WORKING PAPERS

N° 18-915

April 2018

“How Accurate is the Coordinate Price Pressure Index to Predict Mergers’ Coordinated Effects?"

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This version, April 18th, 2018

Abstract

The Coordinate Price Pressure Index (CPPI) measures the incentives of two competitors to engage in a particular type of Parallel Accommodating Conduct (PAC). Specifically, it measures the incentives of a leader firm to initiate a unilateral percentage price increase, with the expectation that a follower firm will match it. Using a large set of simulated markets, we measure the accuracy of the index in terms of predicting the impact of a merger on firms' incentives to engage in PAC. Results suggest that the CPPI only displays a fair performance when predicting an increase in firm's incentives to engage in PAC, and only in mergers in which the diversion ratio between the target and the acquiring firm is low. However, the index displays a poor performance when predicting mergers with a significant anticompetitive effect.

Keywords Coordinate Price Pressure Index - Parallel Accommodating Conduct - Merger Simulation
JEL classification K21 L41

Acknowledgments The paper has benefited from interesting discussions with participants at the BECCLE 2015 Competition Conference organized by the Norwegian School of Economics, the Ninth Annual Competition Law, Economics and Policy Conference organized by the Competition Commission of South Africa, the 2015 Annual Meeting of the Latin American and Caribbean Economic Association (LACEA), and the 2016 European Summer School and Conference in Competition and Regulation (CRESSE).
Simulation code: The original versions of the code and protocol used in this paper were created by Jérôme Foncel, researcher at the University of Lille in France.

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1. Introduction

The aim of this paper is to evaluate the performance of the Coordinate Price Pressure Index (CPPI) introduced by Moresi *et al.* (2011) The index measures the incentives of two competitors to engage in a specific type of tacit coordination strategy by which a leader firm increases its price by a certain percentage, expecting that a follower firm will observe this change and will match it by exactly the same percentage. This specific conduct is considered as a form of Parallel Accommodating Conduct (PAC, herein).

As explained by Harrington (2013), a PAC could lead firms to reach a supra-competitive outcome. Nevertheless, this conduct requires some kind of retaliation or deterrence mechanism in order to be successfully implemented by firms. The game considered by Moresi *et al.* (2011) is in line with this argumentation. Indeed, the CPPI is derived from a simple model of repeated interaction between two firms, which explicitly considers monitoring and retaliation. The game is built as follows: (i) in a certain period t, a leading firm increases its price by a given percentage; (ii) in the subsequent period $t+1$ a follower firm observes the price increase and decides whether to match it or not; (iii) if matching occurs, the price increase becomes permanent. However, if there is no matching, the leading firm reverses its price to the initial level, with the promise of not initiating any further attempt to engage in PAC.

We build a set of 50,000 simulated markets. The demand is derived from a logit discrete choice model with random coefficients. The supply side is composed by a set of heterogeneous single-product firms that offer differentiated products and compete in prices. The initial level of prices (hereinafter, equilibrium prices) is obtained by computing the Nash equilibrium of the one-shot game. In each simulated market, we consider the engagement in PAC by two firms (say A and B), , and compute both the percentage price increase initiated by Firm A and the percentage price increase initiated by Firm B that would maximize the present value of each firm's future expected profits (assuming that this price increase will be matched by its competitor). We define the Actual Coordinate Price Pressure (ACPP) as the minimum of these two percentage price increases. In this sense, this measure can be seen as the lower bound of the supra-competitive prices that two firms could reach through PAC.

The next step is to simulate a merger between one of these firms (A for instance), the acquiring firm, and a third firm (say C), the acquired or target firm. Under this new scenario, we re-compute the ACPP, but considering the fact that the acquiring firm in willing to initiate and to follow a PAC by increasing the price of its two products (i.e., its original product plus the product acquired after the merger). The impact of the merger on firms' actual incentives to engage in PAC is measured as the variation of the ACPP induced by the acquisition, and this variation is used as the benchmark to measure the performance of the CPPI.

Note that we use a modified version of the CPPI. The baseline index proposed by Moresi *et al.* (2011) considers the percentage price increase that leaves the leader firm indifferent between increasing and not increasing its price (i.e., just-profitable variation). While the index used in this paper considers the percentage price increase that maximizes the present value of firms` expected profits (i.e., profit-maximizing variation). However, as already stated by Moresi *et al.* (2011), in practice this difference is translated into a minor adjustment with respect to the baseline index. Indeed the index built under the profit-maximization assumption is equal to one half of the index build under the just-profitable variation assumption.[1]

The accuracy of the index is measured in two situations: (i) its ability to correctly predict the sign of the change ($\text{ACPP} > 0\%$ or $\text{ACPP} \leq 0\%$), and (ii), its ability to identify mergers that generate a significant anticompetitive impact ($\text{ACPP} > 5\%$ or $\text{ACPP} \leq 5\%$). We measure the percentage of cases in which the index leads us to incur in Type I or Type II errors. As usual, a Type I error denotes a case in which the index erroneously identifies a merger as anticompetitive, when is not. While a Type II error refers to the case in which index fails to identify an anticompetitive merger.

First, regarding the direction of change, results suggest that the CPPI only displays a fair performance, and only for mergers involving firms with low diversion ratios between their products. Second, the results suggest that the CPPI displays a poor performance forpredicting mergers that generate a significant increase of firms' incentives to engage in PAC. While the percentage of cases with a Type I error is almost zero, the percentage of cases where the index incurs in a Type II error is considerably high. The reason is that the index consistently underestimates the magnitudes of the actual ACPP variations. We believe that the cause of this problem is that the index omits important information regarding the strategic interactions between the products sold by the merging parties. Indeed, the index does not consider any of the diversion rations between the acquiring and the target firms. Indeed, when the acquiring firm decides to increase its prices, a part of the diverted sales from one product is captured by its other product, and vice versa. Thus, the higher the diversion ratios between the products of the acquiring and target firms, the lower the cost of initiating a PAC. Therefore, not considering this information is likely to lead to an underestimation of the impact of a merger.

This paper is related to the economic literature that uses simulation methods to measure the performance of screening tools designed to predict the potential anticompetitive effects of mergers. In

[1] See Section II.C.3 of Moresi *et al.* (2011).

this vein, Foncel, Ivaldi and Khimich (2014) assess the accuracy of the Herfindahl-Hirschman Index (HHI) and the Upward Price Pressure (UPP) index in terms of predicting anticompetitive unilateral effects of mergers. Note that we borrow the simulation setting designed by Foncel *et al.* (2014). Similarly, Miller, Remer, Ryan and Sheu (2017) use Monte Carlo experiments to measure the accuracy of the UPP index to predict price effects of mergers. However, the literature on the evaluation of screening tools designed to gauge anticompetitive coordinated effects is still limited. Ivaldi and Lagos (2017) use simulated markets to characterize the risk of coordinated effects (defined as the incentives of firms to collude on the vector of prices that maximizes industry profits), and identify cases in which diversion ratios or cross-price elasticities can be used to screen anticompetitive mergers. However, the accuracy of these tools is not measured. Thus, to the best of our knowledge there are no papers measuring the accuracy of screening tools designed to measure the impact of coordinated effects. The CPPI has been the first index proposed for this purpose.

The rest of the paper is organized as follows. Section 2 briefly reviews the index proposed by Moresi *et al.* (2011). Section 3 explains the simulation approach. Section 4 displays the main results. Finally, Section 5 presents our conclusions.

2. The CPPI index

2.1 Pre-merger case

The PAC strategy consists on a game in which two (or more) competitors engage in a coordinated price increase without the need of explicit communication between them. In particular, a leader firm increases its price by a certain percentage with the expectation that at least one of its competitors will accommodate and follow a similar strategy. The game is defined as follows. First, in period t Firm A raises its price by a percentage equal to S_A for at least two periods. Second, in period $t+1$ Firm B decides whether to match the price increase or not, and if it finally decides to increase, it would do it by increasing its price by the exact same percentage. Third, in period $t+2$,there are two possible results: If Firm B has decided in t+1 to match the price increase, then the change becomes permanent for both firms; if Firm B has decided not to match the price increase, then Firm A returns to its initial price level and commits to not initiating further attempts to engage in a PAC.

Moresi *et al.* (2011) propose an index that captures firm's incentives to participate in the pricing strategy described in the preceding paragraph. This index is based on the maximum percentage price increase that a firm is willing to initiate (i.e., just-profitable variation). However, we choose to study a variation of this original index. Namely, we use the percentage price increase that maximizes the firm's expected profits from initiating a PAC (i.e., profit-maximizing variation). In practice, this latter percentage is just equal to one half of the percentage considered by the original index.[2] The percentage price increase that Firm A is willing to initiate is given by;

$$S_A^I = \frac{\delta F_{BA} - \theta_A}{1 - \delta F_{BA}} \times \frac{m_A}{2}, \tag{1}$$

with $F_{BA} = \frac{DR_{BA} q_B e_B}{q_A e_A}$ and $\theta_A = 1 - \frac{1}{m_A e_A}$. Sales volumes of products sold by Firms A and B are given by q_A and q_B, respectively. The term m_A is the initial percentage margin charged by Firm A, and e_A and e_B are the own-price elasticities of Firms A and B, respectively. The parameter δ is the inter-temporal discount rate, which is assumed to be equal for every firm in the market. The term DR_{BA} is the diversion ratio from Firm B to Firm A.

The cost/benefit trade-off faced by Firm A when initiating a price increase S_A^I at period t is captured by the term F_{BA}. The numerator represents the size of diverted sales from Firm B that Firm A would capture if Firm B decides to match the price increase (from period $t + 1$ onwards), while the denominator provides the size of diverted sales from Firm A generated by the price increase (from period t onwards). In addition, the term θ_A measures potential deviations of Firm A with respect to equilibrium prices. Indeed, in equilibrium, it has to be the case that $m_A e_A = 1$ and $\theta_A = 0$. Therefore, when Firm A is already pricing above the equilibrium, its incentives to initiate a price increase are reduced ($0 < \theta_A < 1$).

The percentage price increase that Firm B (i.e., defined as S_B^I) is willing to initiate is obtained by an identical procedure and it mirrors Equation (1).

Finally, the pre-merger CPPI is given by;

$$CPPI_{AB} = \min\{S_A^I, S_B^I\}. \tag{2}$$

Note that, as explained by Moresi *et al.* (2011), the percentage price increase that a firm is willing to follow is always higher that the percentage price increase that a firm is willing to initiate. Thus, the $CPPI_{AB}$ captures the lower bound of the range of percentage price increases that two Firms A and B could sustain through PAC.

[2] The mathematical derivations of both indexes are presented in the Technical Appendix of Moresi *et al.* (2011).

2.2 Post-merger variation

The purpose is to measure the change in Firms A and B incentives to engage in PAC, after the acquisition of a third Firm C. Thus, assuming that Firm A (the acquiring firm) merges with Firm C (the acquired or target firm), we re-build the post-merger index considering the exact same set of assumptions used by Moresi *et al.* (2011). Specifically, these are:

1. The term ΔS_i^I is measured with respect to the pre-merger price level.
2. The index abstracts from any unilateral effects.[3]
3. The merged firm (or Firm AC) raises the prices of all its products by the same percentage;
4. The post-merger sales volume of Firm AC is equal to the sum of the pre-merger sales of the merging parties;
5. The diversion ratio from Firm B to Firm AC is equal to the sum of the pre-merger diversion ratios DR_{BA} and DR_{BC};
   The diversion ratio from Firm AC to Firm B is equal to the diverted sales from Firm AC that are captured by Firm B after a uniform price increase of both products sold by the merged firm.[4]
6. The product sold by Firm C has the same price and margin than the product sold by Firm A. Thus, after the acquisition, Firm AC faces the same elasticity, price and margin for both products.

Under these assumptions, the post-merger percentage price increase that Firm AC is willing to initiate is given by:

$$S_{AC}^I = \frac{\delta F_{B,AC} - \theta_A}{1 - \delta F_{B,AC}} \times \frac{m_A}{2} \qquad \text{with} \qquad F_{B,AC} = \frac{(DR_{BA} + DR_{BC}) q_B e_B}{(q_A + q_C) e_A}, \tag{3}$$

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[3] As Moresi *et al.* (2011) point it out, the purpose of the CPPI index is to gauge the effect of a merger on firms` incentives to engage in PAC, and not to capture the overall upward pricing pressure caused by all causes.

[4] We approximate this diversion ratio by the following expression: $DR_{AC,B} = \frac{\frac{\partial q_B}{\partial p_A} + \frac{\partial q_B}{\partial p_C}}{\frac{\partial q_A}{\partial p_A} + \frac{\partial q_C}{\partial p_C}}$. All derivatives are computed using pre-merger prices and market shares. Note that, as a simplification assumption, the denominator in $DR_{AC,B}$ does not consider the cross-price derivatives between products of the merging parties, which represents the fraction of diverted sales that would be re-captured by the merged firm. Indeed, a modified version of this diversion ratio that considers this latter effect is given by: $\overline{DR_{AC,B}} = \frac{\frac{\partial q_B}{\partial p_A} + \frac{\partial q_B}{\partial p_C}}{(\frac{\partial q_A}{\partial p_A} - \frac{\partial q_A}{\partial p_C}) + (\frac{\partial q_C}{\partial p_C} - \frac{\partial q_C}{\partial p_A})}$. As a robustness check, later we use $\overline{DR_{AC,B}}$ instead of $DR_{AC,B}$, and show that results are robust to this change. Note that all derivatives in these formulas are expressed in absolute values.

while the post-merger percentage price increase that Firm B is willing to initiate is given by:

$$\bar{S}_{B}^{I}=\frac{\delta F_{AC,B}-\theta_{B}}{1-\delta F_{AC,B}}\times\frac{m_{B}}{2}\qquad\text{with}\qquad F_{AC,B}=\frac{DR_{AC,B}(q_{A}+q_{C})e_{A}}{q_{B}e_{B}}. \tag{4}$$

Note that Equations (3) and (4) are derived from our own interpretation of Moresi *et al.* (2011), since the authors do not present an explicit equation for the post-merger CPPI in the paper.[5]

Finally, the impact of a merger between Firms A and C on the incentives of Firms A and B to engage in PAC is given by:

$$\Delta CPPI_{AC,B}=\min\{S_{AC}^{I},\bar{S}_{B}^{I}\}-CPPI_{AB}. \tag{5}$$

3. Simulations of the Actual Coordinated Price Pressure

We simulate 50,000 markets, with 10,000 consumers and 5 single-brand firms in each of them. It is assumed that consumer preferences behave according to a model of discrete choice demand with random coefficients. In addition, we assume that firms offer products with differentiated characteristics or attributes, including a continuous one and a discrete one. Firms have heterogeneous and constant marginal costs of production and compete in prices. Under the absence of collusion or PAC, prices are determined in each period by the one-shot Nash equilibrium. Using this approach, it is ensured that the simulated markets exhibit a much more realistic pattern of own and cross-price elasticities. (See Nevo, 2000.) In addition, having both continuous and discrete quality attributes renders the model more general, and allows us to capture a wider range of preferences. (See Grigolon and Verboven, 2014.) For further details regarding the simulation setting see Appendix A.

In each market we simulate a PAC strategy between Firms A and B.[6] The actual percentage price increases, that firms involved in the PAC strategy are willing to initiate, are computed by maximizing the sum of firms present and future stream of expected payoffs, assuming that the competitor matches the price increase. This actual percentage price increase is denoted by $S_i^{I,Actual}$.

[5] Moresi et al. (2011) mention that the post-merger index can be computed using the pre-merger formulas, but considering the following adjustments: (i) larger sales volume for the merged firm, (ii) a higher diversion ratio from Firm B to the merged firm, and (iii) a revised diversion ratio from the merged firm to Firm B. In our interpretation of these adjustments, and considering the set of assumptions listed above, we modify the pre-merger formulas by considering: (i) a sales volume for the merged firm equal to $q_A + q_C$, (ii) a diversion ratio from Firm B to the merged firm equal to $D_{B,AC} = D_{B,A} + D_{B,C}$, and (iii) the revised diversion ratio from the merged firm to Firm B presented in Assumption (6) above.

[6] The discount factor δ is assumed to be equal to 0.9.

Therefore, we observe two percentage price increases, i.e., those that Firm A (i.e., $S_A^{I,Actual}$) and Firm B (i.e., $S_B^{I,Actual}$). would be willing to initiate. The derivation of $S_i^{I,Actual}$ is presented in Appendix B.

In this setting, the Actual Coordinate Price Pressure (i.e., $ACPP^{pre-merger}$) is defined as the minimum of these two values, i.e, $ACPP_{AB}^{pre-merger} = \min\{\mathrm{S_A^{I,Actual}}, \mathrm{S_B^{I,Actual}}\}$. In other words, the $ACPP^{pre-merger}$ represents the actual lower bound of supra-competitive prices that Firms A and B could reach through a PAC strategy. It is opposed to the predicted threshold provided by the CPPI)

In the next step, we simulate the impact of a merger between Firm A (acquiring firm) and Firm C (target firm) on firms' incentives to engage in PAC. Specifically, we re-compute the percentage price increase that Firm A is willing to initiate after acquiring Firm C, the merged entity being called Firm AC), assuming that it would apply the same percentage increase for both products. This value is denoted as $S_{AC}^{I,Actual}$. At the same time, we re-compute the percentage price increase that Firm B is willing to initiate, assuming that it will be followed by the two products of the merged firm. This percentage is denoted by $\bar{S}_B^{I,Actual}$. The derivations of $S_{AC}^{I,Actual}$ and $\bar{S}_B^{I,Actual}$ are presented in Appendix B.

The post-merger ACPP (i.e., $ACPP^{post-merger}$) is then defined as the minimum of these two adjusted percentage price increases, i.e., $ACPP_{AC,B}^{post-merger} = \min\{\mathrm{S_{AC}^{I,Actual}}, \bar{S}_B^{I,Actual}\}$. The impact of the merger is measured as the change in the ACPP (i.e., $\Delta ACPP = ACPP^{post-merger} - ACPP^{pre-merger}$). Thus, a positive change in ACPP, i.e., $\Delta ACPP$, represents an increase of the lower bound of prices that two firms can reach through PAC, and it can be considered as an anticompetitive effect generated by a merger.

However, an additional adjustment is made to the simulated price increase initiated by the acquiring firm post-merger. Since we are evaluating the impact of the merger with respect to the pre-merger level of prices, we need to adjust for the potential presence of unilateral effects. In order to do so, we compute the percentage price increase (which is denoted as S_{AC}^{U}). that the merged firm is willing to unilaterally initiate, even if there are no competitors willing to match it. Thus, the post-merger price increase initiated by the acquiring firm and motivated exclusively by PAC is obtained as follows:

Percentage price increase exclusively motivated by PAC ($\mathrm{S_{AC}^{I,Adjusted}}$)	=	Percentage price increase initiated by the merged firm and followed by a third competitor ($\mathrm{S_{AC}^{I,Actual}}$)	-	Percentage price increase that the merger firm would unilaterally initiate (S_{AC}^{U})

In other words:

PAC effect = Overall Effect - Unilateral Effects

Note that it is assumed that competitors that are not involved in the PAC strategy do not react and keep their prices at the pre-merger Nash equilibrium level. In addition, we are restricting the unilateral effects to be a percentage price increase equally applied to all the products offered by the merged firm. However, the post-merger level of Nash equilibrium prices does not necessarily satisfy this condition. For more details regarding the maximization problem necessary to obtain the pre-merger and post-merger values of the ACCP, please refer to the Appendix B.

Table 3 summarizes the main descriptive statistics of the set of simulated markets. There are already two interesting results that can be deduced from this table. First, on average, the CPPI significantly underestimates the actual impact of the merger on firms' incentives to engage in PAC. Second, as predicted by Moresi *et al.* (2011), the merger can actually reduce firms' incentives to engage in PAC (i.e. a negative change in ACPP). Indeed, the ACPP change is negative in 13.57% of the sample.

Table 3 - Summary statistics of the simulated markets

Variable	Mean	Std. Dev.	Min.	Max.
Own-price elasticity Firm A	-3.482956	1.171715	-24.35604	-0.4310398
Own-price elasticity Firm B	-3.482887	1.169006	-25.7864	-0.2349229
Diversion Ratio (Firm C to Firm A)	0.1683257	0.1246738	0.000008	0.7511157
Diversion Ratio (Firm C to Firm B)	0.1720856	0.1252642	0.000011	0.737363
HHI pre-merger	2769.439	702.6352	2000.255	9441.809
Predicted HHI variation	710.6348	581.8557	0.1590207	4890.431
ACPP pre-merger	0.0456778	0.1350181	-0.000457	21.44375
ACPP variation	0.0402753	0.153141	-2.213478	10.89305
CPPI pre-merger	0.0213234	0.0369831	-0.4044157	0.5667104
CPPI variation (*)	0.0068188	0.0549253	-2.449458	0.3343301
Number of observations (**)		46,093		

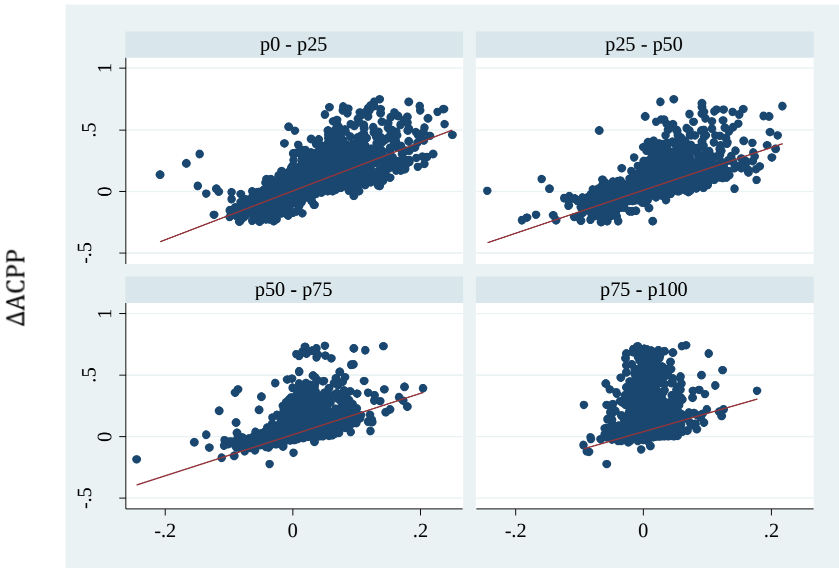
Note: (*) It only considers observations with a CPPI variation higher than -2.5
(**) We do not consider 3,907 observations in which the fixed-point algorithm used to compute Nash equilibrium prices does not converge to a solution after 200 iterations, or observations in which the equilibrium market share of at least one of the firms is equal to zero.

4. Performance of the CPPI

Figure 4.1 contains a set of scatter-graphs displaying the relationship between the value predicted by the index ($\Delta\mathrm{CPPI}_{\mathrm{AC,B}}$) and the actual variation of firms' incentives to engage in PAC ($\Delta\mathrm{ACPP}_{\mathrm{AC,B}}$). The sample is classified in four groups, according to the actual value of the diversion ratio from the target firm (Firm C) to the acquiring firm (Firm A). For instance, the upper left panel displays the scatter plot of the observations under the 25th percentile value of DR_{CA}. It is clear to conclude, from a visual examination of the graphs in Figure 4.1, that the index has a better predictive power for those acquisitions with lower values of this diversion ratio.

One explanation for the existence of this asymmetry is that the index omits the information provided by the diversion ratios between the products offered by the merged firm. Indeed, when Firm A is evaluating to initiate a post-merger PAC with Firm B, it has to consider the cost of unilaterally initiating a price increase (i.e., the value of total diverted sales), which will be reduced if a larger fraction of its diverted sales are captured by Firm A. Thus, the higher the diversion ratios between the merging parties' products, the lower the cost of initiating a PAC, and thus the higher the impact of the merger on the acquiring firm's incentives to initiate such a conduct. Therefore, for higher values of the merging parties' diversion ratios, the index is likely to underestimate the real impact of the merger and becomes less accurate.

Figure 4.1 – Predicted (ΔCPPI) and actual (ΔACPP) variation of firms' incentives to engage in PAC, by different values of DR_{CA} (*)



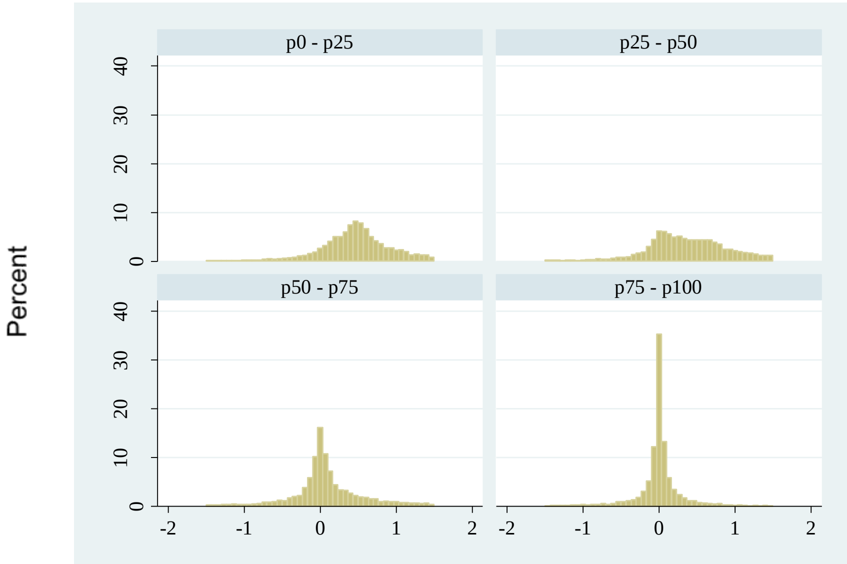
(*) Each pX-pY pair represents the range of values in between percentiles X and Y of the diversion ratio $DR_{C,A}$

Figure 4.2 displays the empirical distribution of the ratio between the predicted variation of the percentage price increase that the acquiring firm is willing to initiate (i.e., $\Delta S_A^I = S_{AC}^I - S_A^I$), and its actual variation (i.e., $\Delta S_A^{I,Actual} = S_{AC}^{I,Actual} - S_A^{I,Actual}$). In other words, it shows the percentage of the actual variation that is explained by the CPPI. As shown in the graphs of Figure 4.2, for higher values of the diversion ratio from the acquired firm (Firm C) to the acquiring firm (Firm A), the distribution is centered around 0 (zero). This fact has two implications. First, the index consistently underestimates the actual price variation (if the prediction was accurate, the distribution would be centered around 1). Second, for higher values of the diversion ratio, the index predicts the wrong direction (or sign) of the change on a high percentage of the cases in the sample (if the prediction was accurate, the value of the ratio would be always positive).

Result 1

For high values of the diversion ratio between the products offered by the target and acquiring firmq (i.e., DR_{CA}), the CPPI tends to consistently underestimate the actual impact of the merger on the merged firm incentives to engage in PAC and to be significantly less accurate when predicting the direction of this change.

Figure 4.2 – Distribution of $\Delta S_A^I / \Delta S_A^{I,Actual}$, by different values of DR_{CA}



$\Delta S_A^I / \Delta S_A^{I,Actual}$

(*) Each pX-pY pair represents the range of values in between percentiles X and Y of the diversion ratio $DR_{C,A}$

4.1 Predicting an increase in firms incentives to engage in PAC

To study the performance of the CPPI when predicting the direction of change, the sample is classified in two groups: cases with $\Delta ACPP > 0\%$ (anticompetitive merger) and cases with $\Delta ACPP \leq 0\%$ (absence of anticompetitive effects). Then we measure the percentage of cases in which the index leads us to incur a Type I error or a Type II error. A Type I error refers to cases in which the index erroneously classifies a merger as potentially anticompetitive (i.e., $\Delta\text{CPPI} > 0\%$) when it is not (i.e., $\Delta\text{ACPP} \leq 0\%$.); a Type II error corresponds to cases in which the index fails to detect an anticompetitive merger (i.e., $\Delta\text{CPPI} \leq 0\%$, and $\Delta\text{ACPP} > 0\%$). Table 4.1 summarizes the results. It can be seen that, in terms of cases displaying a Type II error, the CPPI displays a fair performance for mergers with a low value of the diversion ratio DR_{CA}; however, the number of cases with a Type I error is still significant.

Table C.1 in Appendix C replicates the results displayed in Table 4.1, but using $\overline{\text{DR}_{\text{AC,B}}}$ (instead of $DR_{AC,B}$) to compute $\overline{\text{S}}_{\text{B}}^{\text{I}}$ in Equation (4). Results are robust to this change.

Table 4.1 – Accuracy of the CPPI: predicting the sign of the change

Diversion Ratio (DR_{CA})	$\Delta\text{ACPP} \leq 0\%$		$\Delta\text{ACPP} > 0\%$	
Percentile	Freq.	Type-I error	Freq.	Type-II error
25%	2,483	24.77%	9,040	12.88%
50%	2,255	11.84%	9,268	15.47%
75%	1,176	8.67%	10,347	29.11%
100%	343	21.87%	11,181	38.85%
Total	6,257	16.93%	39,836	24.99%

Result 2

In term of predicting a positive ACPP change (i.e., an anticompetitive effect), the CPPI displays a fair performance only in mergers with low values of the diversion ratio between the products offered by the target and the acquiring firm (i.e., a low DR_{CA}). However, even in these cases, the probability of incurring in a Type I error is still significant.

4.2 Identifying mergers that generate a significant increase in firms incentives to engage in PAC

To study the performance of the CPPI in terms of identifying mergers that generate a significant increase in firms incentives to engage in PAC, the sample is classified in two groups: cases with $\Delta\text{ACPP} > 5\%$ and cases with $\Delta\text{ACPP} \leq 5\%$. As before, we measure the percentage of cases in which the index leads us to incur in a Type I error (i.e., $\Delta\text{CPPI} > 5\%$, and $\Delta\text{ACPP} \leq 5\%$), and in a Type II error (i.e., $\Delta\text{CPPI} \leq 5\%$, and $\Delta\text{ACPP} > 5\%$). Table 4.2 summarizes these results. The occurrence of cases with a Type I error is substantially low (0.41% of the total number of cases) and stable across the sample. Nevertheless, the accuracy of the index in terms of detecting anticompetitive cases is quite poor.

Indeed, the index displays a Type II error in 75.08% of the markets, and in almost 100% of the markets with mergers involving products with high values of the diversion ratio (from Firm C to Firm A).

Table C.2 in Appendix C replicates the results displayed in Table 4.2, but using $\overline{\mathrm{DR}_{\mathrm{AC,B}}}$ (instead of $DR_{AC,B}$) to compute $\bar{\mathrm{S}}_{\mathrm{B}}^{\mathrm{I}}$ in Equation (4). Results are almost identical to the ones presented in this section.

Table 4.2 – Accuracy of the CPPI: predicting a significant variation of the ACPP

Diversion Ratio (Firm C / Firm A)	$\Delta \mathrm{ACPP} \leq 5\%$		$\Delta \mathrm{ACPP} > 5\%$	
Percentiles	Freq.	Type-I error	Freq.	Type-II error
25%	8,453	0.70%	3,070	56.09%
50%	9,420	0.73%	2,103	71.56%
75%	9,832	0.17%	1,691	86.16%
100%	8,990	0.07%	2,534	97.32%
Total	36,695	0.41%	9,398	76.08%

Result 3

The CPPI displays a poor performance when detecting mergers that generate a significant anticompetitive impact (i.e., $\Delta ACPP > 5\%$*) on firms' incentives to engage in PAC.*

5 Conclusions

We test the accuracy of the CPPI within a simulated environment, considering a system of non-linear demands and a supply side composed by heterogeneous firms that compete in prices. The results suggest that the index displays a poor performance for predicting significant changes on firm's incentives to engage in PAC. There are two potential explanations for this result. First, the CPPI is derived from a model with linear demands. Thus, it is expected that its accuracy is reduced in a model based on non-linear demands. Second, the CPPI does not consider the strategic interactions between the merged firm's products. Indeed, the cost of initiating a PAC may be reduced because a fraction of diverted sales from one product are captured by the other products offered by the merged firm. Therefore, not considering this positive externality may lead us to inaccurate predictions.

Recently, Moresi *et al.* (2015) propose a new index (called cGUPPI) that considers all the cross-price effects of firms involved in a PAC strategy; hence, it should outperform the CPPI index in terms of identifying mergers with a signficant anticompetitive impact on firms incentives to engage in PAC. However, the construction of this index requires a larger set of information. . An alternative approach is given by merger simulation models, which requires a similar information set as input, and may result in more accurate predictions (see for instance, Bjőrnerstedt and Verboven, 2016, for the case of unilateral effects, Brito *et al.*, 2013, and Ivaldi and Lagos, 2017, for the case of coordinated effects).

Appendix A – Simulation setting

Discrete choice demand with random coefficients

We consider a set of N consumers, whom buy at most one unit of a product. Preferences are represented by a random utility model, in which product j provides the following level of (indirect) utility to consumer n:[7]

$$U_{j,n} = \beta_{1,n}\, x_{1,j} + \beta_{2,n}\, x_{2,j} - \alpha_n p_j + \varepsilon_{j,n}, \tag{A.1}$$

where $x_{1,j}$ and $x_{2,j}$ represent product characteristics that determine the quality of product j, p_j is the price of product j and $\varepsilon_{j,n}$ is an idiosyncratic term related to both products and individuals. We assume that $x_{1,j}$ is a characteristic drawn from a continuous space, with distribution $F_{x_1}(continuous)$. While the second characteristic is assumed to be a discrete one, with values 0 or 1, according to the distribution $F_2(discrete)$. Moreover, note that all the parameters are specific to each individual, that is to say: $\beta_{1.n} = \beta_1 + \tilde{\beta}_{1,n}$, $\beta_{2.n} = \beta_2 + \tilde{\beta}_{2,n}$, and $\alpha_n = \alpha + \tilde{\alpha}_n$, where $\tilde{\beta}_{1,n}$, $\tilde{\beta}_{2,n}$ and $\tilde{\alpha}_n$ are random variables that follows the known distributions $F_{\tilde{\beta}_1}$, $F_{\tilde{\beta}_2}$ and $F_{\tilde{\alpha}}$, respectively. In addition, consumers face an outside option which gives them the following level of utility:

$$U_{0,n} = x_0 + \tilde{x}_{0,n} + \varepsilon_{0,n}, \tag{A.2}$$

where the random term $\tilde{x}_{0,n}$ follows a known distribution as well, denoted by $F_{\tilde{x}_0}$.

The supply side

We consider F firms and the set of products B, where each firm produces the subset of products (or brands) B_f. Thus the profits of firms are the following:

$$\Pi_f = \sum_{j\in B_f} \pi_j = \sum_{j\in B_f} \left(p_j - c_j\right) s_j(p) N, \tag{A.3}$$

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[7] Note that this indirect utility function can be derived from a quasi-linear utility function. It does not contain income variable implicitly, because when consumers compare between different products ($U_{j,n} \lesseqgtr U_{k,n}$), the income variable vanishes. According to Nevo (2000), the quasi-linear assumption is only reasonable for some products. For instance, it would not be a good assumption for the car market, in which income effects should be taken into account.

where p_j , c_j and s_j are the price, constant marginal cost and market share of product j respectively. The variable p is the vector of prices of all the brands in the market and N is the number of potential consumers. Firms have complete information regarding the parameters β_1, β_2 and α and the distributions of the random parameters are assumed to be common knowledge.

Firms' marginal costs are assumed to have the following form:

$$c_j = exp(\gamma_1 x_{1,j} + \gamma_2 x_{2,j} + \omega_j), \tag{A.4}$$

There is a firm-specific cost component given by ω_j. In addition, γ_1 and γ_2 are common to all the firms in a given industry.

Market Shares

For a given vector of prices p and assuming independence of consumer idiosyncrasies for product characteristics and the error term, the market share of product j is given by the following expression:

$$s_j(p) = \int_{A_j} dF\big(\tilde{\beta}_1, \tilde{\beta}_2, \tilde{\alpha}, \tilde{x}_0, \varepsilon\big) = \int_{A_j} dF\big(\tilde{\beta}_1\big)\, dF\big(\tilde{\beta}_2\big) dF(\tilde{\alpha}) dF(\tilde{x}_0) dF(\varepsilon), \tag{A.5}$$

with $A_j = \{(\tilde{\beta}_1, \tilde{\beta}_2, \tilde{\alpha}, \tilde{x}_0, \varepsilon) \mid U_{j,n} \geq U_{l,n}\}$, for all l, denoting the set of consumers that choose product j. We assume that ε is distributed according to a Type I extreme-value distribution, so the error term can be integrated out giving rise to the well-known Logit probabilities.

Timing of the game

The timing of the game can be summarized as follows:

1) Nature draws the underlying consumers' preferences parameters (α, β_1, β_2, x_0) and firms' common costs components (γ_1, γ_2).
2) Nature draws products characteristics ($x_{1,j}$,$x_{2,j}$) and each firm specific cost component (ω_j).
3) Firms observe consumers' preferences in 1), but they do not know consumers' idiosyncratic tastes ($\tilde{\alpha}_n$, $\tilde{\beta}_{1,n}$, $\tilde{\beta}_{2,n}$, $\tilde{\varepsilon}_{n,j}$, $\tilde{x}_{n,0}$, $\tilde{\varepsilon}_{n,0}$). Thus, conditionally on prices and provided that firms do know the distributions of idiosyncratic tastes, they can compute expected market shares.
4) The Bertrand-Nash equilibrium in prices is solved.
5) Nature draws consumers' idiosyncratic tastes ($\tilde{\alpha}_n$, $\tilde{\beta}_{1,n}$, $\tilde{\beta}_{2,n}$, $\tilde{\varepsilon}_{n,j}$, $\tilde{x}_{n,0}$, $\tilde{\varepsilon}_{n,0}$). Then consumers observe prices and product characteristics and eventually make their choice.

Baseline simulations setting

We replicated the baseline simulations setting used by Ivaldi and Lagos (2017), but only using their calibration number (12) in Table B.3 of Appendix B of this article.

Parameter	Baseline Setting
F	Number of firms is fixed to 5 for all the markets. Each firm produces only one product.
N	Number of consumers is set to 10,000 for all the markets.
NS	Number of simulations for computing the expected market shares is fixed to 1,000.
α	It is constant within each market, but it varies across markets with uniform distribution $U_{[0,3]}$.
$\tilde{\alpha}_n$	For a given market varies among consumers with exponential distribution E_{1/σ_α}. The parameter σ_α is distributed uniformly $U_{[0,7]}$ across markets.
β_1	It is constant within each market, but it varies across markets with uniform distribution $U_{[0,4]}$.
β_2	It is constant within each market, but it varies across markets with uniform distribution $U_{[0,3]}$.
$\tilde{\beta}_{1,n}$, $\tilde{\beta}_{2,n}$	For a given market both vary among consumers with normal distributions $N_{[0,\sigma_{\beta_1}]}$ and $N_{[0,\sigma_{\beta_2}]}$, respectively. The parameters σ_{β_1} and σ_{β_2} are distributed uniformly $U_{[0,5]}$ across markets.
$\tilde{\varepsilon}_{n,j}$, $\tilde{\varepsilon}_{n,0}$	They are both drawn from an extreme value distribution $F_{[\lambda]}$, where the scale parameter λ is equal to 0.5.
$x_{1,j}$	For each market $x_{1,j} = exp(\tau \cdot \xi_j)$ where $\tau = 0.3$ and ξ_j are distributed normally with $N_{[2,2]}$.
$x_{2,j}$	For each market $x_{2,j} = I(\eta_j > 0)$ where η_j are distributed normally with $N_{[0,1]}$.
x_0	For each market x_0 is drawn from a normal distribution $N_{[0,4]}$.
$\tilde{x}_{n,0}$	For a given market varies among consumers with normal distribution $N_{[0,\sigma_x]}$. The parameter σ_x is distributed uniformly $U_{[0,3]}$ across markets.
ω_j	For each market ω_j is drawn from a normal distribution $N_{[0,0.05]}$.
γ_1, γ_2	Both are fixed for each market, but they vary across markets with the same uniform distribution $U_{[0,1]}$.

Appendix B

Computation of the actual percentage price increases motivated by PAC and computation of the ACPP

The actual pre-merger price increase motivated by PAC and initiated by Firm i, denoted by $S_i^{I,Actual}$, for $i = A, B$, is computed as follows:

$$S_i^{I,Actual} = \max_s \left\{\pi_i(p_i^N(1+s), p_{-i}^N) + \pi_i\big(p_A^N(1+s), p_B^N(1+s), p_{-A,-B}^N\big)\tfrac{\delta}{1-\delta}\right\}, \tag{B.1}$$

where the superscript N stands for Nash equilibrium price.

While the actual post-merger percentage price increases initiated by the merged firm AC and Firm B, denoted by $S_{AC}^{I,Actual}$ and $\bar{S}_B^{I,Actual}$, respectively, are obtained as:

$$\begin{aligned} S_{AC}^{I,Actual} = \max_{s_1} \Big\{ & \pi_A\big(p_A^N(1+s_1), p_C^N(1+s_1), p_{-A,-C}^N\big) + \pi_C\big(p_A^N(1+s_1), p_C^N(1+s_1), p_{-A,-C}^N\big) \\ & + \pi_A\big(p_A^N(1+s_1), p_C^N(1+s_1), p_B^N(1+s_1), p_{-A,-C,-B}^N\big)\frac{\delta}{1-\delta} \\ & + \pi_C\big(p_A^N(1+s_1), p_C^N(1+s_1), p_B^N(1+s_1), p_{-A,-C,-B}^N\big)\frac{\delta}{1-\delta}\Big\} \\ & - \max_{s_2} \Big\{\pi_A\big(p_A^N(1+s_2), p_C^N(1+s_2), p_{-A,-C}^N\big)\frac{1}{1-\delta} \\ & + \pi_C\big(p_A^N(1+s_2), p_C^N(1+s_2), p_{-A,-C}^N\big)\frac{1}{1-\delta}\Big\}, \end{aligned} \tag{B.2}$$

and,

$$\bar{S}_B^{I,Actual} = \max_s \left\{\pi_B(p_B^N(1+s), p_{-B}^N) + \pi_B\big(p_A^N(1+s), p_C^N(1+s), p_B^N(1+s), p_{-A,-C,-B}^N\big)\tfrac{\delta}{1-\delta}\right\}. \tag{B.3}$$

Note that, in Equation (B.2), s_1 represents the percentage price increase that Firm AC would initiate, assuming that it will be matched by Firm C, while s_2 is the percentage price increase that Firm AC would unilaterally initiate. In addition, in Equations (B.1), (B.2) and (B.3) is assumed that firms non-involved in PAC keep their prices at the Nash equilibrium level.

The pre-merger ACPP is given by:

$$\mathrm{ACPP_{AB}} = \min\{\mathrm{S_A^{I,Acual}}, \mathrm{S_B^{I,Actual}}\}. \tag{B.4}$$

The post-merger ACPP is given by:

$$\mathrm{ACPP_{AC,B}} = \min\{\mathrm{S_{AC}^{I,Actual}}, \bar{S}_B^{I,Actual}\}. \tag{B.5}$$

Finally, the impact of the merger on firms' actual incentives to engage in PAC is given by:

$$\Delta\mathrm{ACPP_{AC,B}} = \mathrm{ACPP_{AC,B}} - \mathrm{ACPP_{AB}}. \tag{B.6}$$

Appendix C – Tables

Table C.1 – Accuracy of the CPPI: predicting the sign of the change
(Using $\overline{D_{AC,B}}$ to compute $\bar{S}_B^I$ in Equation 4)

Diversion Ratio (DR_{CA})	$\Delta ACPP \leq 0\%$		$\Delta ACPP > 0\%$	
Percentile	Freq.	Type-I error	Freq.	Type-II error
25%	2,483	24.93%	9,040	12.99%
50%	2,255	12.11%	9,268	15.66%
75%	1,176	8.76%	10,347	29.71%
100%	343	23.91%	11,181	41.99%
Total	6,257	17.21%	39,836	26.09%

Table C.2 – Accuracy of the CPPI: predicting a significant variation of the ACPP
(Using $\overline{D_{AC,B}}$ to compute $\bar{S}_B^I$ in Equation 4)

Diversion Ratio (Firm C / Firm A)	$\Delta ACPP < 5\%$		$\Delta ACPP \geq 5\%$	
Percentiles	Freq.	Type-I error	Freq.	Type-II error
25%	8,453	0.89%	3,070	54.07%
50%	9,420	0.93%	2,103	68.19%
75%	9,832	0.49%	1,691	83.68%
100%	8,990	0.37%	2,534	96.80%
Total	36,695	0.66%	9,398	74.08%

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