THE DIFFERENCE-IN-DIFFERENCES APPROACH TO THE ESTIMATION OF CARTEL DAMAGE

BY FRANK P. MAIER-RIGAUD[1] & SLOBODAN SUDARIC[2,3]

1 Prof. Dr. Frank P. Maier-Rigaud, Managing Director and Head of Competition Economics Europe, NERA Economic Consulting & IESEG (LEM-CNRS), frank.maier-rigaud@nera.com.

2 Dr. Slobodan Sudaric, Economic Analyst, NERA Economic Consulting, slobodan.sudaric@nera.com.

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I. INTRODUCTION

At first, damages claims typically rest on an estimation of cartel price overcharges — the price increase above the competitive price level due to the cartel. As only cartelised prices are observable but not competitive prices, the calculation of cartel overcharges requires an estimation of the competitive price level but-for the infringement, the so-called counterfactual price level.

Competition economists apply a variety of methods for estimating counterfactual prices.[4] Among the most widely used approaches generally recognized by competition authorities are comparator-based methods.[5] These methods rest on the assumption that by comparing the cartelised market to a suitable comparator market the cartel overcharge can be precisely identified if all other differences between the two markets are being controlled for. The comparator market can either be a comparable geographic or product market, the cartelised market itself at a different point in time (either before or after the cartel period), or a combination of the two (the so-called Difference-in-Differences approach, "DiD").[6]

The DiD approach combines the temporal comparison of a before-after ("BA") approach with a comparison to a non-cartelised product market ("comparator market"). Assuming that the comparator market and the cartelised market had evolved through time according to a common trend in the absence of anti-competitive conduct ("common trend assumption"), the cartel overcharge in the cartelised market can be calculated by comparing the price differences between the two markets during the cartel period to price differences in the post-cartel period. The development of the comparator market then essentially mirrors the development of the counterfactual cartelised market.

4 For an overview see Maier-Rigaud, F., & Schwalbe, U. (2018), *Quantification of Antitrust Damages*, in: D. Ashton, Competition Damages Actions in the EU: Law and Practice (2 ed.), Cheltenham: Edward Elgar; Maier-Rigaud, F. (2014) *Toward a European Directive on Damages Actions*, Journal of Competition Law and Economics, 10(2), 341-360; Maier-Rigaud, Frank (2014) *Umbrella Effects and the Ubiquity of Damage Resulting from Competition Law Violations*, Journal of European Competition Law and Practice, 5(4), 247-251; Maier-Rigaud, Frank (2017) *Damages Regimes on Both Sides of the Atlantic: An Economic Critique*, Antitrust Bulletin, 62(2), 334-347. For overviews in German, see Inderst, R., Maier-Rigaud, F., & Schwalbe, U. (2019), *Quantifizierung von Schäden durch Wettbewerbsverstöße*, in: A. Fuchs, & A. Weitbrecht, Handbuch der Privaten Kartellrechtsdurchsetzung (S. 287-332), München: C.H. Beck and Maier-Rigaud, F. (forthcoming), *Quantifizierung von Schäden*, in: A. Traugott, S. Riegler, & A. Lukaschek, Handbuch des österreichischen Kartellschadenersatzrechts, Wien: Manz.

5 See European Commission (2013), *Quantifying harm in actions for damages based on breaches of Article 101 or 102 of the Treaty on the Functioning of the European Union*. Strasbourg: European Commission.

6 In a sense other approaches, ranging from cost-based methods to simulations and structural models, also rely on a comparator. See Maier-Rigaud & Schwalbe (2018).

The DiD approach is sometimes seen as generally superior to other comparator-based estimation procedures. This alleged superiority is in turn often used as the sole justification for the choice of using the DiD approach over other estimation procedures, without consideration of whether the underlying conditions, under which the DiD has the potential to outperform other methods, are actually met.[7]

In the following article we will show that the DiD-approach is not generally superior to other methods, but that its superiority in individual cases is due to specific circumstances and data conditions that are not generally present. In particular, the validity of the DiD approach crucially depends on whether the central assumption of a common trend existing between the cartelised market and the comparator market is met.

The article is structured as follows: Section II introduces the DiD approach in more detail. Section III demonstrates how a violation of the common trend assumption might affect the results of a DiD estimation and discusses robustness tests. Section IV draws implications for the use of DiD in the quantification of damage.

II. THE DIFFERENCE-IN-DIFFERENCES APPROACH

Consider the following example for illustration purposes. Let "A" be the cartelised market and "B" the comparator market. Besides the cartel effects in market A, both markets exhibit identical development, so that market B is a suitable comparator market. Prices during the cartel period in market A are 8 € and prices in market B are 6 €, whereas prices in the post-cartel period are 10 € for market A and 9 € for market B.

A naive before-after comparison of cartel prices (8 €) and post-cartel prices (10 €) in the cartelised market would not allow inferences about the cartel overcharge to be made, as prices were not only affected by the cartel, but also by changes in demand and supply side factors. An overcharge estimation based on the before-after approach therefore requires the decomposition of prices into explanatory variables in order to isolate the cartel effect from other factors driving prices.[8] In the example, the decomposition could have revealed that prices are largely determined by production costs, leaving firms in the cartelised market a profit margin of 1 € in a competitive environment after costs. Supposing production costs during the cartel period were 6 €, the BA approach would suggest counterfactual prices of 6 € (costs) + 1 € (estimated profit margin) = 7 € (competitive price level). Comparing the competitive price level to the observed prices during the cartel period yields the cartel overcharge of 8 € – 7 € = 1 €.

The DiD approach would estimate the cartel overcharge from the comparison of price differences in the cartel and post-cartel period: the price difference in the cartel period is 8 € – 6 € = 2 €, whereas the price difference in the post-cartel period is 10 € – 9 € =1 €. Assuming that the price difference in the post-cartel period corresponds to the "natural" difference in prices between the cartelised market and the comparator market, resulting from different market characteristics, any excess price difference must be the result of cartelised behaviour. The difference in price differences (DiD) 2 € – 1 € =1 € therefore corresponds to the cartel overcharge.

This example demonstrates the inherent difficulty in the estimation of cartel overcharges: the separation of price increases due to cartel behaviour from remaining price influencing factors. While a before-after comparison tries to achieve this separation by predicting counterfactual prices through a set of explanatory variables, the DiD approach attempts to isolate the cartel overcharge through the assumption that the confounding factors are adequately captured in the development of the comparator market.[9]

This gives rise to different data requirements. While a before-after comparison requires data from the cartelised market only, it requires a complete set of data on price influencing factors. The DiD approach requires data for a comparator market but has potentially lower requirements with respect to explanatory factors, as long as the development of these confounding factors is adequately mirrored by the development of prices

7 See, for example, OECD (2011), *Quantification of Harm to Competition by National Courts and Competition Agencies,* Policy Roundtables, p. 36. While the authors acknowledge the DiD approach is superior under the condition that data for a suitable comparator market is available, said condition is often ignored within the quantification of cartel damages. Sources such as the OECD-study are sometimes cited (wrongly) as suggesting the general superiority of the DiD approach, neglecting that the superiority of the method is entirely dependent on the specifics of the case and no general superiority exists.

8 Competition economists typically control for price factors within a regression analysis, either using the forecast method or the dummy-variable method. Properly executed and given sufficient data both methods yield equivalent results. See McCrary, J., & Rubinfeld, D. (2014), *Measuring Benchmark Damages in Antitrust Litigation,* Journal of Econometric Methods, 3(1), 63-74

9 The BA approach therefore requires data on all factors systematically influencing prices, some of which may not be available. While the lack of data for these factors would cause estimation problems in the BA approach, the effect of those unobservable variables would be taken into account in a DiD approach through the observed developments in the comparator market, as long as the unobservable factors affect the comparator market and the cartelised market to the same extent.

in the comparator market.[10] In terms of data requirements, the DiD is therefore particularly powerful if the full set of explanatory variables required for the before-after comparison is either unknown or data is simply not available, and if a suitable comparator market is available. However, identifying a suitable comparator market often poses a substantial challenge.[11]

The validity of the DiD approach stands or falls with the availability of a suitable comparator market. In particular, it relies on the presumption that in the absence of the cartel both the comparator and the cartelised market would have evolved according to a common trend. This assumption is equivalent to saying that there is no difference *in the development* of the two markets over time, except for the existence of a cartel in one of them; in other words, changes in both markets that are unrelated to the cartel are of the same order of magnitude.[12] Going back to the example, if the price difference of 1 € in the post-cartel period does not reflect the counterfactual price difference in the cartel period, then there is no reason to assume that the DiD estimate adequately reflects the cartel overcharge.

While this assumption is easily satisfied in some experimental and quasi-experimental settings, it is much less likely to be an innocuous assumption in situations in which a variety of economic, political and societal factors can impact market changes.
The idea behind the DiD approach was first introduced by Snow (1855),[13] who demonstrated that cholera infections in London were transmitted by contaminated water instead of air by comparing death rates between two city districts. Both districts were initially supplied by a common, contaminated water source, while one district switched its water supply to a non-contaminated water source. The DiD setup allowed Snow to isolate the effect of the switch of water sources from unrelated differences in the death rates of the two districts. The DiD approach was subsequently introduced and developed in the fields of psychology, medical sciences, and public health policy research,[14] and remains a key experimental design setup in instances where a randomised control trial (RCT) is not feasible.[15]

In an RCT a researcher would randomly assign an underlying population to two groups: one group would obtain a treatment (the "treatment group"), the other group would remain untreated (the "control group"). If the assignment to groups is random, there is no reason to believe that the groups exhibit systematic differences besides the treatment. A direct comparison of the two groups is therefore enough to isolate the treatment effect. Clearly, an RCT is rarely feasible in economic research and entirely unfeasible in the estimation of cartel damages: competition economists cannot randomly assign market transactions to a treatment group (cartelised market) and comparator market (control group) and impose a treatment on one of them (cartel). Rather, competition economists must take the treatment (cartel) and the allocation of market transaction across groups (cartelised market and comparator market) as given, and find a suitable method to analyse such a situation. The DiD approach is such a method.

The DiD approach is used to compare the development of a treatment group (city district with new water source; cartelised market) to the development of a control group (city district with old water source; comparator market).[16] The crucial assumption of this quasi-experimental setup is that (i) the treatment only affects the treatment group but not the control group, and (ii) all factors except the treatment affect both the control and the treatment group to the same extent (common trend). The extent to which this quasi-experimental setup — where the only difference between the groups over time is the treatment itself — is applicable to the comparison of a cartelised market to a non-cartelised market is, however, often questionable and requires careful evaluation.

10 Typically, also in the DiD approach additional control variables are used. This is, for example, the case, if a factor affects the common trend property, but the common trend can be restored by adequately controlling for this factor. A typical example would be a regulatory measure that has been introduced in the comparator market, but not in the cartelised market. By controlling for the regulation when conducting the DiD analysis, the effect of the regulation on the comparator market can possibly be isolated allowing the common trend between the two markets to be restored.

11 It is also possible to construct a synthetic comparator market that can be interpreted as a weighted average across different comparator markets. Under certain conditions, this procedure may yield a more suitable comparator market for conducting a DiD analysis. See Abadie, A., Diamond, A., & Hainmueller, J. (2010), *Synthetic control methods for comparative case studies: Estimating the effect of California's tobacco control program*, Journal of the American statistical Association, 105(490), 493-505.

12 Notably, a suitable comparator market does not have to exhibit exactly the same price level, so that systematic (that is constant) differences concerning the level of prices are unproblematic. In a sense, a similar assumption is made in the BA approach, where it is assumed that the only systematic difference between the cartel and the post-cartel period is the existence of a cartel.

13 Snow, J. (1855), *On the Mode of Communication of Cholera*, London: John Churchill.

14 See, for example, Rose, A. M. (1952), *Needed research on the mediation of labor disputes*, Personnel Psychology, 5(3), 187-200.

15 See Wing, C., Simon, K., & Bello-Gomez, R. A. (2018), *Designing Difference in Difference Studies: Best Practices for Public Health Policy Research*, Annual Review of Public Health, 39, 453-469.

16 Early economic applications of the DiD approach focused mostly on the effect of wages on employment. See Lechner, M. (2011), *The estimation of causal effects by difference-in-difference methods*, Foundations and Trends in Econometrics, 4(3), 165-224. for an historical overview.

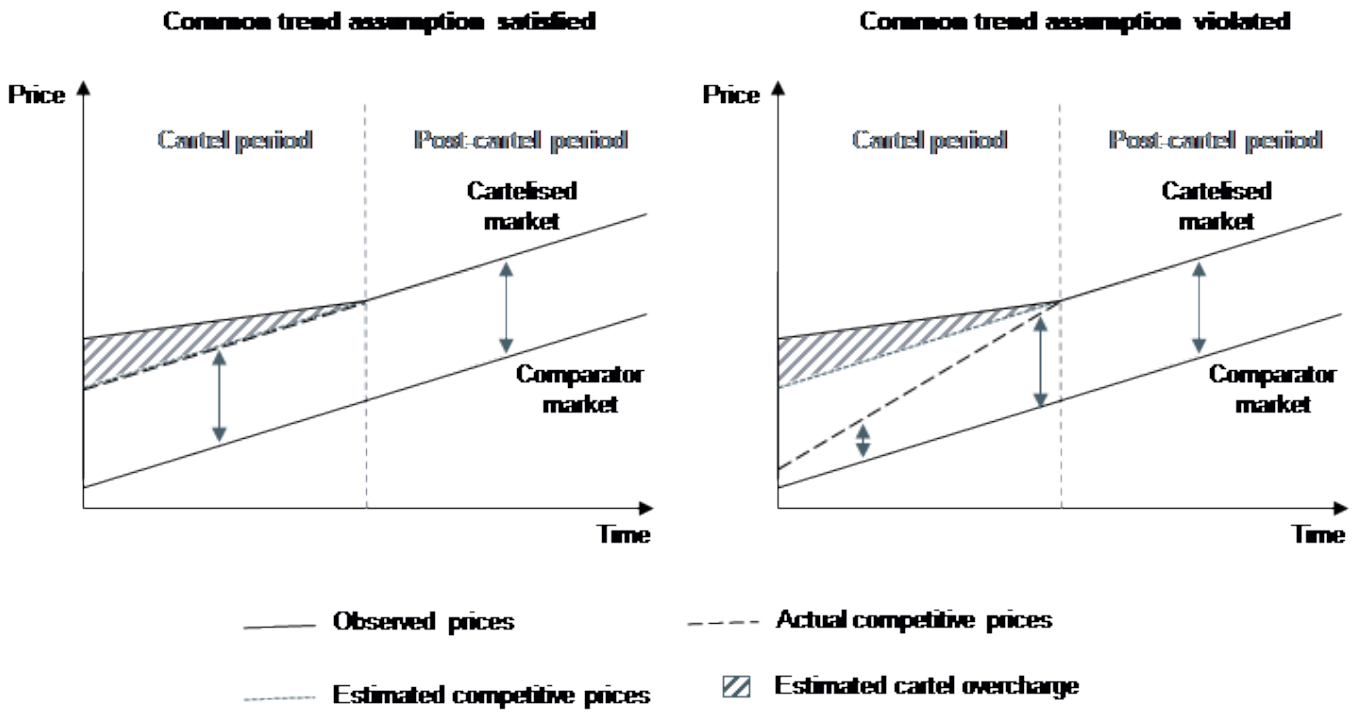
The following section demonstrates how a violation of the common trend assumption may affect the quantification of damage.

III. ROBUSTNESS OF THE COMMON TREND ASSUMPTION

The importance of the common trend assumption for the estimation of cartel damage is illustrated in Figure 1. The DiD approach is demonstrated in a case where the common trend assumption is satisfied (left figure) and in a case where it is violated (right figure). The figures show the observed development of prices over time in the cartelised market (upper black line) and in the comparator markets (lower black line). Suppose that the (unobserved) competitive price level in the absence of the cartel is given by the dashed line.

Consider first the case where the common trend assumption is satisfied (left figure). As indicated in the figure, the comparator market exhibits a constant price difference in the post-cartel period,[17] suggesting a common trend for both markets. Under the assumption that this common trend would also hold in the cartel period in the absence of the cartel, the counterfactual price level can be obtained by adding the price difference to the price level in the comparator market (dotted line). The difference between the counterfactual and factual prices in the cartel period yields the cartel overcharge (shaded area). If the common trend assumption is indeed satisfied, i.e. the price difference observed in the post-cartel period would have been observed in the cartel period in the absence of the cartel, the estimated competitive price level corresponds to the "true" competitive price level (the dashed line and the dotted line coincide). The cartel overcharge is correctly estimated.

Figure 1
Common trend assumption and the estimation of cartel overcharges



17 Note that real market prices typically are not linear lines but exhibit some form of non-linearity. A necessary condition for the common trend assumption to hold, is that the difference between the price series outside the cartel period is constant, irrespective of whether the series are linear or non-linear. The linear specification is only used for illustration purposes. It should be noted, however, that a common trend of transformed data (e.g. log-prices) rules out a common trend in levels. See Angrist, J., & Pischke, J.-S. (2009), *Mostly Harmless Econometrics*, Princeton: Princeton University Press, p. 230. For an estimation procedure which allows for common trends of transformed data, see Athey, S., & Imbens, G. W. (2006), *Identification and inference in nonlinear difference-in-differences models,* Econometrica, 74(2), 431-497.

Now consider the case where the common trend is not satisfied (right figure). As the price difference in the post-cartel period is unchanged, applying the DiD approach would yield the same estimated competitive price level as before (dotted line). If the actual competitive price level had evolved differently (dashed line), i.e. if the common trend assumption is not satisfied, the estimated competitive price level would no longer correspond to the actual competitive price level. In this example this would entail an underestimation of cartel overcharges, as actual competitive prices would have been lower than suggested by the DiD approach.[18]

The robustness of the estimation of cartel overcharges using a DiD approach therefore critically depends on the extent to which the common trend assumption is satisfied. If the common trend assumption is violated, the estimates obtained from the DiD approach are biased and it may not even be possible to tell whether they exhibit an upward or downward bias.[19]

In the example shown, it was straightforward to check whether the common trend assumption is satisfied. The actual competitive price level is, however, unobservable and of a counterfactual nature. Therefore, there is no conclusive test to find out whether the common trend assumption is satisfied. Due to this inherent problem, the use of the DiD approach comes at the cost of potentially uncertain robustness.

While there is no statistical procedure to conclusively test whether the cartelised market indeed would have developed as suggested by a common trend over the cartel period, there are test procedures that can be indicative of whether this is likely to be the case: visual inspection and statistical testing of price trends outside the cartel period.

These tests cannot provide certainty on whether the cartelised market and the comparator market are subject to a sufficiently similar price influencing factors over time which may warrant a common trend assumption. They can, however, be a useful indication of how much confidence one should have that the common trend assumption holds. These tests have been performed by competition authorities in the *ex post* evaluation of mergers,[20] as well as in the academic literature in the assessment of DiD studies.[21]

Visual inspection is a simple yet powerful tool, and can pick up trend differences which may indicate that an uncontrolled candidate comparator market may not be a reasonable counterfactual for the cartelised market.[22] The idea is that, if outside the cartel period the two markets exhibit a common trend, it might be reasonable to assume that this would have also been the case throughout the cartel period. Ideally, the inspection would take place in both the pre-cartel and the post-cartel periods. If in both cases a common trend can be detected, it may be a reasonable assumption that the common trend would have continued to hold throughout the cartel period. If only post-cartel data is available, the visual inspection is already less indicative, in particular if the cartel period spans a longer time period. Nevertheless, a necessary condition for the common trend assumption to be warranted in this case would be that at least the post-cartel period exhibits a common trend.

Visual inspection may be less insightful if the price data is very noisy and highly non-linear. In this case, the test can also be performed more rigorously using a statistical testing procedure as used by the European Commission in their *ex post* analysis of telecom mergers. The key intuition behind the statistical test is to check whether the cartelised market exhibits significant trend differences compared to the comparator market outside the cartel period.[23] If this is the case, then the comparator market is unlikely to adequately capture all the factors that influence prices in the cartelised market; the common trend assumption is unlikely to be satisfied.

18 Of course, a violation of the common trend assumption can also lead to the opposite outcome if the competitive price level had been higher in the cartel period than suggested by the DiD approach.

19 Another source of possible estimation bias in the DiD approach is so-called autocorrelation. See Bertrand, M., Duflo, E., & Mullainathan, S. (2004*), How Much Should We Trust Differences-in-Differences Estimates,* The Quarterly Journal of Economics, 119(1), 249-275.

20 Directorate-General for Competition (European Commission) (2016), *Ex post analysis of two mobile telecom mergers: T-Mobile/tele.ring in Austria and T-Mobile/Orange in the Netherlands*, European Commission.

21 Angrist & Pischke (2009), Ashenfelter, O. C., Hosken, D. S., & Weinberg, M. C. (2013), *The price effects of a large merger of manufacturers: A case study of Maytag-Whirlpool*, American Economic Journal: Economic Policy, 5(1), 239-261. The robustness of DiD settings is also of great concern in the medical sciences. Wing, Simon & Bello-Gomez (2018) provide an overview of best practices for public health policy research.

22 Angrist & Pischke (2009) demonstrate how visual inspection can be used by discussing the DiD setup in Card, D., & Krueger, A. (1994), *Minimum Wages and Employment: A Case Study of the Fast Food Industry in New Jersey and Pennsylvania*, American Economic Review, 84(4), 772-793.

23 More formally, the statistical test used by the European Commission is implemented as follows. In a first step, prices in the pre-treatment period are regressed on observed explanatory variables and a dummy for each point in time that takes on the value of 1 only for the treatment group. In a second step, the coefficients of the dummy variables are regressed against a linear slope to test whether the estimated slope is statistically different from zero. If the slope coefficient is non-zero and statistically significant, it suggests that there could be unobserved confounding factors affecting the treatment group which have not been controlled for by the control group. There are several ways how these "placebo tests" can be implemented. For an alternative test procedure see also Angrist & Pischke (2009), p. 237ff.

It is important to stress, however, that these tests are only indicative but not conclusive regarding the validity of the common trend assumption. Given this uncertainty, the question of robustness arises, as the relevance of the test procedures crucially depends on the extent to which trends outside the cartel period are likely to hold within the cartel period.

Data availability can impose a further substantial restriction. The fewer observations are available, the harder it becomes to substantiate the assumption of a common trend.[24] This is particularly relevant in instances where only few observations outside the cartel period are available, for example, because the cartelised behaviour ended only recently. Similarly, price data is typically available only on "one end" of the cartel period. Constant price differences in the post-cartel period are not necessarily indicative for the entire cartel period, especially if the cartel period spans a longer time period. These data limitations may further reduce the extent to which the underlying common trend assumption can be tested.

IV. CONCLUSION

Given a suitable comparator market, the DiD approach is a powerful method for the estimation of counterfactual prices. The identification of a suitable comparator market, however, poses a substantial challenge as it requires finding a market that satisfies the common trend assumption.

In the absence of a suitable comparator market, i.e. in instances where the common trend assumption is not satisfied, the DiD approach leads to biased estimates and it may be impossible to make predictions about the direction of the bias.

In summary, while the DiD approach can be a very powerful estimation method, it should not be considered as generally superior compared to other estimation methods. Rather, the choice of the estimation method should be the result of a careful evaluation of all relevant circumstances, including constraints imposed by data availability.

24 Consider the introductory example where only one observation per market is available in the post-cartel period. In this case, there is no trend in the development of prices which could be statistically tested or even inspected.

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