10-2022

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Jonathan Baker

Journal of Antitrust Enforcement, 2022, 10, 248–259
https://doi.org/10.1093/jaenfo/jnac009
Advance Access Publication Date: 28 May 2022
Article

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On the misuse of regressions of price on the HHI in merger review

Nathan Miller*, Steven Berry†, Fiona Scott Morton†, Jonathan Baker‡, Timothy Bresnahan**, Martin Gaynor††, Richard Gilbert‡‡, George Hay***, Ginger Jin†††, Bruce Kobayashi‡‡‡, Francine Lafontaine****, James Levinsohn†, Leslie Marx††††, John Mayo*, Aviv Nevo‡‡‡‡, Ariel Pakes*****, Nancy Rose†††††, Daniel Rubinfeld‡‡‡‡‡, Steven Salop*, Marius Schwartz*, Katja Seim†, Carl Shapiro‡‡, Howard Shelanski*, David Sibley******, Andrew Sweeting††† and Marta Wosinska†††††,[1]

*Nathan Miller, John Mayo, Steven Salop, Marius Schwartz and Howard Shelanski, Professor, Georgetown University
†Steven Berry, Fiona Scott Morton, James Levinsohn and Katja Seim, Professor, Yale University
‡Jonathan Baker, Professor, American University
**Timothy Bresnahan, Professor, Stanford University
††Martin Gaynor, Professor, Carnegie-Mellon University
‡‡Richard Gilbert and Carl Shapiro, Professor, University of California, Berkeley
***George Hay, Professor, Cornell University
†††Ginger Jin and Andrew Sweeting, Professor, University of Maryland
‡‡‡Bruce Kobayashi, Professor, George Mason University
****Francine Lafontaine, Professor, University of Michigan
††††Leslie Marx, Professor, Duke University
‡‡‡‡Aviv Nevo, Professor, University of Pennsylvania
*****Ariel Pakes, Professor, Harvard University
†††††Nancy Rose, Professor, Massachusetts Institute of Technology
‡‡‡‡‡Daniel Rubinfeld, Professor, New York University
******David Sibley, Professor, University of Texas, Austin
†††††Marta Wosinska, Visiting Fellow at the USC-Brookings Schaeffer Initiative for Health Policy, Brookings Institute
1 All former academic chief economists from the Federal Trade Commission and the Department of Justice Antitrust Division were invited to join the paper as coauthors.

ABSTRACT

The article explains why regressions of price on HHI should not be used in merger review. Both price and HHI are equilibrium outcomes determined by demand, supply, and the factors that drive them. Thus, a regression of price on the HHI does not recover a causal effect that could inform the likely competitive effects of a merger. Nonetheless, economic theory is consistent with the legal presumption that a merger is likely to have adverse competitive effects if it occurs in a concentrated market and makes that market more concentrated.

KEYWORDS: horizontal mergers, Herfindahl-Hirschman Index, regression analysis, HHI

JEL CLASSIFICATIONS: L11, L40, L41

I. INTRODUCTION

Economists widely agree that absent sufficient efficiencies or other offsetting factors, mergers that increase concentration substantially are likely to be anticompetitive, whether through unilateral or coordinated effects.[2] The reason is that economic theory indicates that competition among firms leads to lower prices.[3] The joint profit of any two competitors is higher if they both raise price, yet neither would do so unilaterally because it would simply lose sales to the competitor. A merger between competitors aligns incentives such that price increases or output restrictions can be implemented profitably, to the detriment of consumers and (often) total welfare.

Economic theory also indicates that the magnitude of these adverse price effects tends to be larger, holding everything else equal, the larger is the increase in concentration caused by the merger. Analogously, greater efficiencies are required to offset adverse price effects if the merger causes a larger increase in concentration. As market concentration is more easily measured than the post-merger equilibrium (which is unobserved *ex ante*), the use of concentration screens in the antitrust review of mergers is sensible and economically well founded. Thus, as economists, we support the established legal presumption that a merger that significantly increases market concentration in an already concentrated market is likely to result in adverse competitive effects.[4]

2 For example, Volker Nocke and Michael Whinston, 'Concentration Screens for Horizontal Mergers', Working Paper 27533, National Bureau of Economic Research (July 2020) <http://www.nber.org/papers/w27533> accessed 26 April 2022; Herbert J Hovenkamp and Carl Shapiro, 'Horizontal Mergers, Market Structure, and Burdens of Proof' (2018) 127 Yale L J 1996; John Kwoka, 'The Structural Presumption and the Safe Harbor in Merger Review: False Positives or Unwarranted Concerns?' (2017) 8 Antitrust Law J 837. The focus of this article is on horizontal mergers, ie mergers between firms that compete with one another. Unilateral effects relate to the effects of mergers that arise 'simply by eliminating the competition between the merging parties' and coordinated effects related to the effects of mergers that arise by increasing 'coordinated, accommodating, or interdependent behavior among rivals' (Horizontal Merger Guidelines, 2).

3 We use the term price for conciseness in exposition, but it should be understood that we are referring to more generally 'terms of trade' that are outcomes of the equilibrium market process, and that may include, for example, prices, auxiliary fees, qualities, product variety, and service.

4 *United States v Philadelphia National Bank*, 374 US 321, 362 (1963). ('[A] merger which produces a firm controlling an undue percentage share of the relevant market, and results in a significant increase in the concentration of firms in that market, is so inherently likely to lessen competition substantially that it must be enjoined in the absence of evidence clearly showing that the merger is not likely to have such

The Horizontal Merger Guidelines of the US Department of Justice and Federal Trade Commission (2010) [hereinafter 2010 Horizontal Merger Guidelines], in line with prior merger guidelines, continues the practice of using the Herfindahl–Hirschman Index (HHI) as a measure of market concentration. Courts too have adopted the HHI as the standard measure of concentration.[5] As an index, the HHI has properties that make it suitable for this purpose, and we agree that it is a useful measure of market concentration.

Given results from economic theory, and the role that the HHI (appropriately) plays in merger review, it might seem natural to determine whether prices and the HHI are positively related for a given set of products, comparing across different geographic markets or time periods. This might be implemented, for example, by using a simple regression of price on the HHI.[6] However, for reasons that we elaborate on below, regressions of price on the HHI should not be interpreted as establishing causation. That is, they do not inform how a change in concentration from a merger would affect prices. Empirical analyses based on such regressions of price on the HHI are uninformative about the likelihood of any adverse competitive effects from a merger. Courts and other policy-makers therefore should not rely on regressions of price on the HHI for the purposes of antitrust merger review.

In this article, we explain why regressions of price on the HHI do not predict the competitive effects of mergers and should not be used in merger review. The main point is that analyses based on regressions of price on the HHI mistake correlation for causation. There are many reasons why the HHI can vary across markets or time periods. Whether the HHI is positively or negatively correlated with price depends on what gives rise to the variation across the markets or periods. As we develop, if a small firm reduces its costs, then both its price and the HHI in its market may decrease, creating a positive correlation between price and the HHI. But if instead a large firm reduces its costs, then its price may decrease and the HHI in its market may increase, creating a negative correlation. Yet whether the large firm or the small firm benefits from a cost reduction has little bearing on the competitive effects of a merger (which indeed might not involve either firm).[7]

The underlying problem with regressions of price on the HHI is that the relationship between price and the HHI is not causal. Instead, both are equilibrium

anticompetitive effects.') At least one of the coauthors of this article believes that market concentration is better used to define a safe harbour, as proposed in Dennis Carlton and Mark Israel, 'Effects on the 2010 Horizontal Merger Guidelines on Merger Review: Based on Ten Years of Practical Experience' (2021) 58 Rev Ind Organ 213.

5 See Carl Shapiro and Howard Shelanski, 'Judicial Response to the 2010 Horizontal Merger Guidelines' (2021) 58 Rev Ind Organ 51.

6 By regression we mean ordinary least squares (OLS) regression, unless explicitly stated otherwise. Economists often use regression analysis to examine how one variable (the 'dependent variable') changes with a set of possible determinants (the 'independent variables'). In the regression of price on HHI, price is the dependent variable and the HHI is an independent variable. A positive coefficient on the HHI indicates a positive correlation between price and the HHI, a negative coefficient indicates a negative correlation, and a coefficient of zero indicates no correlation.

7 To be clear, correlations between price and the HHI that arise due to demand or cost differences across time periods or geographic regions are uninformative about the competitive effects of a merger. A correlation that arises due to prior mergers, or due to prior entry or exit events, can be an exception that provides information, with some caveats. See Section IV for a discussion.

outcomes that are determined by demand, supply, and the factors that drive them. Thus, a regression of price on the HHI does not show the sort of causal effect that would be helpful in predicting the competitive effects of a merger.

By contrast, economic theory does support a causal impact of *mergers* on price. Absent offsetting efficiencies, a merger between competitors creates incentives for the merging firms to raise prices and reduce output. Economic theory provides support for the established legal presumption that a merger in a market is likely to have adverse competitive effects when it occurs in a concentrated market and makes it more concentrated (ie increases the HHI), regardless of whether it is possible to find an empirical relationship between price and the HHI in data.

The article proceeds in four sections. In Section II, we define the HHI, highlight its properties, and describe its role in merger review. In Section III, we provide a numerical example in which the empirical price–HHI relationship is uninformative about the competitive effects of mergers and explain why the example has broader significance for understanding the relationship between prices and the HHIs. In Section IV, we discuss the econometric problem inherent with regressions of price on the HHI, building on the numerical example. Finally, we conclude with discussions about how HHI analyses are useful in merger review, and the types of econometric analyses that can be helpful in merger review.

II. HHI AND THE ECONOMICS OF HORIZONTAL MERGERS

Economic theory indicates that, absent sufficient efficiencies, mergers among competitors create incentives for the merging firms, and possibly its rivals, to raise prices or reduce output. The purpose of merger review is to identify and prevent mergers that are more likely to have such anticompetitive effects. An analysis of market shares and market concentration is standard in merger review because it can help illuminate the potential for anticompetitive effects.[8]

A commonly used summary measure of market shares and concentration is the HHI, which is calculated as the sum of squared market shares of all the firms in the market.[9] The HHI can take values ranging from 0 to 10,000, with the former corresponding to a fragmented market with infinitesimal firms, and the latter to monopoly. All else equal, a decrease in the number of firms leads to a higher HHI. However, the HHI can increase if, for a given number of firms, the market shares of the larger firms increase.[10] Thus, for example, a market with one large firm and two small firms has a higher HHI than a market with three equally sized firms. Holding the number of firms in the market fixed, the HHI is larger with greater asymmetry among firms' market shares.

The 2010 Horizontal Merger Guidelines state that mergers that generate a post-merger HHI above 2500 and an increase in the HHI by 200 or more 'will be presumed to be likely to enhance market power'.[11] HHI thresholds also are described in

8 We take as given the existence of a relevant antitrust market. For a discussion of market definition, see the 2010 Horizontal Merger Guidelines, s 4.

9 Thus, for a market with three firms and shares of 40%, 30%, and 30%, the HHI is $40^2 + 30^2 + 30^2 = 3400$.

10 This is also true of other measures of concentration, such as the four-firm concentration index. Thus, while this article focuses on the HHI, our argument extends more broadly.

11 2010 Horizontal Merger Guidelines, s 5.3. The implied change in the HHI is calculated as twice the multiplicative product of the merging firms' pre-merger market shares. There is some question whether these

the Guidelines of the European Union. The HHIs for these calculations are based on pre-merger market shares. We agree that HHI thresholds can play an important role in merger review.

It can be informative to pair information on the level and increase of the HHI with other evidence, including from business documents, that provide information on market competition, ease of entry, and efficiencies, among other considerations. Measures of upward pricing pressure can also be useful. In some cases, model-based simulation results and econometric studies of previous entry, exit, or mergers can also be useful. However, we exclude from this list regressions of price on the HHI for reasons that we now explain.

III. AN ILLUSTRATIVE EXAMPLE OF MISLEADING PRICE–HHI COMPARISONS

We illustrate the problem with regressions of price on the HHI using a simple numerical example. Consider duopolists (firms 1 and 2) that produce a homogenous product in three distinct geographic markets (regions A, B, and C). Suppose that each duopolist unilaterally chooses its output level (its 'quantity') to maximize profit, taking as given the output level of the other firm. The market price in each region for the product decreases with the combined output of the duopolists. Putting aside fixed costs, the profit of each duopolist equals the market price less its marginal cost of production, multiplied by its quantity.

Together, these assumptions constitute the Cournot oligopoly model.[12] Absent sufficient countervailing efficiencies, and focusing on unilateral effects, mergers to monopoly in this context harm consumers because the monopolist finds it profitable to restrict output and increase the market price.[13] In order to simplify the example, we make the additional assumptions that marginal costs do not change with the level of output, and that demand takes a simple linear form, $P(Q) = 10 - Q$, where $P(Q)$ is the market price and Q is the combined output in the market. Appendix 1 provides generalized expressions for the equilibrium markups, prices and quantities that obtain in this model.

Table 1 summarizes the results of the example. In Region A, which we use as a basis for comparison, suppose both firms have identical marginal costs of 3.00. Given the assumptions already made, this implies market shares of 50 per cent for each firm, a market price of 5.33, and an HHI of 5000.

In Region B, suppose that the marginal costs of the two firms are 4.00 and 3.00, respectively, so that Firm 1 has higher costs than in Region A. This implies market shares of 38 per cent and 62 per cent for the firms, a market price of 5.67, and an HHI of 5288. In Region C, suppose that the marginal costs of the two firms are 1.83 and 3.00, respectively, so that Firm 1 has lower costs than in Region A. This implies

threshold levels are set at an appropriate level. See Steven C Salop and Fiona Scott Morton, 'The 2010 HMGs Ten Years Later: Where Do We Go from Here?' (2021) 58 Rev Ind Organ 81–101.

12 For a theoretical analysis of mergers under Cournot competition, see Farrell and Shapiro, 'Horizontal Mergers: An Equilibrium Analysis' (1990) 80 Am Econ Rev 107.

13 Analogous results can be obtained with other standard models, such as that of differentiated-products Bertrand competition. See, for example, Raymond Deneckere and Carl Davidson, 'Incentives to Form Coalitions with Bertrand Competition' (1985) 16 RAND J Econ 473.

Table 1. The price–HHI relationship with cost variation

	Region A	Region B	Region C	Monopoly
Firm 1's costs	3.00	4.00	1.83	3.00
Firm 2's costs	3.00	3.00	3.00	
Firm 1's share (%)	50	38	62	100
Firm 2's share (%)	50	62	38	
Market price	5.33	5.67	4.94	6.50
Quantity	4.67	4.33	5.06	3.50
HHI	5000	5288	5288	10,000

market shares of 62 per cent and 38 per cent for the firms, a market price of 4.94, and an HHI of 5288.

In each of the three regions, a merger would result in monopoly and would unambiguously raise price. As shown in the last column of the table, if the monopolist's marginal cost is 3.00, then the profit maximizing price is 6.50. Yet the correlation between price and the HHI across regions is ambiguous.[14] An analysis that focuses on regions A and B would suggest that prices and the HHI are positively correlated. The opposite result is obtained with a focus on regions A and C, in which prices and the HHI are negatively correlated, while a comparison of regions B and C suggests no relationship between prices and HHI at all. Finally, a regression of price on the HHI based on the data of all three regions suggests a slightly negative relationship.

In our numerical example, prices and the HHIs vary across markets because of cross-region differences in costs. With Region A as a baseline, the HHI is relatively higher in Regions B and C because the two firms differ in their costs within those regions. However, in Region B the difference arises because Firm 1 has high costs, whereas in Region C the difference arises because Firm 1 has low costs. Because prices increase with costs in this model, whether regions B and C have higher or lower prices than region A depends on *why* costs differ across the regions.

As a general matter, a decrease in the costs of the most efficient firm and an increase in the costs of the least efficient firm naturally will tend to have different effects on prices, even though both increase the HHI by making market shares less symmetric. The same logic would apply to cross-market differences in quality if we included them in our example. This makes the relationship between price and the HHI ambiguous, even in models that have unambiguous predictions about the competitive effects of a merger.

IV. REGRESSIONS OF PRICE ON THE HHI

We now move from the numerical example to a more general discussion of the econometrics underlying regressions of price on the HHI. However, regressions

14 If we assume that after the merger the merged firm produces all output from its more efficient plant, then the merger would increase prices to 6.50, 6.50, and 5.92 in regions A, B, and C, respectively, and the merger would have to reduce the more efficient plant's marginal costs to 0.66, 1.33, and 0.12, respectively, to offset anticompetitive effects.

simply summarize the correlations present in data, so the logic developed using the numerical example extends. The relationship between price and the HHI that is estimated with regression analysis does not reflect the sort of causal effect that would be helpful in predicting the competitive effects of a merger.

A typical regression of price on the HHI takes the form:

$$P_i = \beta_0 + \beta_1 HHI_i + \beta_2 x_i + \epsilon_i$$

where the subscript i refers to observations (markets and/or time periods), the variables in x_i control for other demand and supply factors, and ϵ_i is an error term. Thus, price is the dependent variable and the HHI is an independent variable. An OLS regression that obtains a positive coefficient on the HHI ($\beta_1 > 0$) indicates a positive correlation between price and the HHI, conditional on the controls, just as a regression that obtains a negative coefficient ($\beta_1 < 0$) indicates a negative correlation between price and the HHI.

The underlying problem with this regression, in econometric parlance, is that the relationship between prices and the HHI is not causal.[15] Both price and the HHI are market equilibrium outcomes. The HHI is calculated from market shares, which are market outcomes determined by demand, supply, and the factors that drive them. Price is likewise an outcome, determined by the same factors. Thus, economic theory indicates that prices and the HHI are jointly determined in equilibrium; there is no causal effect of one on the other. The regression estimate of β_1 can pick up various possible correlations that exist due to variation in the underlying demand and supply factors, but it cannot measure a causal effect that does not exist.[16]

This fundamental empirical issue has been widely understood by economists for decades. A seminal paper was Demsetz.[17] The modern empirical articulation of the problem was provided by Bresnahan.[18] A series of alternative methods for evaluating the competitive effects of mergers have been advanced, beginning in the 1980s and continuing through to the present, as discussed (together with voluminous references) in the *Handbook of Industrial Organization*, volumes 3 (2007) and 4 (in process). However, regressions of outcomes, including price, on the HHI have largely been abandoned by Industrial Organization researchers.

15 See, eg, Steven Berry, Martin Gaynor and Fiona Scott Morton, 'Do Increasing Markups Matter? Lessons from Empirical Industrial Organization' (2019) 33(3) J Econ Perspect 44. The statement holds whether firms set prices unilaterally to maximize their own profit or collude to maximize joint profit. Although our numerical results focus on the former case, regressions of price on the HHI are also problematic for mergers that may facilitate or exacerbate coordination.

16 For a recent articulation of this problem, see Daniel P O'Brien, 'Price-Concentration Analysis: Ending the Myth, and Moving Forward' (2017) <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3008326> accessed 26 April 2022. Furthermore, even putting aside the issue we discuss in this article, if the goal of the analysis is to study whether pre-merger HHI levels are predictive of likely anticompetitive harms, this is the wrong regression to estimate. Instead, one should look at past mergers and examine how the pre-merger HHI and the change in HHI predict post-merger outcomes.

17 Harold Demsetz, 'Industry Structure, Market Rivalry and Public Policy' (1973) 16 J Law Econ 1.

18 Timothy Bresnahan, 'Empirical Studies of Industries with Market Power' in Richard Schmalensee and Robert Willig (eds), *The Handbook of Industrial Organization*, Ch 17, vol 2 (North Holland 1989) 1011–57.

Note that the problem here is deeper than the econometric problems that are often called 'endogeneity' and 'simultaneity'. These problems exist when a clear causal path between two variables is posited by the relevant economic theory but the causal factor (on the right side of the regression equation) is either correlated with unobserved factors or, more subtly, is simultaneously determined by the variables (in this case, price) on the left side of the regression. A famous example of simultaneity involves price and quantity, which are simultaneously determined in the classic economic model of supply and demand. There are many possible solutions to the problems of endogeneity and simultaneity. In different contexts, these solutions might include controlling for additional factors in a regression or using what are called instrumental variables. However, these solutions do not solve the problem presented by the regression of price on the HHI. The fundamental problem remains: there is no causal relationship to be estimated. Different methods may pick up different correlations, perhaps complicated ones, but not the sort of causal effect that can be used to predict the effect of a merger.

One might suppose that the variables that control for other factors could resolve the problem. But they cannot. The reason is that some residual variation in price and the HHI must be present after the contribution of control variables has been removed in order to conduct the regression analysis. By definition, this residual variation is due to factors that are not among the control variables. Now a familiar logic applies: the residual factors that create variation in the HHI may happen to raise or lower prices, so either a positive or negative correlation can result. For example, the analyst could perfectly control for all variation in cost conditions. However, if variation in demand factors remains, such that residual variation in price and the HHI exists, then price and the HHI are joint outcomes of that variation, and causal inferences about the effect of mergers cannot be supported. The same result obtains if the analyst controls for demand considerations, or replaces price with 'quality-adjusted price', because cost factors then lead price and the HHI to be co-determined.

Some authors propose more sophisticated instrumental variable methods. A discussion of these methods is beyond this short note, but they face the same kinds of problems. First, even if there was a true 'causal effect' of the HHI on price, it would be difficult if not impossible to find instrumental variables that satisfy the conditions necessary for their use.[19] Moreover, even if one were to find such instrumental variables, they cannot find a causal effect that does not exist. Bresnahan[20] notes that, even given 'correct' instrumental variables, one would likely obtain a complicated mixture of supply and demand effects. Bresnahan's logic follows from the same basic observations that motivate our simple examples above.

A special case arises when the empirical variation in the HHI is driven predominantly by changes in competition, such as past mergers or changes in entry or exit conditions, that have similar competitive effects to a proposed merger. Although the relationship between the HHI and price is still not causal, a correlation in that scenario at least can reflect the impact of the underlying competitive events, and thereby inform the likely impact of a merger on price. Even in this case, however, it can be

19 See Berry, Gaynor and Scott Morton (n 15).
20 Bresnahan (n 18).

more appropriate to analyse directly the impacts on prices of the mergers or entry or exit conditions, rather than their impacts as mediated through the HHI.

Economists have developed more appropriate quantitative methods to determine merger effects, such as structural econometric models and merger retrospectives that more plausibly identify the effects of mergers. Following in the tradition of Bresnahan, and a growing empirical literature, structural econometric models attempt to estimate the true underlying causal effects that determine the effects of proposed mergers on prices. These methods have their own advantages and disadvantages, but they share a necessary attribute: they are designed to reveal causal effects. Regressions of price on HHI are not designed to do so; and, as a result, they typically do not provide credible insight into the price effects of mergers.

V. DISCUSSION

We conclude with a discussion of the appropriate role of the HHI in merger review and the types of regression analyses that can be more informative about the likely competitive effects of proposed mergers.

We have already explained that an understanding of the HHI can help illuminate the competitive effects of mergers. To illustrate why this is the case, we again use a numerical example. We retain the assumptions of Cournot competition, an inverse demand curve of $P(Q) = 10 - Q$, and constant marginal costs of \$3.00. In this new example, we do not change costs. Instead, we consider markets with two, three, four, five, and six competitors. In each market, we consider a merger between two of the competitors and calculate the implied change in the HHI, the percentage price increase, and the percentage reduction in total market quantity, holding costs and demand constant. As in our previous example, we calculate the implied change in the HHI based on the pre-merger market shares of the merging firms.[21]

Table 2 summarizes the results. In the market with two competitors, a merger increases price by 21.88 per cent, reduces total quantity by 25 per cent, and leads to an implied increase in the HHI of 5000, consistent with merger from symmetric

Table 2. Merger price effects and the implied HHI change

	Number of pre-merger competitors				
	Two	Three	Four	Five	Six
Percentage price increase	21.88	12.28	7.95	5.60	4.17
Percentage quantity decrease	25.00	11.11	6.25	4.00	2.78
Implied change in the HHI	5000	2222	1250	800	556

21 We calculate the Implied Change in the HHI as $\Delta HHI = 2s_1s_2$ where s_1 and s_2 are the pre-merger market shares of the merging firms. This is an indicator of how much the merger would affect market concentration, but it is not intended to recover the precise change in HHI that would be realized as the market reaches a new, post-merger equilibrium.

duopoly to monopoly. Comparing across columns, mergers in markets with more competitors generate smaller price increases, smaller reductions in quantity, and smaller implied HHI increases. In the market with six competitors, a merger increases price by 4.17 per cent, reduces output by 2.78 per cent, and leads to an implied increase in the HHI of 556.[22]

The numerical analysis of these mergers reveals a positive correlation between the merger price effect and the implied change in the HHI. The positive correlation exists because, all else equal, mergers that create a larger implied change in the HHI also tend to create greater incentives for the merging firms to increase price or restrict output. There is an important distinction between these results and the numerical results presented earlier (Section III). Here, the change in the HHI is informative about merger price effects because it reflects the reduction in the number of competitors that would be caused by the merger, and the importance of that lost competition. By contrast, the variation in the HHI examined earlier was driven solely by differences in marginal costs across markets, which have less bearing on the competitive effects of mergers.

We are hardly the first to make the observation that merger price effects are positively correlated with the implied change in the HHI from the merger.[23] Economic theory indicates that, all else equal, the likely magnitude of adverse competitive effects tends to be larger, the larger is the increase in concentration caused by the merger. Analogously, greater efficiencies typically are required to offset adverse competitive effects if the merger causes a larger increase in concentration, all else equal. Because pre-merger market shares are more easily measured and analysed than the post-merger equilibrium (which is unobserved *ex ante*), HHI analysis provides economically sensible information about likely merger effects that can be combined with other relevant information. Hence, we view the use of the HHI in merger review, as suggested (for example) in the 2010 Horizontal Merger Guidelines, to be economically well founded.

Of course, it can be helpful to supplement an analysis of the HHI with other qualitative and quantitative evidence. Quantitative evidence may include econometric analyses seeking to understand price variation.[24] When there is sufficient reliable data, such studies can be informative about the competitive effects of mergers, if carefully implemented. The studies might consider the effects of previous entry, exit, or mergers on prices and other variables.[25] For example, it can be informative to understand how prices have responded to previous mergers, and regressions can be appropriate for such an inquiry. Such 'merger retrospectives' can provide direct evidence about the likely competitive effects of a

22 In a model of Cournot competition with constant marginal costs and linear demand, most mergers are not profitable in the absence of efficiencies. For example, see Stephen Salant, Sheldon Switzer and Robert J Reynolds, 'Losses from Horizontal Merger: The Effects of an Exogenous Change in Industry Structure on Cournot-Nash Equilibrium' (1983) 98 Q J Econ 185. The figures reported in Table 2 continue to hold exactly, but those mergers would be profitable, if the mergers yield sufficiently large reductions in fixed costs.

23 See, for example, the citations in Nocke and Whinston (n 2).

24 We are not suggesting that such studies should be treated by agencies and courts as a necessary prerequisite to predicting that proposed mergers are anticompetitive.

25 A more complete discussion is provided in the 2010 Horizontal Merger Guidelines, s 2.

proposed merger, subject to caveats, including that the evidence is more informative when the market environments of the previous mergers and the proposed merger are similar. Similarly, it can be informative to know whether price differences across regions can be attributed to differences in the number of competitors, and carefully conducted regression analyses that identify the causes for the differences in the number of competitors again can be appropriate.[26] Such comparisons helpfully featured in analyses of the Staples/Office Depot merger proposed in 1996, for example.[27] Methodological challenges will still exist, and solutions may go beyond simple OLS regression, but the 'causal effect' of these variables is, at least, well defined.

Our conclusion is straightforward to state: merger analysis benefits from discussions of the HHI, particularly of likely changes in the HHI that would result from a merger. Merger analysis can also benefit greatly from other qualitative and quantitative evidence, including econometric studies that are designed to estimate causal effects on prices and other outcomes. However, merger analysis does not benefit from regressions of price on the HHI, which have been firmly rejected, for excellent reasons, by decades of academic research.

APPENDIX 1

This appendix summarizes the equations used for the numerical results in Sections III and V. Let the market inverse demand curve be $P(Q) = a - bQ$, and let there be $n = 1, 2, \ldots, N$ firms. In equilibrium, the output of firm i is given by:

$$q_i = \frac{a - c_i + N(\overline{c} - c_i)}{b(N+1)}$$

where c_i is the marginal cost of firm i and $\overline{c} = \frac{1}{N}\sum_n c_n$ is the average marginal cost. The equilibrium price is

$$P = \frac{a + N\overline{c}}{N+1}$$

And the equilibrium market quantity is

$$Q = \sum_n q_n = \frac{N(a - \overline{c})}{b(N+1)}$$

26 Our Table 2 example shows that the 'causal effect of a change in the number of firms' is well defined in a simple Cournot model. Thus, while regressions of price on the number of firms may (or may not) face the problems of econometric endogeneity and simultaneity discussed above, they are fundamentally well defined in a way that regressions of price on the HHI are not.

27 Serdar Dalkir and Frederick R Warren-Boulton, 'Prices, Market Definition, and the Effects of Merger: Staples-Office Depot (1997)' in John E Kwoka, Jr and Lawrence J White (eds), *The Antitrust Revolution: Economics Competition, and Policy* (4th edn, Oxford University Press 2004).

The market share of each firm i can be calculated as $s_i = \left(\frac{q_i}{Q}\right)$. The equilibrium HHI is:

$$HHI = 10,000 \times \sum_n {s_n}^2$$

And the implied change in HHI due to a merger of firms i and k is:

$$\Delta HHI = 2 \times s_i \times s_k$$

In the production of Tables 1 and 2, the market shares are rounded prior to the calculation of HHI and ΔHHI. To illustrate, with Region B of Table 1 we have $10,000 \times 0.38^2 \times 0.62^2 = 5288$.