Bazaarvoice/PowerReviews* (2013) trial, the DOJ presented evidence that PowerReviews was the competitor identified with the highest frequency in RFPs that Bazaarvoice participated in.[42]

One of the most commonly available types of data is win/loss. From this information, one can calculate a switching or churn ratio, n_{jk}/N_j, where n_{jk} is the number of customers switching from firm j to firm k, and N_j is the total number of customers switching from j to any other option. This value is frequently used as a measure of pr_{jk}, although depending on the customers' reasons for switching, the churn ratio may not align with the ranking probability.[43] A common benchmark is how the churn ratio compares to what diversion according to share would predict.[44] In *Express Scripts/Medco* (2012), the FTC calculated the churn ratio for RFPs done for pharmacy benefit services and found that the merging firms experienced significant churn to other competitors, even though the combined firm would account for 40% of the market.[45] The FTC subsequently did not challenge the transaction. As part of the economic analysis that appeared in the trial for *Anthem/Cigna* (2016), the DOJ presented churn ratios showing that the share of switches accounted for by Anthem when Cigna was the incumbent and vice versa were larger than would be predicted by either firm's market share.[46]

Merger Simulation

Compared to the work done for Bertrand settings, merger simulation is less common in the auction context. Much of the analysis instead relies on the reduced-form methods discussed above. The somewhat recent trial examples we are aware of are *Sysco/US Foods* (2015) and *Anthem/Cigna* (2016). In both instances, the expert testifying for the FTC and DOJ, respectively, used a second-score auction framework of the type discussed earlier in this section.[47]

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[41] See the demonstrative exhibits used by Kenneth Elzinga and Preston McAfee, available at `https://www.justice.gov/atr/usdoj-antitrust-division-us-and-plaintiff-states-v-oracle-corporation`.

[42] See the Memorandum Opinion at paragraphs 267-273, discussing testimony by Carl Shapiro on behalf of the DOJ.

[43] Relatedly, Chen and Schwartz (2016) show how the churn ratio may depart from diversion.

[44] Diversion according to share is given by $d_{jk} = s_k/(1 - s_j)$, where s_j is the market share of firm j.

[45] See Shelanski et al. (2012).

[46] See the demonstrative exhibit used by David Dranove at pages 46-46, available at `https://www.justice.gov/atr/page/file/914606/download`.

[47] See the *Sysco/US Foods* Memorandum Opinion at pages 89-92, discussing testimony by Mark Israel on behalf of the FTC and the *Anthem/Cigna* district-level Memorandum Opinion at pages 58-59 and 66-67, discussing testimony by David Dranove on behalf of the DOJ.

As is true in most merger simulations, these auction simulations rely on specific structural assumptions in order to generate predictions for price effects. A key assumption pertains to the distribution of surplus (recall: surplus is value less costs), which in turn determines the expected price change in expression (15). Miller (2014, 2017) proposes a logit formulation that results in tractable, closed-form expressions. Specifically, Miller (2017) shows that the pre-merger expected markup for firm j, conditional on j winning an auction, is given by

$$E[p_j - mc_j | j \text{ wins}] = -\frac{1}{s_j}\sigma \ln\left(\frac{1}{1-s_j}\right), \tag{16}$$

where s_j is the market share of firm j, and σ is a scaling parameter that governs the variance of consumer values. If a markup and market shares are observed, this expression allows σ to be calibrated. If a merger between firms j and k were to occur, this markup becomes

$$E[p_j - mc_j | j \text{ wins}] = -\frac{1}{(s_j + s_k)}\sigma \ln\left(\frac{1}{1-s_j-s_k}\right), \tag{17}$$

which reflects the increase in markup that occurs once firms j and k stop bidding against each other. This higher profit margin translates directly into higher prices and lower consumer surplus. Post-merger market shares remain the same as pre-merger, since the merged firms continue to bid as before against non-merging rivals. The analysis presented by the DOJ in *Anthem/Cigna* relied on this Miller framework.

It is interesting to compare and contrast the logit second-score auction simulation with its logit Bertrand counterpart. In both instances, consumer preferences consist of a deterministic portion capturing quality and price alongside a logit random component. The purchase probabilities have the same logit form. The only difference arises in how prices are set. In order to investigate this issue, we generated a series of logit second-score auction simulations in the same manner as for the Bertrand simulations discussed in Section 2. The resulting effect on prices across the two models is strongly positively correlated, with, for example, a correlation coefficient of 0.96 for markets with four pre-merger firms. The levels are similar at values below 5%, and diverge somewhat more as the effects grow in size.

Given that one could conceptualize the Bertrand game as a first-price auction and the existence of revenue equivalence theorems, it seems that the key distinction between the models lies in the information assumptions on what sellers know about buyer preferences. In the second-score auction model, the merging sellers know the value of the random component of consumer payoffs, which causes them to withdraw the lower value product in each auction. The market shares and prices of other competitors are not affected. In the Bertrand model, sellers only observe the distribution of the logit shock. The merging firms raise prices for all customers, which induces changes in market shares and prices for all rivals.

3.3 Powerful Buyers

Auction settings often involve buyers that are themselves large firms, rather than a pool of atomistic consumers. This raises the question of whether these buyers can protect themselves from the negative consequences of a merger among their suppliers. The 2010 Guidelines state that

> The Agencies consider the possibility that powerful buyers may constrain the ability of the merging parties to raise prices. . . . However, the Agencies do not presume that the presence of powerful buyers alone forestalls adverse competitive effects flowing from the merger. Even buyers that can negotiate favorable terms may be harmed by an increase in market power.[48]

Consistent with this statement, the research on mergers in auctions and bargaining games indicates that consumer harm can arise in these contexts.

Waehrer and Perry (2003) and Loertscher and Marx (2019) allow buyers to set one or more reserve prices. In the Waehrer and Perry (2003) model, the reserve price applies uniformly to all suppliers. Mergers can induce buyers to decrease the reserve price as a counterbalance to greater supplier market power. By contrast, in the Loertscher and Marx (2019) model, buyers use discriminatory reserve prices to advantage weaker suppliers. In both cases the use of reserve prices may allow customers to mitigate the harm from mergers, but not to eliminate it.

This issue also appears in a related class of models, those on bargaining. Certain procurement contexts, particularly those that involve long negotiations, are sometimes modeled as bargaining games instead of auctions. The leading examples are the purchase of healthcare services and of television programming. In these models, the presence of bargaining power can lessen the harm from a merger between substitute suppliers, but typically does not fully offset it. For example, Gowrisankaran et al. (2015)

[48] 2010 Guidelines, §8.

use a bargaining framework to study the proposed *Inova Health System/Prince William Hospital* (2006) merger and find that it would have resulted in substantial price increases. The FTC challenged the transaction, and it was later abandoned. Farrell et al. (2011) discuss the bargaining model as it is applied to hospital mergers. A similar model was used in the FCC investigation of the proposed *Comcast/Time Warner Cable* (2014) merger.[49] Sheu and Taragin (2018) show how bargaining models of this type can be calibrated with data commonly available to the agencies and then used for merger simulations.

4 Homogeneous Products

Much of the early game-theoretical literature on mergers examined the properties of Cournot equilibrium (e.g., Salant et al. (1983); Perry and Porter (1985); Farrell and Shapiro (1990)). The subsequent empirical literature, however, has focused more on differentiated products and auctions, and there have been relatively fewer recent modeling innovations for homogeneous products. The 2010 Guidelines thus largely track the 1992 Guidelines, albeit with a somewhat more expansive discussion.[50]

4.1 Analytical Framework

The typical analysis emerges from the Cournot model of oligopoly competition among suppliers of a homogeneous product. Each firm produces at an output level that maximizes its profit, conditional on the output of competitors. Firms in this context face the trade-off that output reductions raise the market price but reduce the quantity sold by the firm. These countervailing effects balance in equilibrium, where again marginal revenue equals marginal cost.[51] Mergers create an incentive for each merging firm to reduce output because its merging partner benefits from the higher market price. Farrell and Shapiro (1990) prove that, absent efficiencies, merging firms reduce their

[49] See, for example, the discussion in the "Proposed Comcast-Time Warner Cable-Charter Transaction Economic Analysis Workshop," the transcript of which is available at `https://ecfsapi.fcc.gov/file/60001031131.pdf`. In this case the merger was one between buyers, not suppliers. The transaction was subsequently abandoned.

[50] It is telling that the Shapiro (2010) article on the drafting of 2010 Guidelines mentions homogeneous products only in passing.

[51] The first order conditions of equation (1) apply with the simplification that $\partial q_i/\partial p_i = \partial Q/\partial p$, for all i, given market quantities $Q \equiv \sum_i q_i$ and market price p.

output in equilibrium and non-merging firms increase output by a lesser amount in response, such that total output falls and the market price increases.

Consistent with this reasoning, the 2010 Guidelines state:

> In markets involving relatively undifferentiated products, the Agencies may evaluate whether the merging firm will find it profitable unilaterally to suppress output and elevate the market price.[52]

Similar language appears in the 1992 Guidelines, §2.22, but the 2010 Guidelines pushes a bit further and enumerates conditions under which unilateral effects are likely to be more pronounced:

> A unilateral suppression of output is more likely to be profitable when (1) the merged firm's market share is relatively high; (2) the share of the merged firm's output already committed for sale at prices unaffected by the output suppression is low; (3) the margin on the suppressed output is relatively low; (4) the supply responses of rivals are relatively small; and (5) the market elasticity of demand is relatively low.[53]

Each of these considerations arises from a game-theoretical analysis of mergers in Cournot equilibrium.[54] However, this "checklist" approach can leave merger review unsettled if market facts are ambiguous—for example, if the market shares of the merging firms are low but market demand is inelastic. Just as with differentiated-products mergers, analyses that are tightly linked to the underlying theoretical model allow for multiple considerations to be evaluated jointly. This may provide a more accurate prediction of merger effects than an evaluation of specific market facts in isolation.

4.2 Quantitative Methods

Perhaps the model most amenable to calibration and simulation is that of Perry and Porter (1985), which features a linear market demand curve and firm-specific marginal cost curves of the form $mc_i = q_i/k_i$, where k_i represents capital. Thus, the model

[52] 2010 Guidelines, §6.3.

[53] 2010 Guidelines, §6.3. The 2010 Guidelines also mention, usefully, that there are many ways to implement output suppression.

[54] The only consideration that does not emerge from a one-shot game of simultaneous production is (2), which can be an important consideration, especially in the presence of forward markets. A caveat to the Guidelines language is that merging firms have an incentive to reduce output commitments, such that forward markets can amplify rather than mitigate price effects (Miller and Podwol (2019)).

embeds that marginal costs increase with output, which has theoretical importance because, otherwise, the output expansion of non-merging firms tends to be large enough to render merger unprofitable. It also matches the stylized fact that the production of chemicals, metals, and other industrial products often is limited by capacity constraints. The marginal cost function is the dual of the Cobb-Douglas production function, $q_i = \sqrt{k_i M_i}$, where M_i is the variable factor. The model can be calibrated with data on market shares, total quantity, and price. Alternatively, denoting as $\bar{q}_i$ as maximum that firm i can economically produce at prevailing market prices, it is possible to recover the capital terms as $k_i = \bar{q}_i/p$, such that data on capacity can substitute for data on output. With both sets of data, or margins, marginal cost intercepts can be incorporated, and over-identification checks can be conducted.[55]

If the parametric assumptions of the Perry and Porter (1985) model are inappropriate in a particular setting, then a CMCR approach can be applied (Froeb and Werden (1998)).[56] Let the share-weighted marginal cost of the merging firms be c^0. After the merger, cost minimization dictates production at a level that equates the marginal costs of the merging firms' plants; incorporating any efficiencies, let this cost be c^1. Finally, defining $\dot{c} \equiv (c^1 - c^0)/c^0$ as the percentage reduction in marginal cost due to the merger, market price increases if and only if

$$\dot{c} < \frac{2s_j s_k}{\epsilon(s_j + s_k) - (s_j^2 + s_k^2)} \tag{18}$$

where $\epsilon > 0$ is the demand elasticity. With symmetric firms, this is equivalent to

$$\dot{c} < \frac{s}{\epsilon - s} \tag{19}$$

Thus, for example, with market shares of 0.20 and a market elasticity of one, the merger increases price unless marginal cost decreases by at least 25 percent. This calculation requires no parametric assumptions on the demand or cost functions.

These models were used in the recent *Tronox/Cristal* (2018) merger trial, which involved the market for chloride-process titanium dioxide.[57] Given market shares and

[55]The calibration and simulation we describe for this model tracks the equations derived in McAfee and Williams (1992). See also Farrell and Shapiro (1990) and Werden (1991).

[56]See Jaffe and Weyl (2013) for a generalized expression for the UPP formula that nests differentiated-products Cournot as a special case. As the amount of differentiation decreases, converging toward the homogeneous-products case, UPP tends to zero but the pass-through of UPP to equilibrium prices tends to infinity. This mathematical difficulty makes the CMCR approach more useful for homogeneous-products markets.

[57]See Greenfield et al. (2019) and the Memorandum Opinion at page 33, discussing testimony by

an estimate of the market elasticity of demand, it was inferred that the merger would have to reduce marginal costs by 74% or more to prevent price increases. The FTC argued that such efficiencies were implausible. The defendants countered that, because simulation indicated that the merger would be unprofitable, the Cournot framework was inappropriate for the setting. However, this argument strikes us as reflecting a misunderstanding of the CMCR approach, which is flexible enough to accommodate convex demand and/or arbitrarily constrained non-merging firms, and therefore is always consistent theoretically with profitable Cournot mergers.[58]

Of course, few industries feature perfectly homogeneous products. For example, even if firms produce identical output, transportation costs may create spatial differentiation, and firms may differ in their ability to deliver reliably and on schedule.[59] Such differences do not necessarily render the Cournot model unhelpful in merger analysis. However, if consumers perceive that some firms' products are substantially closer substitutes than others then an alternative approach may be warranted. One possibility is a Bertrand model in which transportation costs create localized market power for capacity-constrained suppliers, and equilibrium prices reflect the proximity of consumers to each plant and its competitors. Estimation can be accomplished with transaction-level data from the relevant suppliers or with aggregate data on prices and quantities (e.g., see the Miller and Osborne (2014) model of the cement industry). Another possibility is a differentiated-products Cournot model, though we are not aware of empirical research that explores that option.

5 Game-Theoretical Models and HHI

As merger analysis has evolved from the original 1968 Guidelines through the 2010 Guidelines to today, there has been an increasing focus on understanding the precise mechanisms by which mergers affect competition. This affects the types of evidence that the agencies seek to gather and how the evidence is interpreted, with the ultimate goal of better assessing the competitive effects of each merger as it arises in its own unique circumstances. Merger review increasingly has incorporated the game-

Nicholas Hill on behalf of the FTC.

[58]The observation that Cournot mergers with constant marginal cost and linear demand tend to be unprofitable was made originally in Salant et al. (1983). However, the result depends on strong modeling assumptions: profitability is restored if capital is incorporated and the merging firms are sufficiently large (Perry and Porter (1985)) or if demand is convex (Fauli-Oller (1997); Hennessy (2000)).

[59]The 2010 Guidelines describe homogeneous products as being "relatively undifferentiated."

theoretical methods described earlier in this article—an evolution "from hedgehog to fox," as characterized by Shapiro (2010). However, screens based on market shares and market concentration remain the legal standard and continue to be presented in court. Although the existence of these parallel approaches may create the perception of tension within the economics of merger review, we now discuss how the two approaches relate to each other in a unified framework.

We develop the connection using a model of Bertrand competition among firms facing differentiated-products logit demand.[60] This model has been used in antitrust analysis for over 25 years (e.g., Werden and Froeb (1994)). With logit demand, diversion is *proportional to market share*, in the sense that the relative diversion from any product i to any two other products k and j takes the form: $d_{ij}/d_{ik} = s_j/s_k$. Whether this special property of the logit model is a strength or a weakness may be in the eye of the beholder. We rely on the property for the purposes of the analyses to follow, and then return to the question of generalizability.

To start, Nocke and Schutz (2018) reformulate the model as an aggregative game and prove that the predicted change in the HHI (ΔHHI$= 2s_js_k$) provides an approximation to the consumer surplus effects of mergers. We illustrate the approximation using numerical simulations. To implement, we consider markets with either two, three, or four firms (plus an outside good), and randomly draw 500 market share vectors for each. This allows for a partial calibration of the model that is sufficient to obtain merger effects (Caradonna et al. (2020)). There are a total of 1,500 markets. We merge two firms in each market, and calculate the equilibrium merger effects and the ΔHHI.[61] Figure 2 plots the results. The left panel considers changes in the merging firms' markups and the right panel considers changes in consumer surplus. Both are highly correlated to the HHI change, consumer surplus especially so.

A related insight is obtained in Nocke and Whinston (2019), which use the aggregative games reformulation to refine the CMCR of equation (11) for the Bertrand logit model. In particular, a merger of any two firms, j and k, increases consumer surplus if and only if the *type efficiency*, which we denote here with e_{jk}, satisfies $e_{jk} > e^*_{jk}$.[62] We

[60] The model is a special case of the setup presented in Section 2.

[61] We evaluate ΔHHI at pre-merger market shares, with the shares calculated among the inside goods. This is a slight departure from Nocke and Schutz (2018), in which the shares are calculated among all goods, including the outside good.

[62] The type efficiency represents a nonlinear combination of quality and marginal cost improvements. See Nocke and Whinston (2019) for a precise definition.

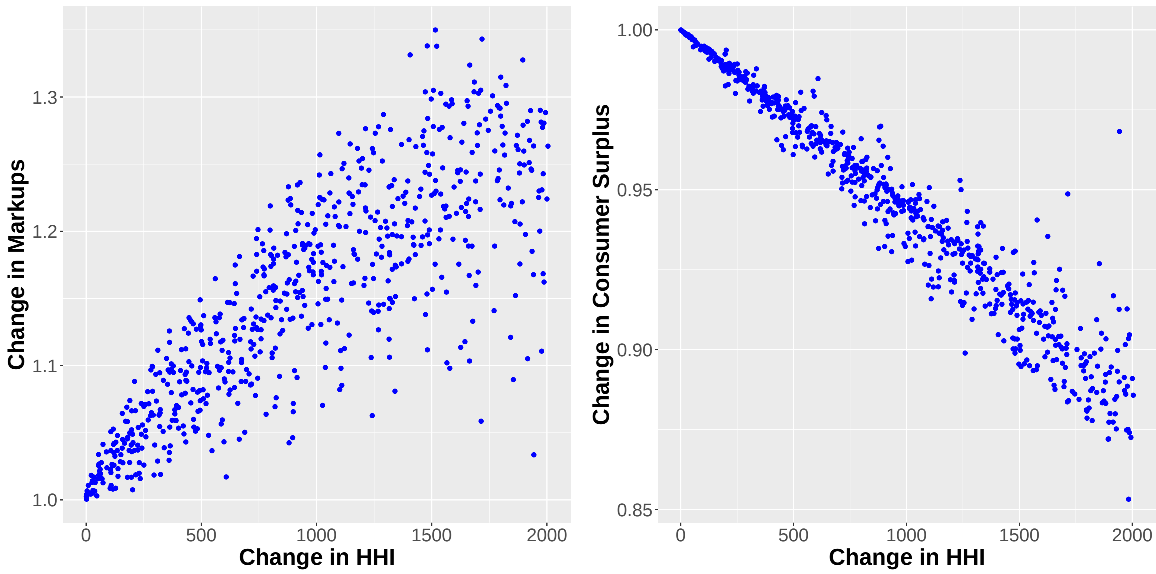

Figure 2: Equilibrium Merger Effects and HHI

Notes: The figure shows equilibrium merger effects obtained from markets with randomly drawn shares. In left panel, the vertical axis is the change in the average share-weighted markups of the merging firms. In the right panel, the vertical axis is the change in consumer surplus. Both are reported as indices relative to the corresponding pre-merger values. The horizontal axis in both panels is the ΔHHI due to the merger. Each dot corresponds to one merger.

define

$$e^*_{jk} \equiv \frac{(s_j + s_k)\exp\left(\frac{1}{1-s_j-s_k}\right)}{s_j \exp\left(\frac{1}{1-s_j}\right) + s_k \exp\left(\frac{1}{1-s_k}\right)}. \tag{20}$$

By inspection, the right-hand side depends only on the pre-merger shares of the merging firms, which suggests that share-based analysis is informative. Figure 3 plots the compensating type efficiency (e^*) against the ΔHHI for the same data set used in Figure 2. A tight correlation is apparent between ΔHHI and the magnitude of efficiencies needed to make a merger neutral for consumer surplus.

Shapiro (2010) provides a theoretical link between diversion and the ΔHHI using an approximation that applies in the Bertrand logit context. Consider a merger that involves two products with pre-merger market shares s_j and s_k, respectively. With logit demand, diversion from product j to product k equals $s_k/(1 - s_j)$ and can be approximated by $s_k(1+s_j)$ for small s_j. Diversion from k to j is analogous, so the sum of the approximate diversion ratios is $s_j + s_k + 2s_j s_k$ or $s_j + s_k + \Delta$HHI. These mathematics also connect ΔHHI to UPP, which scales linearly in diversion (e.g., equation 3).

Together, these analyses indicate that the ΔHHI is predictive of unilateral effects in the Bertrand logit model. Suppose for the moment that the results generalize—a

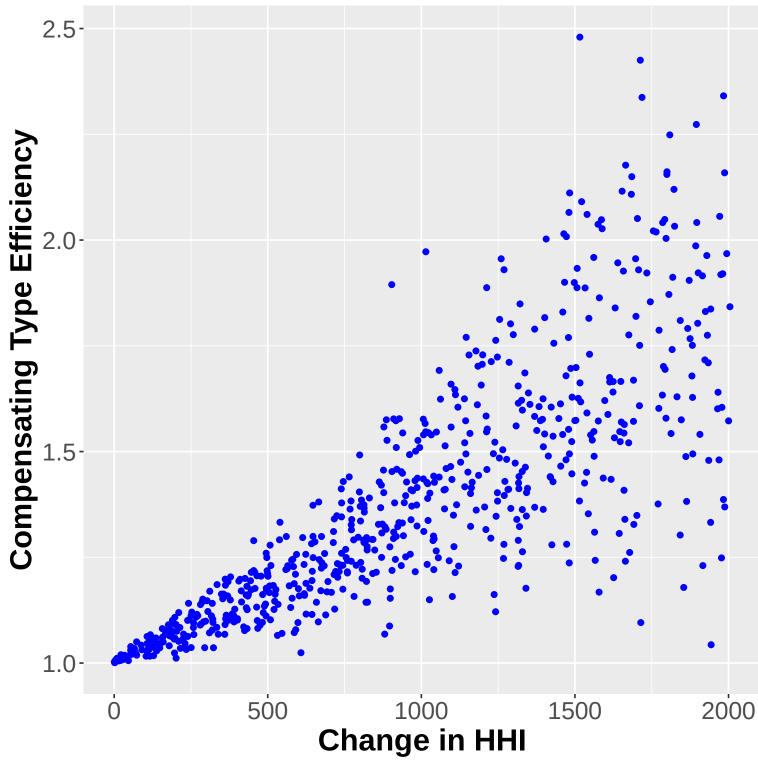

Figure 3: Compensating Type Efficiency and HHI

Notes: The figure plots the compensating type efficiency (vertical axis) against the ΔHHI (horizontal axis), for mergers in markets with randomly drawn shares.

matter to which we return momentarily. Then there is little tension between screens based on ΔHHI and the game-theoretical methodologies described in the 2010 Guidelines for unilateral effects analysis. Rigorous game-theoretical modeling reinforces the usefulness of share-based analyses, rather than making them obsolete. Thus it is that the following statements of Shapiro (2010) fit together:

> Many observers have noted specifically that the 2010 Guidelines place less weight on market shares and market concentration than did predecessors. This is a central example of the fox's eclectic approach, tailoring the methods used to the case at hand and to the available evidence.[63]

> [L]ike the fox, the 2010 Guidelines embrace multiple methods. But this certainly does *not* mean they reject the use of market concentration to predict competitive effects....[64]

[63] Shapiro (2010), p. 707.
[64] Shapiro (2010), p. 708.

The 2010 Guidelines state that mergers that generate in an HHI above 2,500 and a ΔHHI above 200 "will be presumed to be likely to enhance market power."[65] Extending the implications of the preceding analyses, it is worth considering whether the presumption should be maintained if the HHI exceeds 2,500 <u>or</u> the ΔHHI exceeds 200. The former condition would help screen for coordinated effects and losses of potential competition. The latter condition would help screen for unilateral effects.

We now return to the question of generalizability. The main concern is likely to be the property of logit demand that diversion is proportional to share, also known as the Independence of Irrelevant Alternatives (IIA). Seminal articles in industrial organization have developed sophisticated methods to relax diversion-by-share in settings such as automobiles and ready-to-eat cereal (Berry et al. (1995); Nevo (2001)). Take automobiles as the working example. It seems implausible that diversion from a BMW sedan to the Ford F-150 pickup truck would exceed diversion to a Mercedes sedan. Yet, given the popularity of the Ford F-150, that is what would be implied by proportional diversion. Thus, the logit model would be a poor representation of product-level substitution among all automobiles.

Antitrust markets defined for the purposes of merger review, however, often focus on narrower sets of products, following the logic of the hypothetical monopolist test. Consider a merger between BMW and Mercedes. It seems likely that a hypothetical monopolist of luxury automobiles would raise price. Thus, the relevant antitrust market would be comprised of much more comparable products. Even in the random-coefficients logit model of Berry et al. (1995), diversion-by-share emerges as products become more similar in their attributes, suggesting that the logit model often may provide a good representation of properly-defined antitrust markets. Consistent with this line of thought, merger review often maintains the diversion-by-share assumption, at least as analytical starting point.[66] So long as this is reasonable, the connections between HHI and merger effects explored in this section would seem broadly applicable in merger review—though targeted research on this question would be valuable.

[65] 2010 Guidelines, §5.3. For a nice illustrative example of how concentration screens have been applied in merger review, see the demonstrative exhibit used by Aviv Nevo as part of the *Aetna/Humana* (2016) litigation, slides 56-61, available at `https://www.justice.gov/atr/page/file/918706/download`.

[66] See the Memorandum Opinion for *H&R Block/TaxACT* at page 76, or the demonstrative exhibit used by David Dranove during the *Anthem/Cigna* trial at page 48, available at `https://www.justice.gov/atr/page/file/914606/download`, for example.

6 To Infinity and Beyond

In this article, we describe what we view as the state-of-the-art quantitative modeling techniques for merger review, and discuss the important role that the 2010 Guidelines have played in legitimizing these techniques and motivating research. Antitrust economics, and merger review specifically, continues to be a fruitful subject for intellectual inquiry. Indeed, among the articles and books that we cite here, more than half were published *after* the 2010 Guidelines, representing contributions from academics, agency economists, and antitrust consultants. Thus, in the spirit of exploration, we conclude the article with a discussion of two early-stage research projects that we find particularly thought-provoking.

The first project examines how newly developed empirical techniques may allow for more data-driven analysis of unilateral effects (Magnolfi and McLeod (2020)). Consider a standard first order condition for profit maximization, expressed as

$$p_{jt} = b_{jt}(s_{jt}, x_{jt}) + w'_{jt}\gamma + \omega_{jt}$$

where $b(\cdot)$ is a markup function, p and s are endogenous prices and shares, respectively, x and w include markup- and cost-shifters, and ω is a structural error term that represents unobserved costs. The basic insight is that the markup function can be recovered using deep neural networks, a statistical learning algorithm designed to fit high-dimensional nonlinear functions, with the endogeneity of markups being addressed by the use of deep instrumental variables (e.g., Hartford et al. (2017)). If sufficient variation in the markup-shifters is available, then merger simulation can be accomplished using within-sample comparisons, without the parametric assumptions that otherwise are necessary to support out-of-sample prediction.

The second research project is a study of pricing algorithms in one-shot games of oligopoly competition (Brown and MacKay (2019)). Algorithms can be conceptualized as functions that automate firms' responses to their competitors' prices, and increasingly are employed in online markets.[67] A number of insights come out of the analysis. Most important for our purposes, it is not an equilibrium for all firms to use their best-response functions as pricing algorithms, so Bertrand prices do not arise. Instead, competitive prices tend to exceed Bertrand levels, and firms with a late-mover advantage (i.e., a faster algorithm) obtain relatively more profit. Given the growing

[67]Algorithms allow managers to delegate pricing authority. For a review of the broader literature on strategic delegation, see Sengul et al. (2012).

popularity of online markets and the sophistication of information technology, these results present an interesting challenge for unilateral effects modeling, which tends to rely on the Bertrand assumption. We hope future research explores this subject.

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