OFFICE OF FAIR TRADING

Conjectural Variations and Competition Policy: Theory and Empirical Techniques

A Report for the OFT by RBB Economics

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FOREWORD BY AMELIA FLETCHER

This report was commissioned by the Office of Fair Trading (OFT) from RBB Economics. It examines the implications for competition policy of the literature on firms' conjectures as to their rivals' behaviour.

A firm may make a conjecture regarding how its rivals will respond if the firm changes its price or quantity. Many of our standard economic models implicitly assume that this conjecture is fixed. However the conjectural variations literature relaxes this fixed assumption and asks how might competitive equilibria change if firm conjectures can change or vary across different markets.

In assessing the implications of this literature for competition policy the report looks specifically at how varying firms' conjectures impact on: (i) current unilateral merger analysis, (ii) current coordinated merger analysis, and (iii) empirical estimates of the degree of competition. The report considers whether our current competition policy tools are robust to changes in assumptions regarding firm's conjectures. It also contributes to our understanding of when, why, and how we should intervene.

The views of this paper are those of authors and do not necessarily reflect the views of the OFT nor the legal position under existing competition or consumer law which the OFT applies in exercise of its enforcement functions. Rather the aim of the report is to provide some evidence and promote economic debate on this interesting issue.

This report is part of the OFT's Economic Discussion Paper series. If you would like to comment on the paper, please write to me, Amelia Fletcher, at the address below. The OFT welcomes suggestions for future research topics on all aspects of UK competition and consumer policy.

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1 EXECUTIVE SUMMARY

Introduction

1.1 In this report we assess the role of conjectural variations in merger policy and as an empirical tool for the detection of market power and coordinated behaviour.[1]

Definition of conjectural variations

1.2 Conjectural variations capture the **expectation** a firm has about how its rivals will react when it changes its quantity or price. Usually, conjectural variations are discussed in relation to quantities. For example, if firm 1 is contemplating reducing output by 100 units and expects firm 2 to increase output by 60 units **in response**, its conjecture is negative (for example its action leads to an opposite action by its rival) and equal to -0.6. When a firm conjectures that its output reduction would be offset (somewhat) by a rival's output expansion, the output reduction becomes less profitable – intuitively, a given output reduction is perceived to have a smaller impact on raising price. Negative conjectures therefore

[1] Specifically, we were commissioned by the OFT to consider the broad policy implications of conjectural variations with respect to the following three areas of interest. First on empirical estimation we were asked to consider how conjectural variations can be used in the estimation of the level of market competitiveness, and in particular whether there are any 'simplifications' in the use of these approaches which can be used to provide an initial view regarding the underlying degree of competition within markets. Secondly on unilateral effects, we were asked what role the literature on conjectural variations can play in improving our understanding of the potential unilateral effects of mergers. Specifically, we were asked to consider whether they should they play a significant role in addressing some of the recent criticisms of the models used to assess unilateral effects such as the Upwards Pricing Pressure (UPP) index. Thirdly on coordinated effects, we were asked to examine what insights conjectural variations can provide on oligopolistic markets, and how they may potentially be used to better detect less obvious forms of collusion. In particular, we were asked to assess whether certain models in the spirit of the Conjectural Variation literature suggest that the 'Airtours' criteria may be under-inclusive in identifying coordinated-effect SLCs or SIECs.

intensify competition (compared to the case where firms do not take into account how their rivals might react).

1.3 On the other hand, if firm 1 conjectures that a decrease in its own output will be met by a decrease in output by firm 2, then conjectural variations are positive.[2] Reducing output is more profitable (than the case where rival's reactions are ignored), since a reduction in output is perceived to have a greater impact on raising price. In this sense, positive conjectural variations dampen competition.

1.4 More recently, pricing conjectures have come to the fore. Where firms compete in prices, conjectural variations refer to a firm's expectation over how its rivals change their prices in response to a change in its own price. For example, if firm 1 takes the view that its own higher price will induce firm 2 to increase price as well, then conjectural variations are said to be positive or 'accommodating'. Such a conjecture leads firm 1 to set **higher** prices than in the case where it ignores firm 2's response (because if firm 2 increases price as well, firm 1 loses fewer units and so perceives demand to be less price sensitive).[3] As with quantity setting games, competition is softened if conjectural variations are positive, and competition is intensified if they are negative.

1.5 Conjectures can be employed in static, simultaneous move games even though the rules of the game mean that firms cannot in fact react to each other's actions. This (theoretically awkward) feature may be justified on the basis that it may allow the equilibrium of the static game to be the same in terms of **outcomes** as a more complex dynamic game. In this case, it is important to address the question: if there is believed to be a key dynamic aspect to competition, why ignore the 'true' model

[2] For example if firm 1 expects a reduction in its own output of 100 units to result in a reduction in the output of firm 2 by 50 units then its conjecture is equal to 0.5.

[3] Similarly, if firm 1 takes the view that setting a lower price will induce firm 2 to increase price, then conjectural variations are said to be negative. Such a conjecture would induce firm 1 to set **lower** prices than in the case where it ignores firm 2's response (because if firm 2 increases price in response, firm 1 gains more units and so perceives demand to be more price sensitive).

and use instead the more restricted and simplistic conjectural variations adjustment to the static game? Put another way, if rivals react to each other's quantity or price decisions, should we not try to drill down into that process and understand how it occurs?

1.6 One answer is that the conjectural variation models provide tractability without the loss of substantial accuracy. There may be reasons to believe that modelling a dynamic game is highly complex but would ultimately give very similar results to a simple one shot game that incorporates certain conjectures. If that were true, then, to the extent that existing practice uses static models with (implied) zero conjectural variations to analyse unilateral effects, such models would fail to capture dynamic games adequately. It may be the case that incorporating non-zero conjectural variations allows for richer static models that better approximate dynamic games. Some papers therefore sought to develop theoretical models which demonstrated how dynamic games did indeed reduce to outcomes that can be replicated by choosing an appropriate conjectural variations parameter. The literature found that the conjectural variations supported by dynamic games did exist but – depending on the model – such parameters were restricted to (i) zero (outcomes no different from one-shot behaviour), (ii) negative (more intense competition than one-shot behaviour), or (iii) positive (less intense competition than one-shot behaviour) such that no guidance emerged on what a 'typical' conjecture should be.

1.7 The failure to obtain a compelling theoretical grounding for conjectural variations brings out both the strengths and weaknesses of conjectural variations from a policy perspective. On the one hand, it may be helpful to have a single parameter that is flexible enough such that, if estimated correctly, we learn whether an industry outcome is more or less competitive than a benchmark of a one-shot game in which rivals ignore each other's responses. On the other hand, having identified that parameter, we learn very little about the true dynamic process giving rise to the outcome that differs from our benchmark.

Brief overview of the rest of this report

1.8 In order to address our specific research questions, we set out four distinct chapters.

1.9 Chapter 2 provides a brief review of the theory of conjectural variations, discussing some selective papers that have sought to justify their use in a wide range of settings, including dynamic games, bounded rationality and evolutionary games.

1.10 In Chapter 3 we take a **backwards-looking** approach and ask whether **empirical** techniques can tell us anything about how firms have competed historically – this may have value where the Authorities are interested in whether industry **outcomes** are consistent with the exertion of market power, and in particular whether firms have engaged in coordinated behaviour during some well-defined periods.

1.11 In Chapter 4 we turn to a more **forwards-looking** approach to how conjectural variations can be used by policy makers, particularly with respect to unilateral effects analysis in merger control. Specifically, we examine the role that conjectures can potentially play with respect to the initial screens based on simple simulations that the OFT often uses to assess whether or not proposed mergers (especially retail mergers) may give rise to a realistic prospect of anti-competitive effects. We consider both theoretical and empirical issues with doing this.

1.12 Finally, in Chapter 5 we take a **broader perspective** on firm reactions. Rather than stick slavishly to the textbook definition of a conjectural variations model, we instead consider a different issue 'in the spirit' of conjectural variations, with particular reference to coordinated effects. We do this with reference to specific papers identified by the OFT for our review, in particular, we consider the implications of these papers for the analysis of coordinated effects by asking: 'to what extent do the theoretical models considered lead us to think that the so-called **Airtours** criteria should be revised?'

1.13 Next, we summarise our main findings and policy implications from Chapter 3 on empirical estimation of market power and firm conduct, from Chapter 4 on price pressure indices when firms have conjectural variations and from Chapter 5 on coordinated effects when firms account for their rivals' reactions.

Empirical estimation of market power and firm conduct

1.14 Competition authorities often wish to assess the degree of competition in an industry. Typically, this assessment is based on qualitative evidence. In certain cases, notably hardcore cartels, such evidence can lead to a straightforward finding: for example, the FBI videotapes of the lysine cartels were incriminating evidence. In other cases, the evidence is not clear cut. For example, information exchange between competitors may increase transparency on the market; however, it is not straightforward to determine whether the degree of transparency has become sufficient to sustain a collusive price level. Often such findings are based on judgment calls, even if the competition authority thoroughly investigates the economic conditions on the market as well as the characteristics of information exchanged. In this report, we discuss how empirical methods such as those based on conjectural variation models could help assess the extent to which firms are coordinating their commercial strategy to elevate prices above competitive levels.

1.15 The field of industrial organization has shown a long lasting interest in the development of empirical techniques (i) to gauge the degree of market power, and (ii) to identify the existence of collusive behaviour. This report will focus on the contribution of conjectural variation models to this literature, and in particular on how these models have been applied to achieve these two objectives.

1.16 The application of conjectural variation models, which is typically restricted to homogenous product industries, consists in estimating a parameter (a 'conduct' or a conjectural variation parameter), whose value indicates the degree of market power that is exercised in the market: the higher the value, the greater the degree of market power. There are two main methods to estimate the conduct parameter:

- When data on marginal cost, the price-elasticity of demand and market shares are readily available, the analyst can compute the elasticity-adjusted Lerner index (EALI).

- Alternatively, the conduct parameter, which belongs to a firm or industry supply relation, can be estimated along with a demand system using appropriate econometric techniques (this is termed the Conduct Parameter Method (CPM)).

1.17 In the last decade economic research has explored other avenues – the so-called 'menu approach' – to identify empirically firm conduct, and in particular, to assess whether firms collude. Using econometric techniques, the analyst estimates a series of economic models, and ranks the models according to which one best fits the data. Because each model assumes a specific type of firm behaviour, the 'winning' model indicates the conduct that is most consistent with the prevailing price level.

1.18 Before describing each approach in more detail, it is helpful to review the definition of market power. In economics textbooks, market power is described as occurring whenever firms set price above marginal cost.[4] This definition implies that market power is measured against the benchmark of perfect competition. This is a theoretical case in which price equals marginal cost, there are no barriers to entry, and economic profits are competed away.

1.19 In reality, by this definition firms hold market power in nearly all industries. Market power stems from a number of sources such as fixed costs, product differentiation, cost efficiency, or superior products or

[4] As this discussion emphasises, this refers to the treatment of market power in traditional economic theory. This differs significantly from the analysis of market power by competition authorities, in particular because the fact that prices are above marginal cost is not necessarily evidence of market power for the purpose of an antitrust or merger assessment. See for example the OFT Competition Act Guideline: Assessment of Market Power, December 2004, which describes how market power is assessed in relation to existing competition, potential competition and the strength of buyers.

service quality, to name but a few. Virtually all firms exercise some degree of market power. For example, when firms must recover prior investments and/or fixed costs of production, pricing above marginal cost may be necessary in order to break-even. As a result, competition authorities do not rely on the mere presence of market power as a guide for intervention, but typically require the existence of significant market power.

1.20 In addition, competition authorities rarely use perfect competition as a benchmark for determining the 'competitive' price level. For example, in relation to investigation of abuse of dominant position, the European Commission deems a firm dominant only if it is capable of profitably increasing prices above the competitive level for a significant period of time. Although it is never precisely defined, the competitive level could still involve some degree of market power. For example, in differentiated product industries, the competitive outcome involves firms setting price above marginal costs.

1.21 A finding that firms price above marginal cost is not sufficient to determine that competition is ineffective. For example, in markets with high fixed costs, the number of firms is limited by the profitability of entry. This is because firms only enter a market when the expected price level post-entry is sufficiently high to cover not only the variable costs of production but also the fixed cost of entry. Because market power is widespread, and its sources are multiple, it may be of interest to identify that part of market power that results from (tacit) collusion from that which results from other factors.

1.22 In principle, it should be straightforward to determine the extent to which a firm holds market power: it suffices to measure the wedge between price and marginal cost. In practice, however, this exercise is fraught with difficulties. In particular, accounting data often fails to provide a reliable measure of economic marginal cost, as a result, using these data can lead to inaccurate estimates of the price-cost margin.[5] More importantly for determining coordination, such a calculation reveals nothing about the cause of market power.

Estimating conjectural variations to directly measure firm conduct

1.23 An alternative approach, known as New Empirical Industrial Organisation (NEIO) relies on conjectural variation models to estimate firm conduct directly. A typical NEIO study estimates first a model of consumer demand to determine the extent to which consumers are sensitive to price changes (captured by the price-elasticity of demand). This is because consumer behaviour governs the ability of firms to raise price above marginal cost. If consumers are very price sensitive, (for example a large number of consumers stop purchasing the product in response to a price increase), firms in the industry are unable to exercise market power. As a result, the unit price-cost margin is small.

1.24 Second, the analyst also estimates a firm (or industry) supply relation in order to recover a value for the conduct parameter. This operation involves using the estimate of the price elasticity of aggregate demand. The value taken by the estimated conduct parameter tells the analyst about firm behaviour:

- when the conduct parameter is 0, the firm is perfectly competing, and price equals marginal cost
- when the conduct parameter is 1, the firm is competing, albeit it is imperfect competition as its price is set above marginal cost (for example Nash-Cournot competition), and

[5] Of course none of these difficulties are new or indeed specific to the use of conjectural variation models. Many of the price-cost tests used in abuse of dominance cases involve calculating some measure of marginal cost. Likewise critical loss analysis and unilateral effects calculations both involve calculating price-cost margins. Therefore whilst these difficulties must be taken account, it does not necessarily indicate that the analysis cannot be performed.

- when the conduct parameter is equal to the number of firms in the market, say N, the firm is (perfectly) colluding with its competitors.

1.25 This approach is appealing, and it has been applied to estimate both the extent of market power and firm conduct. However, there are a number of issues with its application that we describe in the following paragraphs.

1.26 First, the estimation of the conduct parameter is unlikely to result in any of the three outcomes presented above (perfect competition, Nash-Cournot and perfect collusion). For example, the analyst may estimate the parameter to be 0.6. Although this value does not correspond to any well defined behaviour, the analyst can conclude that firms are competing less vigorously than they would be under perfect competition (in which case the conduct parameter is equal to 0), but more intensely then they would be under Cournot competition (in which case the conduct parameter is equal to 1).

1.27 Alternatively, when the estimated parameter is equal to 2, taken literally this suggests that firms compete less aggressively that they would under Cournot competition. In a market with five firms, a conduct parameter that is equal to 2 also indicates that these five firms fail to achieve the monopoly outcome (for example they are not perfectly colluding).

1.28 It is important to bear in mind that when the conduct parameter does not correspond to any of the three outcomes listed above (for example perfect competition, Nash-Cournot and perfect collusion), the analyst must remain cautious in its interpretation. Indeed, when the conduct parameter takes the following hypothetical values, 0.6 and 2, these do not correspond to any economic model. In other words, it is unclear what these values exactly imply in terms of firm behaviour.

1.29 One way to deal with this issue consists in performing statistical tests to screen out any of the three forms of conduct described above. For example, if the conduct parameter is 2, and the test result shows that it is statistically different from N -- the number of firms in the market -- the analyst can rule out perfect collusion. And if the test shows that the parameter value is not statistically different from 1, the analyst cannot exclude that firms behave in a Nash-Cournot fashion. In other words, there is no reason to conclude that firms collude.

1.30 Second, the NEIO framework is more easily applied in homogenous product industries than in differentiated products industries. As a result, this approach has typically been used to study commodity-like products such as coffee, sugar, and electricity where the assumption that each supplier sells a product that is perfectly interchangeable with that of another supplier is not controversial. In this report we illustrate the application of the NEIO approach using the Genesove and Mullin (1998) study of the Sugar Trust in the US. Their study shows that industry conduct was closer to perfect competition than to collusion. This might be due to the threat of European imports, which prevented the Sugar Trust from increasing price above a certain level.

1.31 There are a number of practical difficulties in implementing the NEIO approach in differentiated products industries that we list below:

- The number of price-elasticities to be estimated increases more than proportionally with the number of products. Whilst in homogeneous industry the analyst estimates a price elasticity, in differentiated product industries the number of elasticities can be very large. For example, in a 10-product market, there would be 100 elasticities. Although economic research has made significant progress in the analysis of demand in differentiated product markets, estimating these models remains a challenge. First, the data requirements can be substantial. To estimate even the simplest of models, the analyst needs data on the price and sales volumes of each product whilst richer models require data on product characteristics and consumer demographics. Second, given the number of elasticities the analyst has to estimate, she may have to make simplifying assumptions, which might restrict unreasonably consumer substitution patterns, and in turn affect the estimation of market power and firm conduct.

- The number of conjectural variation parameters in the supply relation is also very large. In principle, estimating these parameters is possible, in practice, however, it is hardly feasible. For example, in a market with 10 single product firms, each firm's supply relation contains 9 conjectural variation parameters, adding an insurmountable burden on the econometric estimation as the analyst must seek a corresponding number of instrumental variables.

1.32 Finally, Corts (1999) shows that the NEIO approach may fail to measure accurately market power, undermining also any inference about firm behaviour. The so-called Corts critique that we present in more details in Chapter 3 is a serious stumbling block for the application of empirical conjectural variation models to distinguish between non-collusive and collusive conduct.

The menu approach

1.33 The menu approach is an alternative method that the analyst can implement to assess the degree of market power and to identify firm conduct. One of the benefits of this approach is that unlike the NEIO approach it can be applied to differentiated products industries. Instead of estimating a conduct parameter, the menu approach considers a series of economic models, and each model assumes a specific type of firm conduct. The idea is to rank the economic models according to which one yields the market outcome that best fits the data. For example, in some cases the analyst selects the model that predicts a mark-up that most closely corresponds to the observed price-cost margin.

1.34 In the simplest application of the menu approach, the analyst may consider only two models. She estimates a model in which firms are assumed to compete as in a Bertrand-Nash game and a second model in which firms are assumed to perfectly collude so as to achieve the monopoly price level. If one model clearly fits the data better than the other, the analyst concludes that it is a more likely candidate to explain firm conduct. However, it is important to bear in mind that the model that best fits the data may not be the 'true' underlying model.

1.35 In practice, the analyst may specify an array of models to cover a range of conduct: single-product firm behaving as Nash competitor or Stackelberg leader, multi-product firms behaving as Nash competitor, firms colluding over a subset of products (partial collusion) and perfect collusion.

1.36 In summary, the menu approach to estimating industry behaviour follows a two-step process:

- **Step 1**: the analyst specifies a number of economic models, each of which assumes a specific type of firm conduct. Then the analyst estimates each model separately.

- **Step 2**: the analyst ranks the models according to how close they fit the data. Broadly speaking there are three methods that can be employed to select the 'winning' model.

  - First, the predicted outcome of each model can be **compared against observed counterparts**. For example, the analyst may compare predicted price-cost margins with observed price-cost margins. Naturally, the reliability of this approach depends in part on the accuracy of the observed margins. In particular, the use of accounting data may not provide an accurate measure of economic profit margin.

  - Second, the analyst may use **'natural experiments'** such as the introduction of a new product or a change in regulation to see which of the models best predicts the changes caused by this event. Naturally, this approach requires that such an event actually occurs and that data are available before and after the event.

  - Finally, the analyst can perform **non-nested hypotheses testing** to establish which, if any, of the models is best supported by the data. The implementation of this approach requires that the analyst also estimate a supply side relation as in the NEIO approach. In principle, non-nested hypothesis testing can be performed in all cases and in combination with the first two methods.

Concluding remarks

1.37 All of the methods described in this Chapter come with strengths but also weaknesses. In fact, all of these are based on static models of competition, whilst collusive conduct is best explained by taking into account repeated firm interactions. That these methods are imperfect is, however, not a reason to discard them. First, they can prove useful to explain and predict some of the observed market outcomes (for example the price level). Second, the empirical estimation of dynamic oligopoly models is still the subject of academic research, and more progress must be achieved before employing these models in competition policy investigations.

1.38 In investigations in which there is no clear cut evidence, we believe that competition authorities could employ the empirical methods described in this Chapter to measure the degree of market power and identify firms conduct. Obviously, in order to draw reliable conclusions, the implementations of these approaches must follow best practice. First, the model's assumptions should not blatantly contradict basic facts of the industry. Furthermore, the analyst should perform various sensitivity analyses to test the robustness of the results. Finally, the empirical results should be compared with other types of evidence. When the results and the qualitative evidence are inconsistent, both the assumptions that underpins the economic modelling that the analyst has adopted and the reliability and interpretation of the qualitative evidence should be carefully reviewed.

1.39 In homogenous product industries, calibrating the elasticity-adjusted Lerner index (EALI) or implementing the CPM may be useful policy tools for measuring market power. For example, EALI, which is simple to compute if the information is readily available, may be employed to form an initial view on how much market power is being exercised. A well understood difficulty with this approach is to find an accurate measure of marginal cost and the price-elasticity of demand. However, even if an accurate measure of the margin can be obtained, the analyst cannot perform a statistical test to rule out specific forms of behaviour.

1.40 With more data, the analyst may consider performing an NEIO study to estimate the conduct parameter. The CPM allows the analyst to test the conduct parameter against well understood static oligopoly models and avoid the measurement issues of the EALI components. In addition, there is no risk of mixing and matching economic measures that are not directly connected (for example combining the price elasticity of downstream consumer demand with the upstream firms' margins). However, the Corts' critique continues to cast some doubts about the reliability of the results.

1.41 In differentiated products industries, EALI and the CPM cannot realistically be applied. In these industries, the menu approach is better suited to investigate the source of market power, and in particular whether market power stems from product differentiation or from collusive conduct. It is worth noting that the menu approach can also be applied in homogenous product industries. Although this approach is appealing, it requires, however, a large amount of data and the use of econometric techniques. As such a competition authority may only be able to consider this approach in the course of an-depth investigation.

Unilateral effects – survey of price pressure indices when firms have conjectural variations

1.42 The second area in which CVs have been discussed is within the context of measuring unilateral effects of mergers. As we explain in Chapter 4, a price pressure test refers to the combination of data from the merging parties into a (usually) simple formula to predict (i) whether or not a merger is likely to cause a price rise (**for example** give rise to upwards pricing pressure) or (ii) whether upwards pricing pressure is of a magnitude sufficiently high to merit further, detailed investigation. The main inputs to price pressure tests are the percentage gross margins of, and the diversion ratios between, the merging parties. The use of price pressure tests has grown substantially in the UK Authorities' decision making over the past five years. It is based on the view that, in markets where products are differentiated, market share based screens are inappropriate because market shares may fail to capture the closeness of substitution between the products of the merging parties. In short, relative to market share based screens, the Authorities would view price pressure tests as being: (i) as easy for decision makers to understand; (ii) as straightforward to generate (usually) in terms of data requirements; and (iii) more informative in differentiated product (and in particular retail) markets.[6]

1.43 The most well known price pressure tests are upwards pricing pressure ('UPP'), the gross upwards pricing pressure index ('GUPPI') and illustrative price rise ('IPR'). Our research brief was to answer the very specific question of the extent to which the academic literature could inform policy as regards the use of conjectural variation parameters in relation to UPP. In particular, we were asked to consider the work of Jaffe and Weyl (2011).[7] This executive summary therefore focuses on that specific issue, although Chapter 4 discusses price pressure indices more generally.

Accounting for reactions by rivals in UPP

1.44 UPP is one way to capture the idea that if firm 1 (selling product 1) merges with firm 2 (selling product 2), the merged firm has an incentive to increase price (absent efficiency gains arising from the merger). Specifically, prior to the merger, firm 1 would not benefit from profits made on the sale of product 2. However, after the merger, a price increase by firm 1 is more profitable than before. This is because some units lost by product 1 will be gained by product 2. The value of those diverted units (evaluated at pre-merger prices and costs) equals the number of units switched from 1 to 2, multiplied by the absolute margin earned on product 2. The greater this amount, the greater the incentive to impose a post-merger price rise on product 1 (other things being

[6] Parker and Majumdar (2011), Section 12.7.

[7] The original brief referred to initial work by Jaffe and Weyl, a fore-runner to Jaffe and Weyl (2011). We are grateful to Glen Weyl and Sonia Jaffe for their comment on an earlier draft of this chapter, in particular, we have benefited from extensive discussions with Glen Weyl.

equal). [8] For a given margin on product 2, there will be greater upward pricing pressure the larger is the diversion ratio from product 1 to product 2. Measuring the diversion ratio, therefore, is an important part of this (and indeed other) price pressure indices. In a standard UPP context, the diversion ratio is measured holding all other prices constant at their pre-merger levels and assuming that firms do not take into account reactions by their rivals.

1.45 Jaffe and Weyl (2011) outline how conjectural variations can be incorporated into UPP tests, deriving a new measure for doing so, which they denote 'Generalised Pricing Pressure' or GePP. In particular, firm 1 is typically assumed to have a positive conjectural variation with regards to how it expects rivals to react to it changing its own price. That is to say, prior to the merger, it expects rivals to accommodate its price rise – it conjectures that it setting a higher price on product 1 will lead to its rival setting a higher price on product 2, and all other substitute products under consideration. This differs from the standard UPP test which assumes that rivals' prices remain constant at pre-merger levels.

1.46 Two effects have been identified. First, accommodating reactions, as explained in Chapter 2, softens competition between firms 1 and 2 relative to the case where firms do not take into account each other's reactions when setting price. Intuitively, with a positive conjectural variation, firm 1 expects to lose fewer units to firm 2 compared to the case where it expects firm 2 to leave its price unchanged, and this leads it to set a higher price pre-merger that it otherwise would. This means that the removal of competition between firms 1 and 2 post-merger (when considered in isolation) has a reduced impact on raising price: if pre-merger the two merging firms were not competing with each other very aggressively, this reduces the scope for loss of competition post-merger. Jaffe and Weyl denote this feature the end of accommodating reactions between the merging firms, it is a feature that reduces UPP (though the extent to which authorities may approve mergers on the

[8] A similar argument applies for UPP for product 2. For convenience, we shall refer to mainly to how the merger affects the incentives to set the price of product 1.

basis of what some may interpret as pre-merger tacit coordination is unclear).

1.47 Second, the inclusion of positive conjectural variations into a UPP test can also lead to increased estimates of pricing pressure. The mechanism is as follows. Firm 1 will consider how its remaining rivals (for example those other than firm 2) would accommodate any post-merger price rise on product 1, while the price of product 2 is held constant. A higher price on product 1 would, firm 1 conjectures, induce rivals to increase their prices. This means that firm 1 expects greater diversion from product 1 to product 2 (than in a standard UPP scenario) because rivals' products are more expensive (for example the relative price of product 2 vis-à-vis rivals' prices is lower compared to the case where rivals do not accommodate the price increase on product 1). Thus accommodating reactions by the merged firm's rivals increase upward pricing pressure.[9]

1.48 An interesting question, therefore, is which effect dominates: does the failure to take into account accommodating reactions bias the UPP measure upwards or downwards?[10] Does the end of accommodating reactions (which biases UPP upwards) dominate the impact of the greater diversion to the other merging party's product (which biases UPP downwards)?[11] In some (perhaps special) cases, it may be clear that one effect will dominate the other. For example, if (i) prior to the merger, firms 1 and firm 2 conjecture that each will accommodate the other substantially[12] and (ii) firm 1 conjectures that if it changed the price of product 1, the remaining other firms would not alter their prices (and

[9] The diversion ratio is higher than in the case where rivals firms are conjectured not to accommodate the price rise on product 1: increased diversion in absolute terms to product 2 raises the numerator, while fewer lost units on product 1 reduce the denominator.

[10] This assumes that reactions are accommodating – which need not be true.

[11] We discuss single product firms for simplicity, to retain the intuition. Jaffe and Weyl (2011) extend their analysis to multi product firms.

[12] As would be the case, for example, if firm 1 conjectured that firm 2 would exactly match any change in price (so that the conjectural variation term equals 1), and vice versa.

likewise for firm 2), then UPP will overstate the predicted price rise. In that case, UPP would fail to capture the end of accommodating reactions term. However, in general, one might presume that standard UPP tests do not systematically overstate or understate the measure of implied price pressure that would arise from a GePP test, which is a useful insight for practitioners.

Implementation of GePP

1.49 Implementing price pressure tests requires, at a minimum, an estimate of the mark up over marginal cost and the relevant diversion ratio. The former is discussed in Chapter 3 and so we do not discuss this in detail here. The latter can be estimated by a range of techniques, and commonly by using survey data.[13] In theory, a survey question can be designed to capture any form of diversion ratio – whether holding prices constant or not. In practice, of course, doing so may involve the design of complex questions that are hard for respondents to answer accurately.

1.50 Jaffe and Weyl (2011) argue that if firms employ consistent conjectures (such that they accurately conjecture how other firms respond to their price rises) then real-world data on switching may, in principle, allow pre-merger conjectures to be estimated.[14] If conjectures are not consistent, estimating them is substantially more difficult. In either case, we consider that it is probably not achievable to estimate conjectures

[13] For a history of the use of diversion ratios and margins in UK merger control see Parker and Majumdar (2011), Chapter 12.

[14] The problem remains though that we would not know 'where the conjectures come from', meaning that it is hard infer how conjectures would be impacted by the merger. Put another way, if conjectures are consistent, we may know how firms would respond to one another in the pre-merger world but, given that the merger will result in a structural change in the industry, this may not provide an accurate guide to how they would respond post-merger (so even if we know that conjectures remain of the same sign, their magnitude may change). Further, consistent conjectures do not always give rise to an equilibrium (see Chapter 2).

sufficiently robustly in time to act as a screen at Phase I (or even at Phase II) of a merger investigation.

1.51 Jaffe and Weyl also note that it may be possible to implement GePP in a more informal manner if estimated diversion ratios incorporate firm conjectures, which would also have the advantage of not relying on an assumption of consistent conjectures.[15] However, they caution that great care must be taken in adopting such an approach because simply using these estimates in a standard UPP test risks 'mixing models', **for example** in principle an end of accommodating reactions term should also be considered if conjectures are likely to have impacted on the observed diversion ratio, otherwise the measure risks being inconsistent and biased upwards.

1.52 Jaffe and Weyl (2011) also outline two simplified versions of their GePP expression which they highlight may be of more use to practitioners. While these two measures are indeed both far easier to implement in practice than the general form, we highlight that the simplifying assumptions are somewhat restrictive and so their use would need to be dependent on a careful examination of how accurately these reflect the characteristics of the market in question. That said, we note that in practice the use of illustrative price rise screens may also involve strong simplifying assumptions (such as imposing symmetry of percentage margins and diversion ratios). This highlights a common theme of price pressure screens – implementation requires simplification. A key question is thus whether the simplified GePP approach performs better in terms of other equally implementable measures in acting as a screen for mergers giving rise to unilateral effects.[16]

1.53 Finally we discuss the fact that, even when the available data is such that practitioners must stick with the standard UPP approach, Jaffe and

[15] Though note that the observed diversion ratio would not precisely be the appropriate GePP diversion ratio as the price of product 2 would not be held constant.

[16] We leave aside the more fundamental question of how much weight should be placed on price pressure screens – **for example** to what extent does the scope for measurement error and unrealistic assumptions mean that these measures are not fit for purpose?

Weyl's work is useful in highlighting the qualitative conditions under which it may tend to overstate or understate true pricing pressure. For example, if the evidence suggests that there is a lot of accommodation between the merging parties, but yet relatively little from third party competitors, then standard UPP may overstate GePP and therefore inflate the prediction of upwards price pressure.

1.54 Ultimately the approach adopted should be informed by all of the evidence available and the nature of the market in question. It may turn out that the industry conditions (or available data) favour a different approach – be that a more formal merger simulation, a fascia screen (for example, asking the question 'is it a four-to-three merger or worse?'), or a combination of all three.[17]

Possible extensions

1.55 Price pressure indices are subject to the well-known critique that they fail to consider the supply side responses of rivals (such as product repositioning and new entry) which may be critical in shaping the post-merger outcome.[18] In principle, conjectural variation parameters could provide a short-cut to modelling these dynamics and thereby make these analyses more complete and therefore accurate. Firm 1 might conjecture, for example, that a potential competitor setting an infinite price (**for example** not currently active) would lower its price substantially (**for example** enter the market) in the event that firm 1 raised its price. If so, the firm conjectures that the rival does not accommodate its price rise – but the reverse (**for example** a negative conjectural variation).

[17] Joe Farrell (speaking on 17 March 2011 at the BIICL Annual Merger Conference, London) has argued that when different screening methodologies indicate contrasting approaches to intervention, the answer is not to choose one method over the other *a* **priori**, but to look more deeply into the industry and the available information to understand why each measure gives a different result. The screening rules can then be re-assessed after that process of probing further.

[18] Of course, this critique applies to other screens too (such as market share based screens), which is why the assessment of supply side responses is normally considered as a separate, but nonetheless important, stage in the analysis of competitive effects.

Alternatively, firms may form conjectures about rival responses as regards non-price parameters (although modelling this feature could soon give rise to a 'dimensionality' problem, because the combinations of conjectures each firm would hold with respect to each of its rivals rises exponentially with the total number of parameters of competition). The inclusion of conjectures on non-price responses may significantly hinder the implementation of the approach as a screen.

1.56 Further screens (including combinations thereof) are an interesting area for future research. That said, we advocate caution in the use of pricing pressure indices **alone**. They are best viewed in conjunction with (and weighed in the round with) the broader set of quantitative and qualitative evidence that the Agencies assemble during a merger investigation.

Concluding remarks

1.57 Rather than presume a conjectural variation parameter, one might try to model (or at least better understand) the dynamic game. Though in many cases this may be a difficult exercise, it may at least be possible to shed some light on the processes which impact on market outcomes over time. Moreover, if the issue is to assess the impact of the merger, it is better to try to identify the dynamic nature of competition (and how the merger may affect that process) than to avoid that analysis by condensing the dynamics into a single parameter, which, as set out in Chapter 3, may be difficult to estimate.

1.58 In defence of the conjectural variations approach, Jaffe and Weyl have argued that unilateral effects can be thought of as the impact of a merger holding conjectures constant and coordinated effects as the impact of a merger when it leads to a change in conjectures.[19] However, whatever the terminology employed, if pre-merger conjectures are important to take into account, it seems reasonable to ask how they might change as a result of the merger. Unfortunately this is not

[19] Jaffe and Weyl (2011) note 'we only consider the unilateral effects of a merger: the change in incentives holding fixed the strategy space and conjectures. It would be natural to add coordinated effects, changes in the strategy space and conjectures'.

straightforward. We note in Chapter 2 that one of the theoretical difficulties of conjectural variation models is that they do not address the question: where do the conjectures come from? Without this information, it is hard to predict if and how the merger is likely to change the conjectures that firms hold. In Annexe A.2 we outline a simple modelling exercise which examines how accurate a static calibrated conjectural variations model is at predicting the price increase that will result from a merger in a market which is actually characterised by dynamic (Stackelberg) competition. We find that, in this particular example, the CV model would overestimate the actual price increase by 50 per cent, which serves as a caution about the use of simplified CV models in contexts where the true form of competitive interaction is actually dynamic in nature.

1.59 In summary, we await with interest further screens to be employed in the analysis of unilateral effects, which seek to add more realism. However, we are concerned that trying to condense complex strategic interactions into one or a few measures risks failing to account properly for the richness of real-world competition if too much weight is placed on them. We emphasise that the aim of UPP was to establish a simple initial screen that is better than a market share screen for horizontal mergers involving differentiated products. It does not purport to be an accurate predictor of the competitive effects of a merger or a screen that trumps a detailed investigation of the strength of existing competition, potential competition and buyer power.

Survey on coordinated effects when firms account for their rivals' reactions

1.60 In Chapter 5, rather than stick slavishly to the textbook definition of a conjectural variations model, we instead consider a different issue 'in the spirit' of conjectural variations – with particular reference to coordinated effects. That is to say, even if conjectural variations models themselves are subject to criticism, the underlying issue of 'modelling how firms react to changes in their rivals' actions' remains valid. With that key issue in mind, we move beyond a simple conjectural variations approach and examine how the economic literature has modelled competitors responding to each others' actions in a selection of dynamic games, **for example** games that are repeated over time thereby allowing firms to observe their rival's output in one period and react to it in a later period. We do this with reference to specific papers identified by the OFT for our review. In particular, we consider the implications of these papers for the analysis of coordinated effects by asking: 'to what extent do the theoretical models considered lead us to think that the so-called **Airtours** criteria should be revised?'

1.61 As outlined in the new OFT/CC Merger Assessment Guidelines, three cumulative conditions must hold in order for coordination to be possible, which are essentially the so-called **Airtours** criteria:

- firms need to be able to reach and monitor the terms of coordination
- coordination needs to be internally sustainable among the coordinating group, and in particular there must be adequate deterrents to ensure there is no incentive to deviate from the agreement, and
- coordination needs to be externally sustainable, in that there is little likelihood of coordination being undermined by competition from outside the coordinating group.

1.62 We discuss the first two criteria in this chapter which are essentially 'alignment' (agreeing on the coordinated strategy) and 'internal stability' (monitoring deviation quickly enough, and punishing deviants sufficiently greatly, so as to deter deviation). As is well-known from textbook models of coordination, firms weigh up the present value of profits obtained from coordination versus those arising from deviation and subsequent punishment. Thus a consideration of rival responses is a central part of the current approach to analysing coordinated effects; a potential deviant explicitly considers how rival responses to its deviation will result in reduced profits in the future. Nonetheless, an interesting question is whether recent (or neglected) research into competitor reactions has thrown new light on factors that may sustain coordination.

1.63 We do not discuss the third **Airtours** criterion (external stability) in Chapter 5. Ultimately the coordinating group seeks to act as if it were a firm with substantial market power and so it is essential to take account of remaining 'existing competition', potential competition and buyer power. In principle, the coordinating group (and its members) may form conjectures as to the strength of the competitive fringe, the likelihood of new entry, or the ability of buyers to act strategically to undermine the scope for coordination by, say, self-supply. For example, coordination might be more harmful if the coordinating group conjectures that the so-called fringe would accommodate any price rises achieved through coordination (or less harmful if the fringe were expected to respond with an aggressive price cut in the event that a coordinating group sought to increase prices). However, we do not consider these issues further as they are beyond the scope of this report.

1.64 Instead we consider the implication for alignment and internal stability that arises where (i) firms use continuous (but 'soft') punishment strategies; (ii) punishment is instantaneous; and (iii) firms have alternating reactions (taking it in turn to react to each other's change in price or quantity).

Continuous punishment strategies

1.65 One potentially significant limitation of standard coordinated effects analysis is that it assumes that even tiny deviations are met with extremely harsh punishments – for example, grim trigger strategies. In other words a rival would face the same degree of punishment from undercutting the agreed upon price by a single penny as if it undercut it by a large amount, even though the former may have yielded very little gain to the rival (with differentiated products) and/or had negligible effect on the punishing firm – the punishment is **discontinuous** in the degree of deviation. More informally, it can be said that 'the punishment does not fit the crime'. Friedman and Samuelson (1994) note this very point: 'in many circumstances, strategies associating severe penalties with arbitrary small deviations are implausible'. The assertion here is that some forms of punishment, while valid in theory, are unlikely to occur in practice.

1.66 It is arguably more 'realistic' to assume that firms react more to greater deviations from an agreement, so that the size of the punishment increases with the magnitude of the deviation. This does not suggest amending the **Airtours** criteria – punishing deviants remains relevant; rather it leads us to consider whether weaker forms of punishment may sustain coordinated outcomes and the policy implications thereof. For example, with 'softer' punishments, we might ask whether coordinated outcomes are **easier to reach, but less harmful when reached** (compared to those implied with discontinuous punishments). Intuitively, it might be argued that:

- Since successful coordination requires firms to agree on the punishment phase, a simple (more obvious) punishment strategy may be easier to communicate.

- **Given alignment**, softer punishments may entail coordinated prices that lie substantially below the maximum price that could be sustained for a given discount factor where more 'optimal' (but less realistic) punishment strategies are employed. Specifically, if continuous strategies give rise to weaker punishments, then another way to limit the gains from deviation is required (for any given discount factor). This could potentially be achieved by lowering the coordinated price or otherwise making the terms of coordination less profitable (when adhered to by all).[20]

1.67 Linking this to the research project in hand, continuous punishments could be considered in terms of being conjectural variations, as they entail firms considering the responses of rivals if they deviate from a

[20] Though note that a complexity arises from the fact that a reduction in the collusive price reduces not only the profit from deviation but also profit earned during the collusive phase, and so the effect of this on overall stability is not clear cut. In the context of Lu and Wright's (2010) model, they find that tacit collusion requires firms to be more patient to sustain a given collusive outcome under price-matching punishments compared to traditional Nash reversion. This reflects the fact that under price-matching punishments, a defecting firm can always set the same price as it would in the standard analysis, and face a smaller punishment given that rivals simply match its price rather than further undercut it.

coordinated arrangement as being proportional to the size of the deviation they make. Early research into this topic by Stanford (1986a), which restricted attention to strategies for firm **i** that were a function of its rival's actions in the immediately preceding period, suggested that coordinated outcomes could **not** be supported in a continuous punishment framework (where firms have a memory that extends only one period back), a finding that could potentially have had significant implications for coordinated effects analysis.

1.68 However, later work by Samuelson (1987) and Friedman and Samuelson (1990, 1994), which allowed for strategies that depended on both firms' actions in the preceding period, ultimately showed that such a restriction to continuous reaction functions imposes essentially no limitations on the set of prices that can be supported in equilibrium. This is reminiscent of the 'problem' of multiple equilibria associated with the folk-theorem underpinned by discontinuous punishment strategies. In that case, the issue is 'too much' scope for coordination meaning that **alignment** on the coordinated strategy becomes the critical hurdle to overcome. Interestingly, Friedman and Samuelson (1990) suggest that continuous strategies make more sense when firms are not able to communicate with each other explicitly on mutually beneficial behaviour, whereas they indicate that discontinuous strategies make more sense if firms were somehow able to engage in discussions prior to making their strategy selections (as this provides greater scope to make clear the explicit discontinuous threat involved).

1.69 Recent work by Lu and Wright (2010) has considered a very simple example of continuous punishment strategies in the form of **price-matching** punishments – if firm 1 lowers its price, then firm 2 will match that price (within certain bounds). Although such an approach has less generality than some of the preceding literature, it makes the major contribution of examining this issue in a far less complex setup. While they do not explicitly model how each firm comes to understand that the other will match its price, they find that coordinated outcomes may arise with these (simple) punishment strategies, although the monopoly outcome is not sustainable. The finding is important in demonstrating that coordinated outcomes can, in theory, emerge with punishment strategies that are commensurate to observed deviations rather than those employing a grim trigger Nash punishment strategy (**for example** where punishment entails reversion to the one-shot outcome with zero conjectural variations forever). However, for policy purposes, it remains the case that alignment is a puzzle – how do firms actually align on a price matching strategy, can they do so without explicit communication, and how much symmetry is required in order for price-matching strategies to be sustainable?[21] Lu and Wright suggest informally that alignment could arise by signalling, for example, by public statements that firms will match each other's prices, or perhaps through trial and error.[22]

1.70 An interesting takeaway point from Lu and Wright's model is that coordination may be less likely to entirely break down than previously thought, as following a deviation firms may still carry on coordinating, simply to a lesser extent. For example in the case of Lu and Wright's price matching punishment, if a firm undercuts the coordinated price but still charges above the level that would emerge from outright competition, then in the following period prices will still remain above the competitive level. This may, in part, address a standard critique of textbook models of coordination, the issue of renegotiation: if punishment strategies are very harsh, it may be that the punishment phase is not credible because (if it occurred) firms could renegotiate and move to a better equilibrium with higher payoffs. With weak punishments, however, it may be that the scope for renegotiation does not undermine the threat of being punished.

[21] See in particular the discussion of pricing conjectures in Chapter 2.

[22] We note for completeness the separate literature (outside our research brief) that seeks to resolve commitment to strategic responses through binding contracts with customers. Firms could be committed to price matching through their written policy otherwise, they would (say) be guilty of false and misleading advertising. 'Meet or release' clauses are another form of contractual commitment. Here, a firm essentially communicates to its rivals that it will be a second-mover if there is a deviation. It does not need to signal this because it is built in to its contract, given that all can observe this part of the contract.

1.71 In terms of the implication for observed prices, we note that continuous punishment strategies in this setting imply a high degree of correlation in (lagged) prices – one firm's price change being matched in the next period by the other. However, it is well known that where prices move together this need not be caused by coordination between firms and instead may be explained by numerous other factors (such as common cost shocks, common demand shocks or the simple fact that the goods are substitutes – **for example** as the price of one good rises, demand increases for the other inducing a price rise).

Speed of punishment

1.72 Preceding the work of Lu and Wright (2010) is an older literature which considers outcomes when deviations from a coordinated arrangement are met with retaliation that is effective **immediately**. Essentially, such instant responses mean that the firm which cheats on the agreement never achieves enhanced deviation profits as competitors effectively move straight into the punishment phase, so that even in the period of deviation itself reduced profits are made. This literature can be thought of as in the spirit of a conjectural variations approach which implicitly models rivals as responding immediately to a firm's changes in price or output – an expectation of price matching can be thought of as a conjecture by firm 1 that its price cut is exactly matched by its rival. As one may expect, in such cases coordination can be found to be highly stable – deviation profits are ruled out almost by assumption.

1.73 This literature captures instantaneous price-matching strategies (where a deviant's price cut is matched instantly) as well as some of the literature on kinked-demand curves. In the latter case, firms take the view that demand is highly elastic above the prevailing price and inelastic below the prevailing price, although such a perception can be hard to derive in theory without quite specific assumptions. With kinked-demand curves if firms start off at the collusive price, such a price should be quite stable, although the issue of how they arrive at that price is less clear in the literature and would seem to require some form of communication. For example, perhaps firms can test out different prices and see how the rival responds, without sales being made at those prices (as is implicitly the case in Bhaskar 1988, 1989). Hviid and Shaffer (1999) examine a specific case of price matching and show that there are multiple collusive equilibria, and with symmetry the monopoly outcome is the obvious focal point.

1.74 We emphasise that these findings do not suggest any limitations in the standard approaches used by practitioners towards examining coordinated effects concerns, as outlined above. Rather, we highlight that the issue raised here is effectively already covered by the second **Airtours** criterion, which considers the strength of the punishment mechanism available to rivals of a deviating firm. The case of **instant** price matching is simply a particular example of a highly effective monitoring and subsequent punishment mechanism. It is a standard result that the shorter the delay in detecting and then punishing deviation, the less likely that cheating occurs (for a given discount factor). Instant punishment is simply an extreme version of this – there is no delay to detection at all. At the other extreme we have one-shot games (which can be thought of as an infinitely long delay in terms of punishment), in which coordination cannot be sustained.

1.75 In terms of policy prescriptions, one insight is to re-affirm the substantial importance of **monitoring***.* Coordination requires that firms have sufficient ability to monitor how their rivals price (or otherwise stick to the terms of coordination) so as to be able to punish deviants (whatever the precise form of punishment adopted). Put simply, a price-matching policy is bound to fail if rivals cannot accurately observe each other's prices (and thus cannot match them). The implication of contractual commitments is also potentially important, to the extent that these can give rise to credible commitments to rapid punishment in situations where other conditions indicate that coordinated outcomes could be sustained. A further insight is that focal points and punishment strategies need not be sophisticated or discontinuous, they can be quite simple and still support coordination (provided that they are well understood – a feature made easier by their simplicity). However, the absence of an optimal punishment strategy may render coordinated outcomes less harmful.

Alternating move models giving rise to supra-competitive prices

1.76 Finally, we turn to alternative ways that give rise to prices that exceed those predicted by a one-shot, simultaneous move game but which do not rely on the textbook coordination framework of alignment, monitoring and punishment. In the previous section, reactions are assumed to take place instantaneously. This assumption seems extreme for most settings. The repeated game literature discussed earlier does not suffer from this criticism because at least one period must go by before reactions can occur, by the time rivals can react, the initial deviating firm is already assumed to be making its next move. This feature is, of course, a consequence of firms making their choices simultaneously, a setting that is arbitrary although convenient for analytical modelling. Perhaps a more natural environment in many real-world contexts is the case in which firms can react to their rivals' actions while these actions are still in effect — though only after some lag (**for example** not instantaneously). The idea is that firms generally commit to a certain action and rivals may be able to respond while the firm is still committed. This gives rise to a study of tacit collusion in alternating-move games. To the extent that this approach is a more natural and realistic description of how firms respond to one another's actions in practice, it is of interest to practitioners to consider any implications this modelling approach has for coordinated effects analysis.

1.77 We discuss a series of seminal papers by Maskin and Tirole (1987, 1988a and 1988b). Of particular interest in terms of providing an alternative approach to generating supra-competitive prices in repeated games is a paper by Maskin and Tirole (1988b), who conclude (comparing their approach with the standard repeated game literature employed to model coordinated outcomes): 'the strategies in the supergame literature typically have a firm reacting not only to other firms but to what it did itself. By contrast, a Markov strategy has a firm condition its action only on the other firms' behaviour. Thus, **in a price war, a firm cuts its price not to punish its competitor (which would involve keeping track of its own past behaviour as well as that of the**

competitor) but simply to regain market share. It strikes us that these straightforward Markov reactions often resemble the informal concept of reaction stressed in the traditional I.O. discussion of business behaviour (for example, the kinked demand story) more closely than do their supergame counterparts'.[23] The interesting point here is that Maskin and Tirole seek to model a case where a firm rationally anticipates that its own price cut will be matched to some degree by its rival's price cut – but not because the two firms are explicitly colluding or even because they have communicated with each other at all. So while competition may be dampened compared to the case where a firm takes a more short term view that fails to take into account its rival's response, this does not of itself imply that there is any form of anti-competitive behaviour or what can reasonably be termed **coordination**. For this reason, the analysis raises the important question of what the competitive counterfactual should be – why, for example, should firms be expected to behave as if they did not take into account their rivals' reactions – is such a benchmark realistic?

[23] Emphasis added. Maskin and Tirole (1988b) demonstrate not only how fixed (**for example** 'focal') price equilibria may arise, but also how Edgeworth cycles occur. In both cases firms are assumed to move in sequence, they are also presumed to choose prices from a discrete grid (for example prices can be in pounds and pence but there is no scope to charge in smaller units such as one half or one quarter of a pence). Where discount factors are low enough, an Edgeworth cycle may arise. Intuitively, starting from a high (above monopoly) price, firms undercut each other (winning the whole market) in sequence until the price falls so low that the next firm to move would rather restore the high price than undercut further and win the whole market at an even lower price. Prices then 'jump' up to the high price and the undercutting process starts once again. In contrast, the focal price outcome arises where firms are sufficiently patient, in this case the anticipation of the off-equilibrium undercutting process is sufficient to 'deter' a price cut. In Markov games, it is not really appropriate to think in terms of punishment strategies in the typical 'Airtours criteria' sense (**for example** price cuts are not punishing deviation from a prior agreed strategy). Rather, firms rationally anticipate the future consequences of their actions and see that price cutting today would lead to some amount of price cutting in the future as rivals attempt to win back market share. We note that neither the focal point nor the Edgeworth cycling equilibria are necessarily 'coordinated' outcomes (especially where the firms involved do not communicate with each other, as we discuss below).

1.78 The alternating-move game literature is complex which makes general results hard to obtain and, like the supergame literature, gives rise to a multiplicity of equilibria – although Maskin and Tirole (1988b) show that only the monopoly outcome is renegotiation-proof in the context of their duopoly model with homogenous goods.

1.79 Multiple equilibria are also found in alternating-move games with product differentiation. Eaton and Engers (1990), for example, identify a 'spontaneous' equilibrium in which undercutting is not profitable even though it is not followed by further undercutting (and so the fear of a price war is not what deters undercutting). They also identify 'disciplinary equilibria' where undercutting by one firm is deterred by the expectation that the other would undercut further in an attempt to win back market share. The former are more likely to arise where product differentiation is substantial, while as products become closer substitutes disciplinary equilibria appear more likely.

The notion of the competitive level, coordination and multiple equilibria

1.80 The preceding discussion of infinitely-repeated games (**for example**, supergames) and alternating-move Markov games highlights a common theme: multiple equilibria. In this context, the notions of 'coordination', 'the competitive level', and whether accommodating conjectures are per se harmful are worth discussing briefly.

1.81 The competitive level can be thought of in several ways and some ideas are only briefly discussed here as they are beyond the remit of this report.

1.82 First, the competitive level could be thought of as the outcome in a one-shot simultaneous move game where firms do not have conjectural variations. This is the typical textbook approach. However, a standard result is that in an infinitely repeated simultaneous move game, any range of prices can be sustained between the one-shot outcome (for example the price obtained if the game is played once) and the monopoly price, provided firms value profits earned in the future sufficiently highly.

Textbook theory says that prices above the one-shot level can be sustained in repeated games. Firms may ignore short term deviatory gains from undercutting the 'collusive' price because they fear that deviating would lead to a punishment (for example a lower price for a certain number of time periods in the future) that is sufficiently great such that the present value of profit from sticking to the 'collusive' price exceeds that from deviating today and then being punished in subsequent periods. Against that benchmark, a coordinated outcome is arguably any outcome (even if just one penny) above the price that would emerge in a game played just once. Of course, from a policy perspective, to claim that to price a tiny amount above the one-shot level is a coordinated outcome might well be undesirable – thus **there is a distinction between what economists might refer in theory as 'collusion' and what competition authorities and courts might consider to be collusion in practice.** This, in itself, is important to emphasise even before we turn to how conjectures enter the fray.

1.83 An alternative approach is to state that the 'competitive level' could be the best outcome for consumers of all the multiple equilibria of a repeated game. That is to say, a theme of this report is that dynamic models often give rise to many possible equilibria – some of which are better for consumers than others. It can be argued that if it is appropriate to model the competitive environment as a repeated game (for example because in practice firms do indeed interact repeatedly), it would be harsh on firms to expect them to behave as if the game were entirely different (**for example** one-shot) – as noted above, why should firms be expected to ignore the likely reactions of their rivals? In other words, **the fact that a firm may have a conjecture as to how its rivals will respond is not in and of itself anti-competitive, even if the conjecture is 'accommodating'.**

1.84 A third approach might be to consider the mechanism by which the ultimate equilibrium is reached. For example, even if the industry equilibrium is worse for consumers than another possible equilibrium, this may simply be a result of shocks to the environment in which firms compete, as opposed to any anti-competitive behaviour. On the other hand, if firms communicate with each other so as to ensure the 'system' in which they compete settles on a high-price equilibrium when a low-price equilibrium was also possible, it might be argued that such communication is anti-competitive. In other words, there is a distinction between outcomes (the ultimate equilibrium attained) and how they are attained (for example as a result of random shocks to the dynamic system or because firms have **communicated** somehow to ensure that a harmful outcome for consumers is reached). Applying this to the Airtours criteria, 'alignment' can be seen as important because it captures the idea that where multiple equilibria exist, firms may well need to communicate to arrive at equilibria that raise their own profitability at the expense of consumers. Thus, in relation to the research topic in hand, it seems important to make a distinction between firms being aware of (and conditioning their behaviour on) their rivals' likely reactions (which is not necessarily coordinated behaviour) and behaviour where **firms seek to shape their rivals' expectations to make them more accommodating,** for example via some form of communication (whether overt or not).

1.85 More generally, this serves to re-emphasise that coordination is not a simplistic binary concept, with perfect coordination on the one hand and perfect competition on the other and nothing in between. Neither is communication between firms a concept that is neatly divided into 'pro-competitive' and 'harmful'. It is beyond our remit to solve these (difficult) issues but we consider it helpful to distinguish between the existence of conjectures (not per se anti-competitive) and actions to make conjectures more accommodating.

Should the Airtours criteria to define 'coordinated effects' be revised?

1.86 Our research question was to consider whether, having reviewed these models, there emerges a good case to revise the three **Airtours** criteria. Our thoughts are as follows.

1.87 First, alignment remains important and under-researched in our view.[24] While **simple** punishment strategies may facilitate reaching the terms of coordination in the event that they are somehow 'easier' on which to agree, there remains the question of **how** firms come to agreement: can they do so without explicit communication?[25] Put another way, even if price matching policies can facilitate coordination, how do rivals align on pursuing such matching policies in the first place? Indeed even if the terms of coordination - such as price matching - are in some cases relatively simple, it still needs to be made clear how firms come to mutually understand what these terms are. In these instances public communication or commitment to such strategies may be an important factor.

1.88 Second, we have argued that the role of monitoring and punishment remain important in the theory of coordinated effects. While soft or instant punishment may facilitate coordination, it can nonetheless be understood in the standard framework of trading off profits from deviation and subsequent punishment against those gained by sticking to the terms of coordination. What the literature does suggest is that 'extreme' punishment strategies may not be required in order to reach some degree of coordination.

1.89 Turning to the final **Airtours** criterion, we note that the models that we have considered do not address external stability – they typically take as given that there is no external competitive force that would disrupt coordination. However, the standard competitive constraints (existing

[24] Academic research often overlooks the practical difficulties involved in alignment and simply examines whether coordinated outcomes are stable, taking it as given that firms can arrive at them in the first place.

[25] This is important because some research suggests that it may be difficult to reach a collusive agreement absent explicit communication. See Cooper, and Kuhn (2010) who find that laboratory studies on the role of communication and collusion suggest that explicit communication increases the likelihood of collusion. This research also shows the importance of explicit threats to sustain a collusive agreement – **for example** communicating on (say) a price is not sufficient; it is important to communicate on what happens if someone does not stick to that price (**for example** the punishment strategy).

competition, potential competition and buyer power) remain important in preventing the exercise of collective market power by a coordinating group, whichever way coordination is underpinned.

1.90 In our view, the preceding three criteria are cumulative. In contrast, one might view the following statement in the Department of Justice / Federal Trade Commission horizontal merger guidelines in the section on coordinated effects as suggesting that **neither** of the first two (alignment and monitoring/punishment) is required:

> 'Parallel accommodating conduct includes situations in which each rival's response to competitive moves made by others is individually rational, and not motivated by retaliation or deterrence nor intended to sustain an agreed-upon market outcome, but nevertheless emboldens price increases and weakens competitive incentives to reduce prices or offer customers better terms'.[26]

1.91 This statement may be interpreted in several different ways. The statement could relate to the idea that harmful outcomes may arise (whether one calls them 'coordination' or not) through focal point equilibria (see Maskin and Tirole, 1988b, quoted above) where firms rationally expect (or **conjecture**) that their rivals will accommodate their pricing behaviour even though there is no agreement as such that accommodation will occur.

1.92 This raises two issues worthy of debate. First, if, as a result of a merger, firms (i) 'arrive at' a worse equilibrium for consumers without any form of communication – say because the equilibrium is so 'obvious', and (ii) the equilibrium is underpinned by accommodating conjectures, it seems awkward to denote that outcome a merger **coordinated** effect. Of course, the fact that it is not labelled as a 'coordinated effect' does not make the merger benign. If for some reason a merger gave rise to a situation where a harmful 'focal point' equilibrium seemed very likely or one in which firm's conjectures became significantly more

[26] See http://www.ftc.gov/os/2010/08/100819hmg.pdf, pp. 24-25.

accommodating, this may be a reason to block the merger (whether under the terminology of 'unilateral' or 'coordinated' effects). That said, it is not immediately apparent how often such focal points would arise in practice as a result of a merger. In contrast, if firms were expected to reach that worse equilibrium through actively shaping their rivals' conjectures, then this case might indeed be best described as a **coordinated** effect.[27]

1.93 Second, it is worth drawing a link between this discussion and that described in Chapter 4. The impact of a merger where firms have accommodating conjectures has been considered by Jaffe and Weyl (2011) and is discussed in Chapter 4. We note there that Jaffe and Weyl have argued that unilateral effects can be thought of as **holding conjectures constant,** while coordinated effects would allow them to **change.** This reminds us of one of the themes in our report: where do the conjectures come from? If we do not know this, it is hard to predict how the merger will change them. Yet this question must be addressed in an analysis of coordinated effects if one is to use conjectures. The specific question of 'what makes conjectures change' is beyond our research brief. The papers that we have reviewed indicate (to us at least) that changing conjectures may require (additional) communication between firms. They also indicate that coordination is harder when firms are asymmetric (although it is beyond our remit to review the literature on the specific types of symmetry that may make coordination more stable).[28]

1.94 In our view, whilst the above may change the relative importance of each of the **Airtours** criteria, none of it renders the **Airtours** criteria as a whole irrelevant – it simply reminds us that there are alternative economic models that give rise to outcomes that are worse (from a customer perspective) than that predicted by a one-shot, simultaneous move game. The question, therefore, is whether the **Airtours** criteria

[28] See Kuhn (2008) for a recent contribution which assesses the factors that may (or may not) be important in the assessment of coordinated effects.

should be expanded to take into account insights from these arguably richer models. In that regard, we note that from the perspective of merger enforcement policy the key questions are: **how does a merger make it more likely that a harmful outcome would arise** (or how an existing harmful outcome would be made worse) and **can this theory of harm be substantiated to the appropriate standard?** In its current form the description of 'parallel accommodating conduct' set out in the quote above, does not clarify the policy approach as regards what types of mergers would be blocked on those grounds. Future US cases may provide further guidance on this although our personal view is that additional theoretical and empirical research is required before robust guidance can be provided. At this stage, therefore, it is not clear (to us at least) that the **Airtours** criteria which are the basis for assessing 'coordinated effects' should be amended. We are not denying the possibility that a merger could harm competition for reasons that are not neatly captured by standard unilateral effects or coordinated effects analysis. Rather we take the view that more work is needed before it is possible to provide **robust guidance** on how to assess the type of merger that would be harmful but yet not captured by the standard approach to merger analysis.

2 BACKGROUND[29]

Introduction to conjectural variations

2.1 Oligopoly models trace their roots to the seminal works of Cournot (1838) and Bertrand (1883). In Cournot's model, firms simultaneously choose quantities assuming their rivals' quantities are fixed. In Bertrand's model, firms simultaneously choose prices assuming their rivals' prices are fixed. In both cases, whether firms have 'Cournot conjectures' or 'Bertrand conjectures,' firms act as if their rivals' choices are fixed when they make their own choices.

2.2 Bowley (1924) was the first to introduce the notion of a 'reaction function' and the idea that firms might anticipate their rivals' reactions when making their choices. His model and those that trace their roots from it have become known as conjectural-variations models, where the term 'conjectural variations' was coined by Frisch (1933) to describe the slopes of the conjectured reaction functions. The concept pre-dates the introduction of game-theoretic models in economics, and is meant to capture a firm's belief or expectation about how its rivals would react to changes in its own behaviour. Although conjectural variations are generally discussed with respect to quantity setting games, and therefore consider how rivals' output levels will respond to changes in a firm's own output level, they can equally be applied to price-setting games and indeed situations where firms set other competitive parameters.

2.3 Different conjectures will typically give rise to different outcomes. In fact, one can in general obtain any outcome ranging from perfect competition to the monopoly price and quantity with appropriately chosen conjectures. For example, consider firm i that operates in a homogenous goods industry with n firms, and selects quantity to maximise profit; its profit function is given by:

[29] We are grateful to Greg Shaffer for extensive contributions to this chapter. Errors are our own.

$$\pi_i = q_i P(Q) - C(q_i)$$

where q_i is firm i's level of output, P is the market price which is a function of total market output Q and $C(q_i)$ is the total cost to firm i of producing its chosen level of output. As is standard, to calculate firm i's optimum quantity we maximise this profit function by taking the derivative of it with respect to its own level of output. However, with conjectural variations, when selecting what volume of output to produce in order to maximise this profit function, firm i also thinks about how its rivals' outputs will vary in response to changes in its own. Firm i's first order condition is therefore adjusted to incorporate a 'CV' parameter, and is given by:

$$P(Q) + q_i P'(Q)\left[\frac{dq_i}{dq_i} + \sum_{j \neq i} \frac{dq_j}{dq_i}\right] - C'(q_i) = 0,$$

2.4 Here we see the presence of $\frac{dq_j}{dq_i}$ terms which are not present in standard first order conditions – these relate to firm i's conjectures about how its rivals will adjust their levels of output in response to changes in its own level. Adopting the notation that $v_{ij} = \frac{dq_j}{dq_i}$ is firm i's conjecture about how each rival (that is, each firm j) responds to changes in its own quantity q_i, this can be rewritten as

$$P(Q) + q_i P'(Q)\left[1 + \sum_{j \neq i} v_{ij}\right] - C'(q_i) = 0,$$

2.5 Under symmetry, v_{ij} is the same for all firms, and the aggregate industry-level CV is $v = (n-1)v_{ij}$. The modified first order condition is given by:

$$P(Q) + q_i P'(Q)[1 + v] - C'(q_i) = 0.$$

2.6 In the context set out above, the value of the industry-level CV parameter (also called the 'conjectural derivative'[30]) can be linked to three distinct market equilibria: perfect competition, Cournot competition and collusion. This is explained as follows.

- When the aggregate industry-level CV parameter is -1, the industry participants act as if they are perfectly competitive.[31] In this case, each firm is effectively a price-taker because it conjectures that any change in its own output will be exactly offset by a change in the rivals' output, thereby leaving price unchanged.

- When the aggregate industry-level CV parameter is 0, the outcome corresponds to the Cournot outcome. In this case, each firm conjectures that its rivals will hold their output levels constant when it selects its own quantity level.

- When the aggregate industry-level CV parameter is $(n-1)$, an individual firm conjectures that any change in its quantity will be matched by all other firms so that market shares remain constant.[32] Intuitively, if firms are unable to change their share of the market then they will simply have an incentive to seek to maximise the overall profit pie that is jointly split between them. This therefore corresponds to the case where the industry participants act as if they were perfectly colluding to achieve the monopoly outcome.

2.7 Conjectural variations models have been widely criticised ever since they were first introduced. These criticisms generally fall into three categories:

[30] See Bowley (1924), Hicks (1935) and, in particular, the discussion in Martin (2002). The conjectural derivative differs from the conjectural elasticity adopted by Frisch (1933). Frisch modelled conjectures by assuming the elasticity implied by the conjectural derivative, **for example** $\frac{q_i}{q_j} \times \frac{\partial q_i}{\partial q_j}$, to be constant.

[31] In this case, under symmetry, the firm-level CV parameter, **for example** how firm i conjectures an individual firm j will respond to firm i's change in output, is equal to $\frac{-1}{(n-1)}$

[32] In this case, the firm-level CV parameter is 1.

- CV models are generally static models, so dynamic interpretations such as firms 'reacting' to each other's decisions are not appropriate. In these static games firms **simultaneously** choose output (or prices) and, moreover, do so just once. This is important: there is no scope for firms to respond to the actions of their rivals in the standard 'one-shot' models typically employed. Given the 'rules of the game' therefore, a conjectural variation of zero seems quite natural. Moreover, references to reaction functions, also known as 'best response functions', are somewhat misleading as firms do not react or respond to one another at all. Instead, best response functions are a theoretical concept used to aid in the identification of a Nash equilibrium.[33] This means that solutions to conjectural variations models are generally not Nash equilibria because firms base their choices on the idea that rivals will respond to their actions, when in Nash games their optimum responses would be based on the fact that there will be no such responses.

- In CV models, firms in equilibrium will typically be 'right for the wrong reasons'.[34] That is, even though the firms will correctly predict their rivals' output and/o**r price levels i**n equilibrium, they will

[33] By definition, equilibrium in one-shot quantity setting games requires that no firm would wish to change its output given the output choice of its rivals. Put another way, the choice of output by one firm is, in equilibrium, the 'best response' to the output levels chosen by its rivals. Equilibrium is thus determined where best response functions intersect.

[34] The quote is from Fellner (1949), who was among the first to argue that CV models were ad-hoc and generally inconsistent with rational firm behaviour out of equilibrium. Similarly Makowski (1987) makes a fundamental criticism that so called 'rational conjectures' are in fact based on entirely ad hoc assumptions. He highlights that in examining whether conjectures are rational the standard approach is to consider whether if the responding firm found itself at the candidate equilibrium it would wish to deviate; the absence of such an incentive is then taken as proof that the conjectures are indeed rational. However he highlights that even when this is the case it does not mean that ex ante, from a position where it was still pursuing its initial strategy, the responding firm's best response would actually be to move to this point – indeed he shows that in some cases it is not. Rather, in the standard analysis of rational conjectures this is a critical but entirely hidden assumption.

generally be incorrect about how their rivals would behave if they were to deviate from the equilibrium and rivals were given the opportunity to respond. In other words, firms' conjectures on how rivals would seek to respond to changes in their own behaviour generally are not equal to rival's best response functions, which describe how they would actually react to such changes. Consider a different example. Suppose that two identical quantity setting duopolists manage to achieve perfect collusion that is supported by a grim trigger strategy, that is, the understanding that should one firm deviate from the collusive level of output, the other will punish it forever by returning to the competitive level of output. To model this case in a duopoly CV game, we would assume a CV parameter equal to 1 (that is, one firm matches the output level of the other) so as to obtain the monopoly outcome. By adopting this conjecture we model (accurately in this case) the **outcome** of a richer dynamic game. However, the conjecture is incorrect. If deviation from the collusive output were to occur, this would not be observed until the next period – so the deviator could increase output without any response by its rival. Moreover, when the rival does respond, it will **increase** output and, knowing this, the deviator will **reduce** output (compared to the level it would choose when it deviates). In short, actual responses would not match conjectured responses.

- Third, CV models often give rise to a multiplicity of equilibria in which almost any outcome can arise. This may be undesirable from a policy perspective because it limits the predictive power of these approaches. However, this 'flexibility' of the CV approach can be useful in empirical settings.

2.8 As noted above, although conjectural variations are typically thought of in terms of quantity setting games, they can equally be used as a modelling tool in price setting games, or in principle also with respect to non-price parameters of competition. Price conjectures are discussed in more detail below.

Rationalisation of conjectural variations

2.9 The criticisms of conjectural variations discussed above appear to severely limit their usefulness as an approach to modelling competitive outcomes. In light of these failings researchers have examined various ways in which conjectural variations can potentially be placed on a firmer theoretical footing. In this section, we discuss five approaches that have been adopted in order to attempt to justify their use as a modelling tool:

- consistent conjectures
- CVs in the context of dynamic games
- CVs as a reduced form of a dynamic game
- CVs as evolutionary stable strategies, and
- CVs emerging from bounded rationality.

2.10 We consider each of these in turn below. We then turn to CVs and price-setting games.

Consistent conjectures

2.11 One criticism of CVs that we noted was that in general firms' conjectures about how their competitors would respond to changes in their own actions need not match rivals' best response functions, which describe how they would actually react. In order to address this criticism the concept of consistent conjectures was introduced, which required that a firm's conjecture about a rival's reaction must, at least in the neighbourhood of the equilibrium, equate with what the rival's actual response would be if there were changes in the firm's output (or other parameters of competition).[35] Such an approach arguably also has the

[35] Put another way, suppose that Firm A conjectures that a 10 unit increase in its output would induce Firm B to reduce output by five units. At equilibrium levels of output, it

advantage of addressing the third criticism of CVs noted above, that of a multiplicity of equilibria. This follows because a requirement that conjectures are consistent typically rules out the vast majority of possibilities. However, while Bresnahan (1981) shows that under certain conditions there is a unique Consistent Conjectural-Variations Equilibrium (CCVE), he also highlights the possibility that a CCVE may not exist at all.[36]

2.12 Applying this concept to a quantity setting game it emerges that the standard Cournot equilibrium is not a CCVE. This is because in the Cournot model firms take it as given that their rivals will not respond to changes in their own output level (because it is a one-shot static game), while in fact **if** rivals did have the opportunity to react then they would seek to respond to an increase in output by one firm by reducing their own outputs – output levels are typically 'strategic substitutes'.[37]

2.13 The fact that the Cournot outcome is not a CCVE raises questions about what is being assumed (implicitly) about the firms' information and rationality in a CCVE. As noted by Figuieres et al (2004), '... on what grounds should firm i believe the actual choice made by firm j depends on something firm j does not observe [**for example** firm i's output] and about which it has no information prior to making its choice'. Put differently, only the Cournot equilibrium in quantity-setting games is consistent with the assumptions of **complete information** and **common knowledge.** It follows therefore that '... for a conjectural variations equilibrium of any kind (consistent or not, but with non-zero conjectures) to make sense in this static framework it is necessary that either firms don't have complete information, or the common knowledge assumption is relaxed, or both possibilities. A third possibility would be that the

must be that if Firm A did deviate from equilibrium by increasing output by 10 units, Firm B would indeed reduce output by five units.

[36] The concept of consistent conjectures bears relation to firms competing in supply functions (price and quantity pairs), for example see Klemperer and Meyer (1989).

[37] As noted above, however, one might argue that the Cournot equilibrium is not really inconsistent as it is in fact a one-shot game where there is no opportunity for rivals to respond to each other's actions.

static model itself does not properly render the game situation at hand, and that a fully dynamic formulation would be preferable'.

Conjectural variations in dynamic games

2.14 We have highlighted the criticism that standard CV models are static games where firms are assumed to maximize single period profits, rather than being dynamic models, where firms maximize a discounted stream of profits over time and where they do actually have the opportunity to respond to the actions of their rivals. To address this concern a number of researchers have considered dynamic models featuring conjectural variations.

2.15 An immediate concern that arises in these models is whether equilibria which involve the use of dynamic conjectural variations would necessarily suffer from a credibility problem (as is the case with static conjectural variations).[38] That is, would such equilibria be subgame perfect. These models raise a similar question regarding whether such a dynamic conjectural variations equilibrium would suffer from a similar credibility problem, in particular whether they would be subgame perfect.

2.16 One of the first to address this issue and thus to provide to a dynamic formulation of CVs was Kalai and Stanford (1985). Their model considered an infinitely repeated game in which two firms select the quantities to produce of a homogenous product. They examine a set of strategies where each firms' output in one period varies linearly with the output of its rival in the **previous** period.

2.17 Kalai and Stanford note that there is a relationship between the notion of consistent conjectures in static games and subgame perfection in repeated games in the sense that both are credibility notions used to distinguish among multiple equilibria. In addressing this credibility issue, they introduce a framework which approximates immediate reactions by

[38] Recall that a static conjectural variations equilibrium is not a Nash equilibrium.

the firms to show that the strategies they consider exhibit strong credibility properties. Specifically, they have in mind a type of limit theorem which states that short reaction times ensure that the approach to subgame perfection can be as close as desired. They find this approach to be preferable to the assumption in conjectural-variation models that firms attribute instantaneous reactions to rivals in static, simultaneous-move games. Put another way, they consider firm i responding to a **prior** move made by firm j, but then shrink the reaction time such that i responds just after but almost at exactly the same time as firm j; in this way the authors **approximate immediate reactions.**

2.18 Given this setup they show, under the assumption of linear demand, that there is a whole range of equilibria corresponding to different conjectures, thus giving rise to a multiplicity problem similar to that highlighted earlier in static CV games. Put differently, in contrast to the findings of Bresnahan's (1981) work on consistent conjectural variations equilibria, all outcomes between the perfectly competitive and the perfectly-collusive outcome can be supported in equilibrium. However, when they restrict attention to subgame perfect equilibria, which eliminates non-credible outcomes, they find that the only equilibrium is the repetition of the standard Cournot outcome where firms do not respond to their rivals at all.

2.19 Kalai and Stanford also consider a technical alternative equilibrium concept to subgame perfection, perfect epsilon equilibrium, which requires that the payoff to a firm of playing its equilibrium strategy is within an arbitrarily small amount, ϵ, of what it could achieve by playing its best response.[39] The interpretation of this is that if the firms can react quickly enough to changes in the rival's output, then the adoption of conjectural variations strategies can have strong credibility properties. Using this equilibrium concept they show that, provided that firms can

[39] As discussed by Radner (1980) this can be justified as being relevant to situations where it may be costly for a firm to improve its strategy, as in such an equilibrium it would not be worth the effort of doing so.

react quickly enough to changes in their rival's output, it is possible to find credible non-Cournot Nash equilibria.

2.20 However, even here the multiplicity problem still arises, as any output between the competitive and monopoly levels can arise in equilibrium depending on the firms' conjectures. This raises a significant question that recurs throughout the literature on conjectural variations, which is how do firms form their conjectures in the first place, for example where do these conjectures come from? Why should one believe, for example, that it is plausible for firms to conjecture that their rivals will match them in output? If, for example, output is lowered, why would one not expect rivals to respond by raising their outputs, as is usual with downward-sloping best responses in quantity-setting games.

Conjectural variations as the reduced form of a dynamic game

2.21 One of the most widespread claimed justifications for the use of conjectural variations is that they can be interpreted as a reduced form of an (un-modelled) dynamic game, which may potentially be too complex to be considered directly. Two papers in particular have attempted to formalise this approach.

2.22 First, Dockner (1992) considers two firms playing an infinite horizon quantity setting game, they both produce a homogenous product and face a continuous rate of adjustment costs when scaling output up or down. Firms change output in each period until they reach a steady state (long run equilibrium), if one exists. Dockner finds that any subgame perfect equilibrium of this dynamic game can be viewed as a conjectural variations equilibrium of the corresponding static game.[40] Interestingly, the subgame perfect equilibria in Dockner's model give rise to outcomes that are **more competitive** than static Cournot competition. That is to say, while Dockner shows that a static model that incorporates conjectural variations may 'capture' the outcome of a dynamic game,

[40] More technically, Dockner considers steady state closed loop equilibria, which corresponds to the concept of subgame perfect equilibria.

this is only the case for conjectural variations that give rise to **non-collusive** outcomes. The intuition is that each firm takes into account its own current output and the reaction of its rival when determining future output. If rival j is expected to reduce output tomorrow in response to higher output by firm i today, then firm i has a greater incentive to expand output compared to a static Cournot model where firm i would **not** take into account the rival's reaction. This corresponds to negative conjectures in a static quantity setting model.

2.23 In summary, while unable to provide support for using conjectural variations to model collusive outcomes (**for example** unable to justify positive conjectures), Dockner nonetheless provides a dynamic justification for the use of static conjectural variations models with constant and symmetric (non-positive) conjectures. In particular, Dockner shows that by varying the discount factor (or the adjustment cost factor), while keeping demand and cost conditions constant, different steady state values may result, thereby justifying a range of (non-positive) conjectures.

2.24 Second, Cabral (1995) considers firms in a quantity setting game, and adopts a specific modelling approach where if a firm deviates from its designated quantity it suffers 'minmax' punishment by its rivals (in other words its payoff is reduced to zero for several periods). Cabral demonstrates the equivalence between the outcome of this dynamic game with a given discount factor and the outcome of a static CV model with a corresponding conjecture. He concludes that he has thus provided a justification 'for the use of the CV solution as the reduced form of the equilibrium of an (un-modelled) dynamic game'. However, Cabral's result only holds for the case of linear duopolies and for a particular class of equilibria of the dynamic game. Moreover, the value of conjectures that corresponds to plausible real-world discount factors do not appear to be reasonable. For example, a dynamic game where the next period's profits are given a weight of 50 per cent (alternatively, 90 per cent) compared to those in the current period corresponds to a static conjectural variations model with a conjecture of 2.7 (alternatively, 4.4).

2.25 Despite the limitations of both Dockner's and Cabral's models, it is interesting to note that Cabral is able to find collusive outcomes while Dockner is not. In turn, this relates to Dockner's use of **continuous** (Markov) strategies (where history of play enters the game only through the use of state variables, and so any 'important' history is captured in the value of the state variable in the most recent period). In contrast, Cabral is able to generate collusive outcomes through the use of a **discontinuous** trigger strategies (for example, whereby cheating would give rise to a 'jump' in output as a time limited punishment period ensues, after which output returns – via a marked downward shift – to collusive levels). The theme of whether collusion can be supported with continuous punishment is addressed in more detail below (see paragraphs 5.26 to 5.59).

2.26 Beyond these specific criticisms, we also note more generally that both of these papers rely on strong assumptions to derive highly specific conclusions with regard to the precise modelling setups which they consider. It is not at all clear that these results are robust to even small changes in the underlying assumptions (for example, a movement away from duopoly with linear demand), never mind providing a justification for a general broad-based conclusion that conjectural variations are an appropriate theoretical means through which to model dynamic games.

Conjectural variations as evolutionary stable strategies

2.27 More recent research has attempted to justify the use of consistent conjectures by considering the concept of evolutionary stable strategies. This considers a Darwinian process where different beliefs compete against one another, with a process of social evolution meaning that beliefs that yield more profitable outcomes become more common. This has some intuitive appeal in the sense that firms in the economy that are more profitable are more likely to survive and thrive, while those that are less profitable are more likely to go out of business. It may therefore be likely that those beliefs present in the long run are those which yield the most profitable outcomes for the firms in question.

2.28 Three recent papers that consider conjectures in this context are Dixon and Somma (2003), Muller and Normann (2005) and Possajennikov (2009). They all show that the only conjecture that survives the evolutionary process, and therefore constitutes the unique evolutionary stable strategy, are consistent conjectures – providing additional support for these as a modelling concept. The first two papers do this in the context of Cournot duopolies with linear demand and quadratic costs, though Possajennikov considers a more general case.

2.29 Dixon and Somma (2003) consider an economy populated by firms playing a quantity-setting duopoly game in randomly matched pairs. A process of social evolution occurs, meaning that beliefs that yield more profitable behaviour in the competitive process will become more common. They find that with finite conjectures, 'the only beliefs that survive in the long run are close to the consistent conjecture. Consistency here means that the conjecture of a firm about the slope of its competitor's reaction function is equal to the actual slope. The set of surviving strategies correspond to the set of pure strategies that survives the iterative elimination of strategies that are strictly dominated by another pure strategy'. In the case of a continuous strategy set, 'the consistent conjecture is generally the unique evolutionary stable strategy'.

2.30 Muller and Normann (2005) note that the epistemic approach which attempts to explain conjectures in terms of rationality and the information available to agents have generally found conjectural variations to be difficult to rationalize. They argue that attempts to derive conjectures merely from rationality assumptions have not been successful. Conjectures are essentially a-rational. They propose an evolutionary approach to explain conjectures and do not impose any rationality or consistency criterion on the conjectures firms may hold. However, given the conjectures, they assume firms play the market game rationally. The link between market performance and conjectures is that profits in the duopoly game determine the success in an evolutionary game. Thus, they impose evolutionary selection of conjectures and rational choice of actions in the basic market game. As a result, they show that the conjectures surviving the evolutionary process are the consistent conjectures proposed by Bresnahan (1981). That is, they do not only justify the market outcome implied by consistent conjectures, they justify the conjectures themselves.[41]

2.31 In Possajennikov (2009), two large populations of players are repeatedly randomly matched. There is a certain distribution of conjectures (taken to be exogenous) in the populations. In a match, players observe each other's conjectures and behave according to an equilibrium of the game with these conjectures. The evolutionary success of a given conjecture is then determined by averaging the equilibrium payoffs of the players endowed with this conjecture over all matches. The proportion of players with given conjectures changes according to their evolutionary success. It is shown that consistent conjectures are evolutionarily stable in this game. The intuition is that a player with a consistent conjecture correctly estimates the response of the other player to his action and thus maximises the right function, outperforming in evolutionary terms

[41] They note that Dixon and Somma (2003) obtained similar results but suggest there are some differences: (1) they analyze both price and quantity competition; (2) they consider a heterogeneous goods markets; and (3) whereas Dixon and Somma (2003) find that consistent conjectures are not evolutionary stable when marginal costs are constant, they show that the consistent conjectures are evolutionarily stable – as long as the goods are not perfect substitutes.

players with other conjectures.[42] Possajennikov notes that it is interesting that the more rational (consistency) approaches and less rational (evolutionary) approaches lead to the same outcome in many classes of games.

2.32 Although an interesting line of investigation, this research appears to be in its infancy and it is therefore perhaps too early to rely on this as a strong justification of conjectural variations. In particular, it remains to be verified that the outcomes described also hold in price-setting games. Perhaps most fundamentally, this line of research does not consider where the conjectures themselves come from in the first place (or how certain players happen to be endowed with certain conjectures).

Conjectural variations emerging from bounded rationality

2.33 An alternative approach to justifying conjectural variations in a dynamic setting involves considering players with bounded rationality, in other words assuming that decision makers are limited in their ability to process the information they have to make optimum decisions.

2.34 In a model with price conjectures, Friedman and Mezzetti (2002) consider that firms intuitively understand that rivals' future choices are linked to their own current choices, but do not correctly perceive exactly how future choices of their rivals depend on the past. Thus, they note that their model combines profit maximization with boundedly rational behaviour (the latter relating to conjectures as to how rival players make their choices). This assumption is made because – according to Friedman and Mezzetti: 'it seems more in tune with the way real people make decisions'.

[42] An evolutionary stable strategy is a best response against itself and performs better than any other conjecture. Intuitively, a player endowed with a consistent conjecture correctly anticipates the conjectures of his rivals, and thus is at least as well placed as his rivals in each game. Put another way, unlike his rivals (when they have different conjectures), a player with a consistent conjecture correctly predicts the impact on equilibrium of changing his action.

2.35 These authors believe that a model with conjectural variations beliefs requires a dynamic setting with boundedly rational firms. In their model, they use the beliefs embodied in the CV approach, but apply them to the past: each firm i believes that its most recent price change will induce a price change by the other firms. That is, firm i conjectures that firm j's price next period will be firm j's price this period plus a fraction of firm I's price change.[43] At a steady state, when prices cease to change, expectations are realised in the sense that each firm expects and sees no change in prices and is maximising its (discounted) profit relative to its beliefs (although in the approach to a steady state, firms' choices are typically different from the predictions made about them). As in standard CV models, they find that equilibria of the game can range from complete cooperation to perfectly competitive outcomes.

2.36 An interesting feature of the model is that beliefs can be updated.[44] In the model, a firm observes the past choices made by the other firms and has beliefs about how their current choices are related to its own past choices, but it need not be aware of others' profit functions. Given these beliefs, the firm selects a price that maximises its (perceived) discounted profit. It is assumed that beliefs change slowly over time in light of the observed choices of the other firms. Thus, the firm does not analyze the strategic behaviour of others, the other firms affect the environment within which it makes decisions and its cognizance of the other firms is summarized by its beliefs about the way their choices are linked to its own. These beliefs and the way that they are modified over time constitute the firm's theory of the behaviour of rivals.

[43] Suppose for example that firm i conjectures that firm j will match one half of its price change. In this case, if firm j set a price of 10 this period and if, in this period, firm i's price increases by 5, then firm i will conjecture j's next period price to be 12.5 (*i.e.* this period's price of 10 plus one half of firm I's price increment).

[44] This can be compared to the models discussed above on evolutionary stable equilibria where agents were endowed with a given conjecture but did not update them. (The updating rule employed by Friedman and Mezzetti is (roughly) that firm I's belief is updated based on how, on average, firm j's price has responded to I's price.)

2.37 In this set up, Friedman and Mezzetti provide conditions under which the firms' behaviour and beliefs are dynamically stable and converge to a steady state. Their main result is that, as in static CV models, equilibria of the game can range from complete cooperation to perfect competition. In discussing the problem of having a multiplicity of equilibria (steady states), the authors note that both the folk theorem and their dynamic conjectural variations model can have many steady states and, in this sense, neither can make sharp predictions of what players will do. However, they argue that this does not make it a bad theory. They say 'whether a theory is good or bad depends on the extent to which it correctly captures the forces it is meant to describe. Suppose, for example, that real life processes are such that infinitely many steady state equilibria are possible, but that historical accident will determine which particular steady state will be reached. This seems plausible to us and is a feature of our model. From a particular starting point, a unique steady state will be reached. This history dependence is part of many game situations in life, it is most natural that an abstract theory that says nothing about the initial conditions of the system will be unable to pick out a unique equilibrium or a unique steady state'. Their theory differs from the folk theorem for repeated games by explicitly modelling how initial conditions determine final outcomes and how the system moves towards an equilibrium.

2.38 Jean-Marie and Tidball (2006) consider an alternative model featuring agents with bounded rationality and reach similar findings, again allowing agents to revise their beliefs over time. The model in this paper has some similarities to Friedman and Mezzetti in that it assumes bounded rationality, but it differs in how the rationality of the agents is modelled. While Friedman and Mezzetti analyse a discrete time infinite horizon oligopoly game with conjectures, the paper here proposes a learning model bearing on conjectures with a 'step by step optimization'. As Jean-Marie and Tidball note, 'This makes the model closer to Control theory than to Game theory, in particular, we do not assume that agents look for some sort of equilibrium'. Economic agents are assumed to have a limited knowledge and a limited rationality. Although they do not know the payoff functions of the other agents, they do observe the outcomes of past actions. Given this, the agents are assumed to maximize their immediate profit subject to learning about their rivals over time. In particular, they are endowed with the possibility of revising their beliefs according to observations. This will result in a learning process where agents, at each step of the game, update the ideas they have about the behaviour of other agents.

2.39 The result is a dynamic system of conjectures. Agents form conjectures on the actions of their rivals, and they have the ability to revise their beliefs as a function of the discrepancy between the actual conjectural variation deduced from the observed actions of the rivals and their current conjectural variations. In particular, each agent i starts with some (linear) conjecture about her rivals' expected response to her action, based on her observations up to time t. She then updates her conjecture as a function of the discrepancy between the current value and this expected value. This mechanism has the advantage of not assuming that players have knowledge of their opponent's payoffs, since each acts only according to her observations. In continuous time, each agent solves a differential equation.[45] Conjectures are said to be consistent if they converge over time, thereby convincing the agents that they were somehow right in their beliefs.

2.40 The main finding is that convergence to Pareto optima (**for example**, to cooperative behaviour) is possible for both quantity-setting and price-setting games. This is so even though players are boundedly rational and interactions are modelled by simple linear conjectures.[46]

[45] This may sound quite impressive given their bounded rationality. The authors might defend this assumption by arguing that the question of interest is how beliefs regarding rival responses are updated, and not the optimality of decision making given those beliefs.

[46] However, it is also shown that convergence to Pareto optimal outcomes depends strongly on the value of the reference strategy of the linear conjecture: in some cases, convergence may occur with a limit strategy that is not a Pareto optimum, or convergence may not occur at all. In addition, the authors note that their results are restricted to local convergence. Still, among this variety of behaviours, they note that they have found that taking the Nash equilibrium as a reference point yields, for both quantity and price-setting games, a local convergence towards a Pareto solution.

2.41 These papers therefore provide some support for the concept of conjectural variations as arising from firms' imperfect knowledge and decision making. However, there is still much disagreement about the appropriate approach to modelling bounded rationality, and it is unclear the extent to which their results are robust to alternative formulations of this behaviour. The models are of interest in that agents update their beliefs. However, it remains unclear where each agent gets its initial conjecture (reference point), and how the results would be altered by other changes in their economic environment.

Conjectural variations and price setting games

2.42 Much of the conjectural variations literature focuses on firms competing in quantity-setting games with homogeneous products. Although the homogeneity restriction may be innocuous if firms are choosing quantities, it almost certainly matters if firms are instead choosing prices.

2.43 Moreover, as is well known in the I.O. literature, there are often fundamental differences between price-setting and quantity-setting games which arise from the fact that static best responses curves tend to be upward sloping in the former case and downward sloping in the latter case. To extend conjectural variations to price-setting games with differentiated products, let $\mathbf{q_i(p_i, p_j)}$ denote the demand for firm **i**'s product when prices are $\mathbf{p_i}$ and $\mathbf{p_j}$ respectively. Assume firms have constant marginal cost **c**. Then firm **i**'s profit is

$$\pi^i = (p_i - c)q_i(p_i, p_j)$$

2.44 In choosing $\mathbf{p_i}$ to maximize its profit, firm **i** must first conjecture the price it thinks firm **j** will choose, as this will affect its own optimal choice. The fundamental assumption with conjectural variations is that firm **i** believes that its rival's choice will be a function of its own choice, **for example**, $\mathbf{p_j = f_j(p_i)}$. Firm **i**'s profit-maximizing choice of $\mathbf{p_i}$ thus solves the following maximization.

$$\max_{p^i}(p_i - c)\, q_i(p_i, f_j(p_i))$$

2.45 An interior equilibrium satisfies the system of first-order conditions

$$(p_i - c)\left(\frac{\delta q_i}{\delta p_i} + \frac{\delta q_i}{\delta p_j} f_j^{'}(p_i)\right) + q_i = 0$$

2.46 Where **i** =1,2, **j** =1,2 and **i** ≠ **j.** Note that if $f_j^{'}(p_i) = 0$, so that fir **i** believes firm **j**'s choice is independent of its own choice, then the Bertrand outcome is obtained. If, however, $f_j^{'}(p_i) = 1$ and the firms' products are symmetrically differentiated, then the monopoly prices and quantities will result. In general, negative conjectures will lead to outcomes that are more competitive than Bertrand, and positive conjectures will lead to outcomes that are less competitive than Bertrand – positive conjectures (as will be discussed further in Chapter 4. are also known as 'accommodating' in this setting.

2.47 This result suggests that coordinated effects can arise in differentiated-products price-setting games when firms have positive conjectures about their rival's reactions. Clearly, however, the same criticisms we outlined above would apply in this instance as well. In addition, the result that monopoly pricing can occur when firms believe that their rivals engage in price matching appears to rely on an assumption of symmetric demands, which need not hold in practice. To investigate this last point, suppose the two firms' products are asymmetrically differentiated. Then, it follows that they will in general disagree on a common price to charge consumers. Let (p_i^m, p_i^m) and (p_j^m, p_j^m) denote firm **i** and **j**'s preferred common price pair, respectively, and without loss of generality, suppose firm **i**'s preferred common price is higher, such that $p_i^m > p_j^m$. Note that in this case there cannot be a conjectural-variations equilibrium with price matching in which both firms charge p_i^m because at p_i^m firm **j** could profitably decrease its price to p_j^m knowing that firm **i** would be committed to matching it. However, there also cannot be a conjectural-variations equilibrium with price matching in which both firms charge p_j^m because at p_j^m firm **i** could profitably increase its price to p_i^m given its belief that firm **j** would match it.

2.48 In fact, no conjectural variations equilibrium with price matching exists in this setting. Asymmetries, whether they be on the demand or cost side, thus pose a potential problem for alignment on coordinated outcomes. Another possibility to consider is that downward price movements would be matched but not necessarily upward price movements. Both these points are discussed further in Chapter 5.

3 EMPIRICAL ESTIMATION OF MARKET POWER AND FIRM CONDUCT

Introduction

3.1 In this Chapter we take a **backwards-looking** approach and present **empirical** techniques that can be used to investigate how firms have competed historically. For the purpose of enforcing competition rules, the Authorities could apply these empirical techniques to assess whether industry outcomes are consistent with the exercise of market power, and in particular whether firms have engaged in coordinated behaviour during some well-defined periods.[47]

3.2 To this end, a modelling approach based on conjectural variation models can be used to estimate the so-called conduct parameter (which is related to the conjectural variation parameter). This approach allows the analyst to test whether market outcomes (for example the prevailing price level) is consistent with either perfect competition, Nash-conduct or 'as if' firms are perfectly colluding.

3.3 Subsequent research has shown that the results based on the implementation of empirical conjectural variation models are unreliable in some cases. Nowadays, economists have favoured an alternative approach, the so-called 'menu approach'. In its simplest form, the analyst specifies a menu comprising just two models: one in which firms are perfectly competing and one in which they are perfectly colluding. The analyst then determines which of the two models best fit the data. In practice, the analyst may specify an array of models, and each model

[47] In the UK, the OFT is in charge of enforcing Chapter I and II of the Competition Act (1998). Chapter I, inter alia, prohibits agreements that enable firms to collude, whereas Chapter II prohibits abuses of dominant position, that is, a firm that exercises significant market power is not allowed to use practices that restrict competition such as refusal to supply, predatory pricing etc. Under the Enterprise Act (2002) the Competition Commission conducts market investigations to determine whether there are features that have an adverse effect on competition.

assumes a specific form of conduct (single-product firm playing Nash, Stackelberg leadership, multi-product firms playing Nash, partial collusion and perfect collusion). The objective of this approach is to determine which form of conduct best fits the data. Using this method, a competition authority may be able to conclude that some forms of collusion are not supported by the data, and thus appear unlikely.

3.4 In this Chapter we describe each of these approaches in turn and illustrate how they might be employed in practice. The last section provides some remarks on the application of these empirical techniques in the course of an investigation.

Empirical applications of conjectural variation models: measuring market power and investigating firm conduct

3.5 In this section, we present the empirical application of conjectural variation models that have been used in the academic literature to measure market power and identify firm conduct.

3.6 Using market or firm level data, the analyst estimates a supply equation, which is derived from the firm's profit maximisation problem. This econometric model includes a specific parameter whose value reflects the level of market power held by the firms in the industry being analysed. Specifically, this parameter measures the wedge between price and marginal cost. When price is above marginal cost, firms are said to exercise market power, and the wider the gap between price and marginal cost, the less competitive the market.

3.7 In addition to measuring market power, the theory of conjectural variations links the value of the parameter to some specific types of firm conduct, and thus provides a behavioural interpretation (hence it is called the 'conduct parameter').

3.8 In homogenous product industries, the conduct parameter, which corresponds to the Elasticity-Adjusted Lerner Index (EALI), can be computed directly provided the analyst has access to reliable data on marginal cost, the aggregate demand elasticity and market shares.

Often, the analyst does not possess the relevant cost information, but she can use market data and econometric techniques to estimate marginal cost as well as the conduct parameter. Unfortunately, as we will see in this Chapter the econometric estimation of the conduct parameter may be unreliable. This is because in some situations, conjectural variation models are unable to generate the same collusive equilibrium price and quantity as the underlying economic model. In this case the estimated conduct parameter is biased and inconsistent.

3.9 This section is organized as follows. First, we present the conduct parameter method, distinguishing between the two interpretations, one based solely on market power and the other one linking the value of the parameter to a specific type of behaviour. Second, we show how the conduct parameter can be estimated in the absence of reliable cost data. Third, we show that econometric estimation of the conduct parameter is, in many situations, unlikely to be accurate. Finally, we briefly explain the practical obstacles that prevent the implementation of the conduct parameter method in differentiated products industries.

Market power and firm conduct

3.10 In economic theory a firm has market power when it is profitable to raise price above marginal cost.[48] Economic textbooks refer to the Lerner index to measure market power, which is defined below as:

$$L_t = \frac{P_t - MC_t}{P_t} \quad (1)$$

where P_t is price and MC_t is the marginal cost in period t, that is, the cost of producing an additional unit of output. The Lerner index is a relative measure of the firm unit profit margin ($P_t - MC_t$) and its price. As the gap between price and marginal cost increases, so does the Lerner index.

[48] Crucially, as discussed in the Executive Summary, we emphasise that this refers to the treatment of market power in traditional economic theory. This differs significantly from the analysis of market power in antitrust, in which the fact that prices are above marginal cost is not necessarily evidence of market power.

3.11 The Lerner index can take any value between 0 and 1. Under perfect competition, price equals marginal cost and the Lerner index is zero. Any positive value indicates that firms exercise market power. The Lerner index, however, is not an indicator of firm conduct (for example we cannot tell whether a firm acts as a monopolist or whether firms in the market are colluding from the Lerner Index alone)[49]. For example, in some industries the marginal cost is close to zero (for example, the software sector), which implies a Lerner index near 1, yet firms may be actively competing. We must be wary of associating higher Lerner indices with collusive conduct because there are multiple sources of market power. In this Chapter we show how economists attempt to separate market power that stems from collusive behaviour and that part of market power that comes from other factors.

3.12 The New Empirical Industrial Organisation (NEIO) provides a framework to measure and assess market power as well as estimate directly firm conduct. The NEIO literature that emerged in the late 1970s relies in part on conjectural variation models, and was established upon the criticism lodged against the Structural Conduct Performance (SCP) approach, which was the prior methodology that economists applied to infer firm conduct notably in the 1950s and 1960s. A typical SCP study seeks to establish the relationship between firm's profitability and market concentration. The idea is that greater concentration facilitates coordination among competitors, for example when there are few big firms, they tend not to compete as much as markets populated with a large number of small firms leads to greater economic profit (thus revealing more market power). Although this approach does not estimate directly firm conduct, it assumes that higher market concentration is associated with more coordination. The SCP approach suffers from a number of well-documented shortcomings (see Church and Ware (2000) Chapter 12 for a comprehensive summary).

3.13 In particular NEIO considers the following:

[49] The analyst can make some comparisons. For example, if one firm's Lerner index has a value of 0.3, it exercises less market power than a firm whose index is 0.5.

- Marginal cost is not readily available. Therefore, the price-cost margin $(P - MC)$ cannot be directly calculated. This is because marginal cost is defined as the incremental cost of selling one more unit of output, and firms do not record costs this way. Instead, the analyst will have to either infer marginal cost from firm behaviour or quantify market power without any cost information.

- Firm and industry conduct can be estimated so as to determine the source of market power.

3.14 The standard NEIO study involves the estimation of a demand function and a supply relation. These two equations form a system of simultaneous equations, which can be applied to the data to recover a conduct parameter from the supply relation. The NEIO literature was pioneered by, inter alia, Iwata (1974), Gollop and Roberts (1979), Bresnahan (1981, 1982), and Lau (1982). These papers brought about ample research in this area as surveyed by Bresnahan (1989). Subsequently, NEIO has remained an active area of empirical research with a multitude of ensuing studies.

The supply relation and measuring market power

3.15 In this section, we introduce the NEIO general framework that is used to estimate firm or industry market power. We first consider the case in which firms supply a homogenous product.[50]

Firm level market power

3.16 We introduce some assumptions and notation to present this framework. First, the model needs to account for consumer behaviour, which is summarised by a demand function. In particular, this function specifies how consumers react to a change in the market price. Generally, as price increases consumer demand ebbs, and the demand function is meant to

[50] This means that consumers view the product offering from competing suppliers as perfectly substitutable, and all firms charge the same price, the market price.

represent such behaviour. The (inverse) aggregate demand function (for example the industry demand function) is given by $P_t = f(Q_t)$, where P_t is the market price and Q_t is the entire output produced by all firms active in the industry ($Q_t = \sum q_{it}$) in each period t.

3.17 Second, the supply side consists of N firms, which are all similar.[51] $MC(q_{it})$ denotes the marginal cost function. The marginal cost is the cost of an additional unit of output, and the marginal cost function is just a representation of how marginal cost changes with the production level.

3.18 Finally, firms are assumed to maximise profit. This assumption leads firms to follow a rule whereby they set price (or production level) so that perceived marginal revenue equals marginal cost. This is what the first order condition from firm i's profit maximisation represents:

$$\underbrace{P_t + \theta_{it} q_{it} \frac{\partial P_t}{\partial Q_t}}_{perceived\ marginal\ revenue} = \underbrace{MC(q_{it})}_{marginal\ cost} \quad (2)$$

where the left-hand side of equation (2) represents firm i's perceived marginal revenue in period t, and the right-hand side its marginal cost function in that period. If it were a monopoly the marginal revenue would simply be equal to $P_t + Q_t \frac{\partial P_t}{\partial Q_t}$.

3.19 In the perceived marginal revenue term equation (2) contains a parameter, θ_{it}, which can take any value. This parameter measures the wedge between price and marginal cost for firm i in period t. When $\theta_{it} = 0$ market price equals marginal cost, and therefore firm i has no 'market power'. As θ_{it} moves away from zero, firm i's market power increases and this is reflected by a larger price-cost margin.

3.20 In theory, this parameter can vary from one period to the next. However, as we shall see in paragraphs 3.61 to 3.94, the empirical application of

[51] For simplicity we assume that the number of firms is the same in all periods. That is, there is no entry or exit.

CV models typically requires that firms have the same value of this parameter over time.

3.21 Rearranging terms of the supply relation in equation (2), we show that the market power parameter, θ_{it}, can be interpreted as an elasticity-adjusted Lerner index (see Corts (1999) and Reiss and Wolak (2007)):

$$\tilde{L}_{it} = \theta_{it} = \frac{P_t - MC(q_{it})}{P_t}\frac{\eta_t}{s_{it}} \qquad (3)$$

where η_t is the price-elasticity of aggregate demand and s_{it} is firm i's market share in period t.

3.22 This parameter is very similar to the Lerner index, except that it is normalised by the inverse aggregate elasticity of demand $\left(e_t = \frac{1}{\eta_t}\right)$.[52] Adjusting the Lerner index by the price-elasticity of demand allows the analyst to distinguish between markets that have a high margin because demand is inelastic from those that have high margins because they are less competitive. Typically, a very elastic consumer demand leads to a low margin. However if firms are engaged in some form of collusion this can increase their margin. In this case, the adjusted Lerner index is relatively high, reflecting the fact that firms collude in spite of a high elasticity of demand. On the other hand, in the case of a very inelastic demand, even when firms compete, margins remain high. In this situation, the adjusted Lerner index is low reflecting the fact firms compete vigorously.

[52] The price-elasticity of demand tells us by how much demand will fall when price goes up. This is because consumer behaviour governs the ability of firms to raise price above marginal cost. If consumers are very price sensitive, that is, they migrate away from the product in response to a price increase, this would limit the firms' ability to exercise market power. As a result, the price-cost margin would be small. Alternatively, when the price-elasticity is low (inelastic demand), firms have more room to manoeuvre, which result in high profit margins.

Industry level market power

3.23 Summing equation (2) over all firms in the market and dividing by the number of firms supplying the homogenous product, N, yields the following industry level supply relation in each period t:

$$P_t + \frac{\partial P_t}{\partial Q_t} \sum_{i=1}^{N} \frac{\theta_{it} q_{it}}{N} = \sum_{i=1}^{N} \frac{MC(q_{it})}{N} \quad (4)$$

3.24 Using industry level data and assuming each firm's parameter is the same in each period, the analyst estimates the following supply relation:

$$P_t + \theta_t \frac{\partial P_t}{\partial Q_t} Q_t = \overline{MC(q_{it})} \quad (5)$$

where $\overline{MC(q_{it})}$ is the average marginal cost across the N firms in the industry, and θ_t provides a measure of the industry market power. Reiss and Wolak (2007) show that the industry parameter is an average of market share times the individual firm parameter: $\theta_t = \frac{1}{N} \sum_{i=1}^{N} \frac{\theta_{it} q_{it}}{Q_t}$. If θ_{it} varies across firms but remains constant over time, then when firms' market shares fluctuate over time, so does θ_t – even if the intensity of competition is unchanged. As a result, when the analyst investigates an industry over different time periods, unless market shares are stable, it makes little sense to assume that θ_t remains constant. Alternatively, the analyst may assume that θ_i is the same for all firms in the industry, and in this case θ_t does not vary when market shares fluctuate overtime.

3.25 Solving equation (5) yields an industry level version of the elasticity-adjusted Lerner index.

$$\tilde{L}_t = \theta_t = \frac{P_t - \overline{MC(q_{it})}}{P_t} \eta_t \quad (6)$$

3.26 In paragraphs 3.44 to 3.60 we discuss how the elasticity-adjusted Lerner index can be computed.

Conjectural variation: linking firm behaviour to market power

3.27 In the academic literature, θ_t, which also measures market power, is more commonly referred to as the 'conduct parameter'. This is because the theory of conjectural variations links θ_{it} directly to firm conduct.

3.28 To see how, we follow the conjectural variation literature and take the total derivative of a homogenous product firm's single period profit function with respect to its quantity. This yields the following (static) first order condition for profit maximisation:

$$\frac{d\pi_{it}}{dq_{it}} = P_t + q_{it}\frac{\partial P_t}{\partial Q_t}\frac{dQ_t}{dq_{it}} - MC(q_{it}) = 0 \qquad (7)$$

3.29 Comparing equation (7) to equation (2), we can see that the market power parameter is equal to the derivative of total industry output with respect to the firm's quantity $\left(\theta_{it} = \frac{dQ_t}{dq_{it}}\right)$. In other words, the level of market power is linked to firms' conduct through firm i's expectations about how aggregate quantity responds to changes in its own quantity.

3.30 The link between market power and firm i's beliefs about rivals' responses to their actions is made explicit by restating the conduct parameter as a conjectural variation (CV) parameter, r_{it}. By decomposing aggregate industry quantity into the sum of the change in all firm's quantities, the first-order condition in equation (7) becomes:

$$P_t + (1 + r_{it})q_{it}\frac{\partial P_t}{\partial Q_t} = MC(q_{it}) \qquad (8)$$

3.31 In the equation above, the conduct parameter θ_{it} has been replaced by $1 + r_{it}$, where r_{it} is firm **i'**s conjectural variation (CV) parameter.[53]

3.32 In principle, the CV (and conduct) parameter can take on an array of values indexing firm conjectures which, in turn, give rise to market

[53] Where $(1 + r_{it}) = \sum_{j=1}^{N}\frac{dq_{jt}}{dq_{it}} = \frac{dq_1}{dq_1} + \sum_{j=2}^{N}\frac{dq_{jt}}{dq_{1t}}$.

outcomes ranging from perfect competition to monopoly (perfect collusion).

- When $r_{it} = -1$, firm i expects that all other firms would collectively reduce quantity by the same amount that it increases output. In other words, firm i believes that whatever action it undertakes the industry output will remain constant ($1 + r_{it} = 0$), and, as a result, there will be no change in the market price. This conjecture is consistent with the price-taking behaviour of perfect competition, that is, $r_{it} = -1$ implies that $\theta_{it} = 0$, and thus in equilibrium price equals marginal cost.

- When the firm's CV parameter is 0, firm **i** conjectures that its rivals will not respond when it changes quantity. This is the defining feature of static Nash-Cournot oligopoly model.

- The CV parameter also describes firm conduct in industries that sustain perfect collusion. In this case, the group of colluding firms replicate the behaviour of a monopolist, and the CV parameter is equal to the number of rivals. The firm conjectures that an output increase will be met by a one-for-one increase by each of its rivals.

3.33 Table 1 below summarises the relationship between the CV and the conduct parameter for the three cases presented above.

Table 1: The market power parameter and firm conduct

	r_{it}	θ_{it}	θ_t
Perfect competition (Bertrand-Nash)	-1	0	0
Nash-Cournot	0	1	$1/N$†
Perfect collusion	$N-1$	N	1

† This assumes that all the N firms in the industry are symmetric.

3.34 From a theoretical perspective, individual conjectural variation represent the firm's beliefs about what its rivals would do in reaction to a change in its quantity.[54] Indeed, this is what the conjectural variation parameter, r_{it}, is supposed to capture in equation (6).

3.35 One of the apparent advantages of the conjectural variation approach is that the parameter that measures the degree of market power, θ_i can be directly linked to firm's conduct. However, Reiss and Wolak (2007) point out that:

> '... the problem with this interpretation is that there are only a few values of θ_i where economists have a good explanation for how firms arrived at such a conjecture. ... We know of no satisfactory static model that allows for arbitrary values of θ_i'.

3.36 This highlights one important shortcoming of conjectural variation models. Namely, when the estimated conduct parameter diverges from the value displayed in Table 1 above, the analyst is unable to define precisely the firm behaviour. For example, it is not clear what $\theta_i = 2$ means in terms of conduct. This raises an issue about how the analyst can use the results to understand the nature of competition in the industry (see paragraphs 3.250 to 3.283 for further discussion).[55]

[54] In principle, the conjectural variation model could be applied to any of the firm's choice variables. For convenience, and in line with much of the literature, we focus on the conjectural variation on firm's quantity choices.

[55] As we shall discuss in paragraphs 3.111 to 3.161, the empirical application of the conjectural variation model (the conduct parameter method) adds further complications with respect to the interpretation of the result. The econometric estimation of the supply relation introduces the possibility that the empirical model might be misspecified. This might be due to the omission of important variables for which the analyst has no information or because the analyst imposes inappropriate functional forms for marginal cost and/or the demand equation. In this case; the conduct parameter estimate may be biased. As a result, departure from the parameter values displayed in Table 1 might simply be the result of a misspecified model.

3.37 Some economists have argued that firms form conjectures through repeated interactions (see Chapter 2), and conjectural variation models can be viewed as a reduced form of the underlying dynamic oligopoly model. However, here too Reiss and Wolak (2007) remain sceptical as to whether conjectural variation models can approximate the underlying dynamic game:

> 'Given the subtleties involved with reasoning through how today's competitive interactions might affect future beliefs, it seems unlikely dynamic models will produce simple parameterizations of conjectures or easily estimated first order conditions. Moreover, the literature on repeated games has shown that when modelling current behaviour, one has to recognize that threats or promises about future behaviour can influence current behaviour'.

3.38 If the goal of applying this approach is to assess how high prices are set in relation to marginal costs, then it provides a **descriptive** measure of market power. If however, the analyst is interested in measuring firm conduct, then she must be cautious about the behavioural interpretation.

3.39 However, as we shall argue later, this does not necessarily make empirical conjectural variation models totally useless. The method described above can provide a measure of market power and it may be a useful tool to gain an understanding about the nature of competition that prevails in a particular industry (see paragraphs 3.250 to 3.283).

Measuring market power and inferences on firm conduct

3.40 The empirical literature makes a distinction between what firms conjecture about their competitors' reaction and what firms actually do as a result of these expectations. For example, Bresnahan (1989) interprets the conjectural variation parameter not as firm's expectations about their rival's reaction, but instead as what firms do as a function of these expectations.

> 'The crucial distinction here is between (i) what firms believe will happen if they deviate from the tacitly collusive arrangements and (ii)

what firms do as a result of those expectations. In the 'conjectural variation' language for how supply relations are specified, it is clearly (ii) that is estimated. Thus, the estimated parameters tell us about price- and quantity-setting behaviour, if the estimated 'conjectures' are constant over time, and if breakdowns in the collusive arrangements are infrequent, we can safely interpret the parameters as measuring average collusiveness of conduct.'

3.41 Therefore, empirical applications of conjectural variation models estimate a conduct parameter which is interpreted 'as-if' the firm were playing the conjectural variation to which the value of θ_{it} corresponds to. For example, when using firm level data, if the estimated value of θ_{it} is close to N, then the analyst would conclude that firms behave 'as-if' firms were perfectly colluding.

3.42 It is important to realise that the analyst does not estimate strictly a conjectural variation parameter. That is, the value of the estimate cannot be used to predict how total output changes when a firm expands its output.

3.43 Depending on the data availability there are two different ways to estimate the conduct parameters, (whether it is the firm level θ_{it} or industry level θ_t). First, if reliable cost information is available, the analyst can compute the elasticity-adjusted Learn index (EALI), which correspond to the conduct parameter. But as most of the time marginal cost data do not exist, the analyst can also recover the parameter directly by estimating a firm or industry supply relation. This is the conduct parameter method (CPM), which we discuss at length in paragraphs 3.61 to 3.94.

Calibrating the conduct parameter

3.44 To illustrate how to calculate the conduct parameter for each firm i in period t, we solve equation (2) for θ_{it}, which yields the following:[56]

$$\widetilde{L_{it}} = \theta_{it} = \frac{P_t - MC(q_{it})}{P_t}\frac{\eta_t}{s_{it}} \qquad (9)$$

3.45 At the firm level or the industry level, the adjusted Lerner index can be computed directly using the four inputs listed below:

- price
- market shares
- marginal cost, and
- industry elasticity of demand.

3.46 Using these four inputs, the analyst may compute $\widetilde{L_{it}}$ the elasticity-adjusted Lerner index.

How to compute the elasticity-adjusted Lerner index: an example

3.47 To illustrate how we might apply this index, consider the following hypothetical example. Suppose that following a customer complaint a competition authority wants to investigate the degree of market power exerted by three firms selling widgets, and in particular whether they are charging above-competitive level prices. The three firms control 60 per cent of the widget market and face a less efficient fringe that consists of many small producers. The complainant states that the demand for widgets is highly inelastic and further claims that the three firms are taking advantage of their collective market power to set high prices.

[56] To 'calibrate' the industry level conduct parameter we would require average marginal costs in the industry.

3.48 Following an information request, the analyst working for the competition authority obtains estimates for the market price, and for each firm's marginal cost and market share. The three firms confirm the complainant's view that demand is close to perfectly inelastic. They even submit that the aggregate elasticity of demand is -0.05. From third party source, the analyst obtains the weighted average margin for a typical fringe supplier. The information collected is summarised in Table 2 below.

Table 2: Using the elasticity-adjusted Lerner Index

	Firm 1	**Firm 2**	**Firm 3**	**Fringe**
Market Share	25%	20%	15%	40%
Price per widget	150	150	150	150
Marginal Cost per widget	30	40	45	80
Margin (%)	80%	73%	70%	47%
Industry elasticity†	-0.05	-0.05	-0.05	-0.05

† The absolute value of the industry elasticity of demand is used in equations (2) and (3).

3.49 Using this information the analyst computes the elasticity-adjusted Lerner Index as set out in equation (3). The results for each firm (and the fringe) are shown in Table 3 below.

Table 3: Using the elasticity-adjusted Lerner Index: Firm and Industry level conduct parameters

	Firm 1	Firm 2	Firm 3	Industry-Level
Conduct Parameter	0.16	0.18	0.23	0.03

3.50 The value of the elasticity-adjusted Lerner Index is 0.16, 0.18, and 0.23 for firms 1, 2, and 3 respectively. Therefore, despite having margins in excess of 70 per cent and accounting for 60 per cent of the market collectively, the index suggests that each firm is behaving quite competitively.[57] Moreover, the analyst combines all of the information from the three firms and the fringe to compute a weighted average industry margin of 64 per cent. Using equation (3), the analyst computes the industry level elasticity-adjusted Lerner Index and finds that the conduct parameter for the industry as a whole is 0.03. This result also suggests that the level of market power in the widget industry is equivalent to that of a Nash-Cournot market with 33 symmetric firms. Considering that 3 firms control 60 per cent of the market, this suggests that the widget industry is highly competitive.[58]

3.51 In sum, based on this simple computation, the analyst finds little evidence to support the view that the three major firms in the market are engaged in some form of collusion that maintain price above the competitive level.

[57] Recall from Table 1 above that when the conduct parameter is 0, it is consistent with perfect competition; when it is 1 it is consistent with Nash-Cournot competition; when it is equals to *N* it is consistent with monopoly pricing.

[58] As noted above, the industry-level analogue of the elasticity-adjusted Lerner Index imposes the restriction that all firms' conduct parameters are the same in the period of interest.

The pros and cons of applying the elasticity-adjusted Lerner Index

3.52 As the example described above shows, calibrating the conduct parameter using the elasticity-adjusted Lerner Index may be useful as to form an initial view about the extent of market power and firm conduct. However, the analyst must be mindful of the shortcomings of this method.

3.53 On the plus side, the elasticity-adjusted Lerner Index has the desirable property of being simple and quick to calculate at either the firm or industry level.[59] In addition, it depends on relatively few pieces of information: price-cost margins, market shares, and the industry elasticity of demand. However, it is important to note that not all of these components are easy to measure accurately. Below, we discuss some of the issues involved in measuring these inputs.

- First, in order to compute market shares the analyst must first define the size of the relevant market. In general, the relevant market is defined in line with the hypothetical monopolist test.[60] However, the outcome of the test may be subject of debate, thereby impacting the reliability of the market shares.

- Second, the price-elasticity of aggregate demand is usually not readily available. One approach consists in estimating a demand model, which requires an assumption about the functional form of the demand curve and access to enough data to recover the price-elasticity of demand. Alternatively, the elasticity of demand may be

[59] See paragraphs 3.23 to 3.26 for a discussion of the additional assumptions required to calculate industry level conduct and CV parameters.

[60] See Chapter 10 of Majumdar *et al* (2011) for a discussion on the application of the hypothetical monopolist test and Durand (2010) for a presentation of the hypothetical monopolist test.

computed based on customer surveys or inferred from marketing studies.

- Third, like the unilateral effect 'screens' discussed in Chapter 4, using an elasticity-adjusted Lerner Index relies on the availability of the necessary cost data to input the margin. When good information is available about marginal cost, the analyst can directly compute the level of market power using the formula in equation (9). However, this is not always the case. Whilst well known in the context of IPR and UPP merger analysis, we restate some of the main issues in relation to the use of accounting margins below.

  - First, marginal cost is rarely observed. This is because companies do not keep track of this particular type of cost. Often average variable cost (AVC) is taken as a surrogate.[61] However, Carlton (2011) states that using AVC can make a significant difference in estimating price-cost margin. For example, if in the long run the industry is competitive, equilibrium price would equate marginal cost and average cost (that is, the firm would earn break-even profits), but the price would be above average variable cost. Although firms in such an industry have no market power, using AVC would indicate a positive price-cost margin.

  - Second, even if the analyst is convinced that average variable cost is a good enough proxy, she will face another practical challenge: determining which components of total costs are variable and which are fixed. In theory the split is clear: in the long run all costs are variable, whilst in the short run, some costs vary and others do not. In reality, it may be difficult to draw the line that splits the short-run and the long run, and that line can vary across industries. The absence of clear practical rules to

[61] In theory firms set price in function of marginal costs. Whether firms have a short or long term perspective when setting price, marginal cost is the relevant measure that is taken into account. For example, a firm may consider that the decision to offer a product creates a long term commitment to manufacture, market and support that product. In that case, short-term variable cost is an inadequate measure of product cost.

identify variable costs is likely to cause some measurement errors, leading the analyst to either overstate or understate the price-cost margin.

- Finally, accounting cost data is often used to compute average variable cost, but this type of data often does not reflect adequately the true economic costs in particular the cost of capital. One of the main problems stems from the difference in the accounting and economic valuation of durable assets. In accounting, the cost of an asset is equal to the initial price paid less some arbitrary measure of depreciation. In economic terms, the cost of an asset corresponds to its valuation in its next best alternative. This is particularly difficult to appreciate when there is no second hand market for the assets at issue. Other assets such as expenditures in advertising or R&D which provide future but intangible benefits to a firm are often accounted as expenditures instead of investments. If these were treated as investments in capital (intangible assets), the cost of capital will also include the economic returns on these particular investments. Overall, accounting data may provide a very poor approximation of economic costs, let alone marginal cost[62].

- Finally, this method cannot be easily implemented in differentiated product industries. As we discuss in paragraphs 3.162 to 3.168 below computing the conduct parameter requires a different set of inputs, in particular detailed information about the own and cross-price elasticities of all products in the industry.

3.54 If there is some disagreement on the exact value of each input given the simplicity of the approach, it is straightforward to conduct a sensitivity analysis to check (a) which of the assumptions about each input affects the estimate most and (b) the proportion of scenarios under which significant market power arises.

[62] For a discussion on the use of accounting data to estimate economic costs see Fisher and McGowan (1982).

3.55 To illustrate how this might play out in practice let's return to the hypothetical example that was presented in the section above. Suppose the competition authority shares its findings with the complainant (for example that the parties' estimates did not indicate that they were setting supra-competitive prices). The complainant is surprised to see the input supplied by the firms to the authority, in particular, she claims that the parties have (a) overstated their marginal costs by including fixed costs, and (b) they have grossly exaggerated how inelastic aggregate demand is. The complainant believes that the firms' margins are more likely to lie between 70 per cent to 90 per cent rather than 70 per cent to 80 per cent. Moreover, the complainant finds an academic paper which reports that the short-run aggregate demand elasticity is in the region of -0.15. The complainant considers that the elasticity of demand can take any value between -0.1 and -0.2 with equal probability (for example it is uniformly distributed in that interval).

3.56 To test the implications of the complainant's view, the authority conducts a sensitivity analysis by drawing the frequency distribution of the conduct parameter assuming the aggregate demand elasticity lies in the interval between perfect inelastic demand and -0.1 and assumes margins are uniformly distributed between 70 per cent and 80 per cent.

3.57 A summary of the input assumptions for both the firms' and complainant's views are shown in Table 4 and the resulting distributions of the firm level conduct parameters are shown in Figure 1

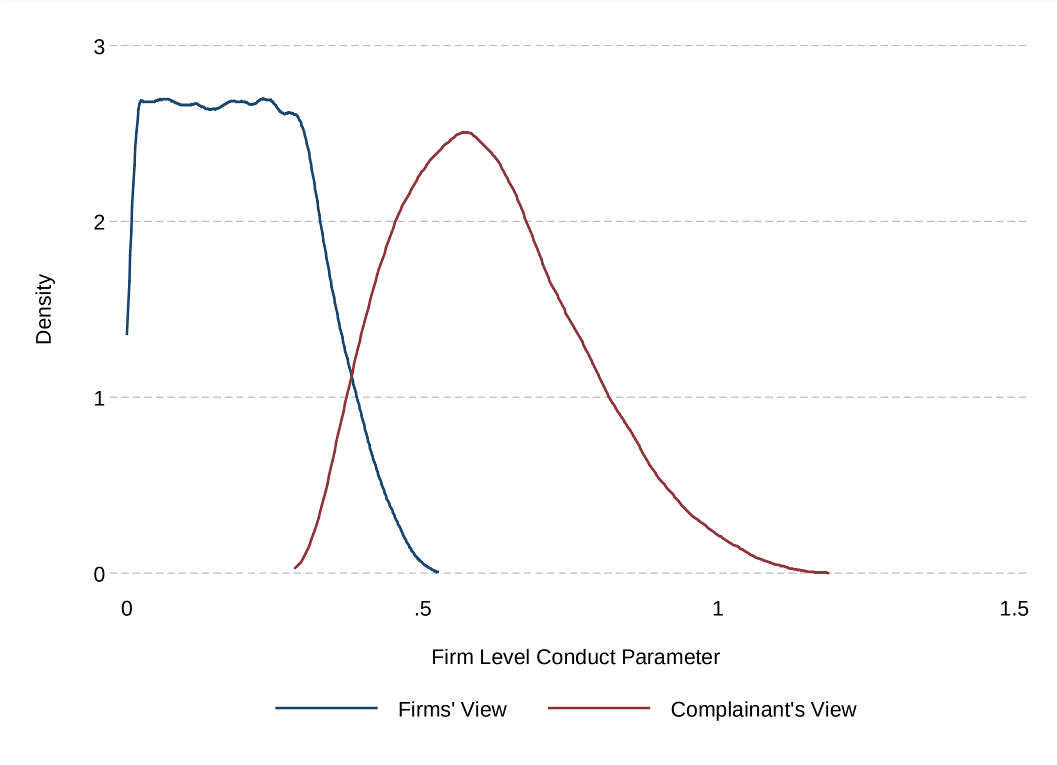
Table 4: Assumed input ranges for Elasticity-Adjusted Lerner Index

Input	Firms' View	Complainant's view
Margin	[70%, 80%]	[70%, 90%]
Market Share	[15%, 25%]	[15%, 25%]
Elasticity of demand	[-0.1, 0]	[-0.2, -0.1]

3.58 The figure below shows that almost all of the firm level conduct parameters estimated under the firms' view are closer to perfect competition than Nash-Cournot. The mean value is 0.19, and 99 percent of the conduct parameter values are below 0.44. Alternatively, under the complainant's view the average value for the firm level conduct parameter is 0.61. About 75 per cent of the conduct parameter values are above 0.5, that is, most of the conduct parameter values are closer to Nash-Cournot behaviour than perfect competition. And less than 1 per cent is above 1, the value which exactly corresponds to Nash-Cournot behaviour.

3.59 Overall, the sensitivity analysis reveals that under a range of reasonable values for market shares, the aggregate elasticity of demand and firm margin, there is a very small chance that firms behave in a collusive fashion. It appears that the competition authority would not need to investigate much further the complainant's claim. In other cases, however, the results of such sensitivity analysis may not be that clear-cut.

Figure 1: Distribution of the conduct parameter under two opposing views



3.60 The calibration of the conduct parameter is not the only way to empirically evaluate market power. An alternative strategy is to estimate marginal cost together with the conduct parameter in the supply relation. This is the topic of the next section.

The Conduct Parameter Method (CPM): estimating the supply relation

3.61 We present the conduct parameter method (CPM), a term that was coined by Corts (1999). In general marginal cost is not directly observable. However, it is still possible to estimate the conduct parameter θ_i if we impose additional restrictions on the conjectural variation model and estimate it using the so-called conduct parameter method (CPM).

- First, the CPM assumes that the same static oligopoly model is played in each period (or at least for a pre-specified period – see paragraphs 3.95 to 3.110). Therefore, each firm conduct parameter is assumed to be fixed over the period used for estimation, $\theta_i = \theta_{it}$.

- Second, as noted in paragraphs 3.23 to 3.26, to ensure that the **industry** level conduct parameter is constant over time requires additional assumption. For example, the analyst has to assume that all conduct parameters are exactly the same for all firms or that they vary inversely with market shares.

- Third, the CPM requires the estimation of the price elasticity of demand and of the marginal cost function. To identify these together with the conduct parameter, the analyst has to assume specific functional forms for the demand and marginal cost functions.

3.62 Combining these assumptions with sufficient data, it is possible to recover the conduct parameter.

3.63 To illustrate the implementation of the CPM, consider that the analyst wishes to estimate the industry level parameter θusing the pricing equation (5). To this end, the analyst also has to estimate a demand equation to retrieve the price elasticity of demand. The econometric estimation involves a system of equations which can be written as follows:

Industry supply relation:

$$P_t = MC(Q_t, W_t, Z_t) - \theta \frac{\partial P_t}{\partial Q_t} Q_t + \varepsilon_t^S \quad (10)$$

Aggregate demand:

$$P_t = f(Q_t, Y_t) + \varepsilon_t^D \quad (11)$$

where Y_t is a vector of demand shifters, W_t represents a vector of input factor prices and Z_t other cost shifters, and the ε_t's are unobserved supply and demand shocks. To estimate these equations, the analyst has to make some assumptions about the functional form for the demand function, $f(Q_t, Y_t)$, and the marginal cost function $MC(Q_t, W_t, Z_t)$.

3.64 To estimate the conduct parameter in the system of equations given by (10) and (11), the analyst must overcome two hurdles:

- simultaneity bias, and
- identification of the conduct parameter.

3.65 We present briefly the first hurdle, which is a well-known econometric problem, and then we discuss in more detail the second issue, which is specific to the CPM.

Simultaneity bias

3.66 The estimation of the supply relation involves a well-known simultaneity bias. Since Q_t is an endogenous variable in both the supply and demand equations, the estimation of equations (10) and (11) yields biased and inconsistent estimates unless the analyst employs appropriate econometric techniques, such as an IV or a GMM estimator. In this report we do not dwell on this issue. We refer the interested reader to standard textbooks such as Wooldridge Chapter 9 for a thorough exposition of the simultaneity bias that arise when estimating such a system of equations as well as an introduction to the IV/GMM estimator.

3.67 One requirement for applying an IV or a GMM estimator on equation (10) is that at least one of the variables in Y_t is not included in the supply relation (for example it is not part of W_t or Z_t). This is because demand shifters that are excluded from equation (10) but are included in equation (11) allow the demand curve to trace out the supply relation.

3.68 For example, suppose that demand for ice cream is higher in the summer than in the winter. A seasonal dummy variable that is equal to 1 during the summer months is a demand shifter. Note, however, that if this seasonal dummy variable is also included in the supply relation because costs are higher during the summer months, then the analyst is unable to estimate the parameters of the supply relation.

3.69 Similarly, to estimate the demand equation we need to use cost shifters to locate the supply relation and trace out the aggregate demand curve. That is, when variables that belong to W_t and Z_t are excluded from the demand equation, shifts of the supply curve permit the estimation of the demand curve parameters, and thus the price-elasticity of demand.

Identifying the conduct parameter

3.70 A second hurdle to identifying conduct is that the analyst might be unable to recover the parameter θafter estimating the pricing equation (or supply relation) given by equation (11). Excluding demand shifters from the supply equation is a necessary requirement to estimate consistently equation (10), this does not guarantee, however, that the conduct parameter itself, θ, is identified. Put simply, the analyst may not be able to separate the parameter $\theta$from other parameters of the supply relation. This implies that the analyst is unable to distinguish perfect competition from perfect collusion.

3.71 The analyst estimates the supply relation to recover the econometric estimate of the slope of that supply relation, for example how a change in Q_t affects P_t. The identification problem stems from the fact that $\theta$is one of several factors determining the slope of the supply relation. There are several components to the slope because Q_t enters equation (10) in two distinct ways: (i) it is part of the marginal cost function, $MC(Q_t, W_t, Z_t)$, and, (ii) it is also part of the marginal revenue function.[63] Even though the analyst can recover the slope of the aggregate demand curve by estimating the demand equation (11) – that is the term $\frac{\partial P_t}{\partial Q_t}$ is known – the slope of equation (10) consists also of $\theta$and the impact of a change in Q_t on marginal cost. As a result, the analyst is unable to separate the conduct parameter from the effect of Q_t on marginal cost. In other terms, the conduct parameter θremains unidentified.

3.72 For example, consider that marginal cost does increase with output. In this case, without any information on costs, it is impossible to know whether the supply relation corresponds to a situation in which the relation $MR = MC$holds as in the perfect collusion case, or corresponds to $P = MC$as in the perfect competition case. In both cases, the supply relation is upward sloping, and thus an increase in consumer demand (an outward shift of the demand curve) leads to a higher price. Instead if the

[63] Through the term $\theta \frac{\partial P_t}{\partial Q_t} Q_t$

marginal cost is constant, the shift in the demand curve does not change the equilibrium price when $P = MC$, whilst it does if the supply curve is upward sloping and $MR = MC$.

3.73 We present below different solutions to overcome this problem.

Using the cost function

3.74 A firm marginal cost may depend on the production level. For example, when the firm production costs exhibit economies (or diseconomies) of scale, the cost of the last unit produced varies with the output level. In particular, in regions of diseconomies of scale (the firm average cost is increasing), marginal cost is always rising, whereas it might be declining or rising when the average cost falls whilst output expands. What prevents the identification of θ stems from the inclusion of quantity in the marginal cost function. Intuitively, as the firm exercises more market power, its price-cost margin increases whilst its output declines. But the resulting change in output also impacts marginal cost. As a result, the size of the price-cost gap is caused by two distinct factors: on one hand as the firm exercises more market power, the gap widens, and on the other hand, the lower production level reduces marginal costs, which also increases price-cost margin.

3.75 Naturally, the analyst would want to infer that part of the price-cost margin that is caused by firm conduct, not by a change in marginal cost. There are two possible solutions to this problem which entails making some assumptions about the cost function. We discuss each solution in turn.

3.76 First, the simplest solution is to assume that marginal cost is constant across the relevant range of output. In this case, the marginal cost function reduces to $MC(W_t, Z_t)$, and $\theta$is identified so long as the demand curve is itself consistently estimated.[64] However, setting marginal cost

[64] This is because the gradient of the demand curve is estimated by the demand equation, it is straightforward to recover θ.

constant might be seen as a strong assumption that may not always hold, in particular when the analyst studies an industry over a certain period of time, in which there are fixed costs and output varies significantly from year to year.

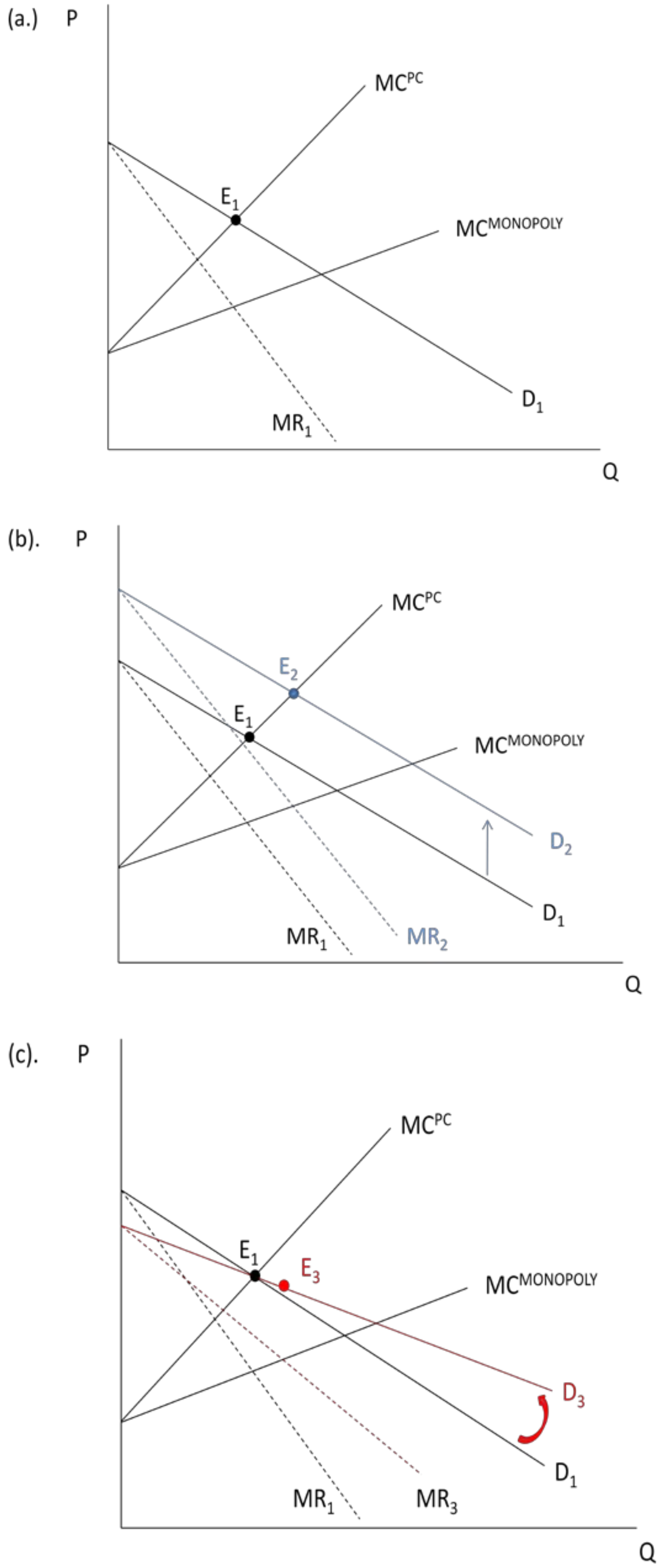
3.77 Second, the analyst can estimate a cost or marginal cost function alongside equations (10) and (11). Gollop and Roberts (1979), and Appelbaum (1979, 1982) adopt this approach. The advantage of this approach is that the parameters of the cost function are estimated separately. Therefore, all the components of the slope of the supply relation are estimated thanks to other equations, except for θ. It is then straightforward to recover the conduct parameter.

Comparative statics in demand

3.78 The most popular method that has been implemented by many NEIO studies is to rely on comparative statics in demand. The general idea was proposed by Bresnahan (1982), and formalised by Lau (1982) for a conjectural variation model in a homogenous good industry. This identification strategy is limited to cases where the analyst can isolate the impact of 'rotations in demand' on market outcomes.

3.79 In this section we present the intuition behind the Bresnahan's (1982) identification using rotations in demand. Suppose an analyst is interested in distinguishing between perfectly competitive and monopoly behaviour. A shift in the demand curve (other things being equal) identifies the supply relation. A rotation of the demand curve serves to separate the monopoly outcome from that of perfect competition because it changes the monopolist's marginal revenue, whilst it has not impact on price-taking firms. The logic of this identification strategy is illustrated in Figure 2 below.

Figure 2: Identifying conduct using rotations in aggregate demand



3.80 To clarify we follow Bresnahan (1982). Consider a perfect cartel (acting as if it were a monopolist) with marginal cost function given by $MC^{MONOPOLY}$ and a perfectly competitive industry whose marginal cost function is given by MC^{PC}. Note that in this example, the cartel industry is more efficient than the perfect competition industry. It is also important to remember that the analyst does not observe the marginal cost functions, but she observes equilibrium price and quantity.

3.81 In this set up, perfect competition and cartels yield exactly the same equilibrium price and quantity (E_1) with the same price and quantity level (see Figure 2a). A shift in aggregate demand does identify the supply relation (here simply the marginal cost function). When the demand curve shifts outward (from D_1 to D_2 – see figure 2b), perfect competition and collusion generate the same equilibrium price and quantity level (E_2). It is clear that without information about the marginal cost function, the analyst is unable to tell apart whether firms are perfectly colluding or acting as price-takers.

3.82 Now suppose that the demand curve instead rotates around the first equilibrium point (from D_1 to D_3 – see Figure 2c). However, the monopoly marginal revenue curve is altered, which lead to a new equilibrium price and quantity (E3). As the slope of demand curve changes, so does the elasticity of demand. When markets are perfectly competitive, a change in the elasticity of aggregate demand does not change the pricing rule: price remains equal to marginal cost. However, in the case of monopoly (and, more generally, imperfect competition), the pricing rule is altered, and thus equilibrium price and quantity will vary.

An illustration using the CPM: The US Sugar Trust

3.83 We illustrate the implementation of the CPM for homogenous good by presenting Genesove and Mullin's (1998) study of the US sugar industry in the late 19th and early 20th century. During that time, the American Sugar Refining Company (also known as the Sugar Trust) attempted to dominate the industry, whilst fighting several entry attempts. Genesove and Mullin estimate the industry level conduct parameter during this period.

3.84 In a first step, they estimate a demand curve to recover the estimate of the price elasticity of demand. Given that the estimated conduct may vary depending on the specification of the demand curve, they consider four functional forms. The demand equation in its general form is equal to: $Q(P) = [\beta(\alpha - P)]^{\gamma}$. By assuming that γ and α take some specific values, they can estimate four different functional forms:

- Quadratic ($\gamma = 2$)
- Linear ($\gamma = 1$)
- Log-linear ($\alpha = 0$, $\gamma < 0$), and
- Exponential (α,$\gamma \rightarrow \infty$, and α/γ constant).

3.85 Genesove and Mullin estimate the demand equations using data on US refined sugar prices and take production data as a proxy for consumption. Because refined sugar is typically not stocked for long, production should be a decent surrogate for consumption volumes.

3.86 As most economic textbooks show, price as a right-hand variable is endogenous. Therefore, to obtain unbiased and consistent estimate of the elasticity estimate, Genesove and Mullin employ an instrumental variable estimator.[65] As instruments for the price of refined sugar, the authors select imports of Cuban raw sugar.[66]

3.87 In a second step, they specify the pricing equation (11):

$$P = \frac{\left(\theta\alpha + \gamma MC(q_i)\right)}{(\gamma + \theta)} + \varepsilon \tag{12}$$

3.88 The analyst may estimate equation (12) to recover the parameter estimate $\hat{\theta}$. However, for this purpose they have to make some assumption about the marginal cost function, $MC(q_i)$. As explained in the preceding section, if the analyst is willing to assume that marginal cost is constant, then the parameter θ is identified given that estimates for γ and α are obtained via the estimation of the demand equation.

3.89 Rather than assuming that marginal cost is constant, Genesove and Mullin posit that the marginal cost function for refined sugar is based on the price of raw sugar:

$$MC(q_i) = c_0 + kP_{RAW}, \tag{13}$$

where P_{RAW} is the price of raw sugar. In this case, the parameter θ is no longer identified in equation (12). To see this, consider the case of the linear demand curve in which $\gamma = 1$. Substituting (13) into (12) yields the following pricing equation:

[65] See Wooldrigde 2002, Chapters 5 and 8 for an exposition of IV estimator and the requirements to select relevant and valid instruments.

[66] In principle, imports of Cuban raw sugar should be uncorrelated with US demand shocks, at least in the short-run. This is because Cuban imports represented an infra-marginal source of raw sugar for the US. Indeed most Cuban production of raw sugar was exported to the US, whilst European markets were far too distant to represent a viable alternative (for additional discussion on the rationale for selecting Cuban imports as instruments see Genesove and Mullin at pages 362-364).

$$P = \frac{(\theta\alpha + c_0)}{(1+\theta)} + \frac{k}{(1+\theta)} P_{RAW} + \varepsilon \quad (14)$$

3.90 Even though the analyst will recover an estimate for α by estimating the demand equation, it is not possible to separately identify, c_0, k and θ. Practically, the analyst would estimate the following pricing equation:

$$P = \delta^0 + \delta^1 P_{RAW} + \varepsilon, \quad (15)$$

where $\delta_0 = \frac{(\theta\alpha + c_0)}{(1+\theta)}$ and $\delta_1 = \frac{k}{(1+\theta)}$. With more unknown structural parameters than the number of estimated parameters, the system cannot identify c_0, k and θ.

3.91 To overcome this problem Genesove and Mullin adopt the solution proposed by Bresnahan (1982) and introduce a demand rotator. They observe that demand for sugar is seasonal. The peak season takes place in the summer (third quarter) when sugar is used as an input into fruit canning. Both the slope and the intercept of the demand functions are allowed to vary between the high and low season. The estimation results show that demand expands during the peak season and become more inelastic.

3.92 Using a linear demand we illustrate how the introduction of a 'demand rotator' allows the analyst to identify θ. The new demand equation is given by:

$$Q = \beta\alpha + \beta^H \alpha^H D^H - \beta P - \beta^H D^H P + \varepsilon \quad (16)$$

where $D^H = 1$ in the third quarter for the peak season and zero otherwise. The slope of the demand curve is allowed to vary between the high and low season. In the low season the slope is given by β, whereas in the high season it is given by the sum $\beta + \beta^H$. The pricing equation (14) becomes:

$$P = \frac{\theta}{(1+\theta)} \frac{\beta\alpha + \beta^H \alpha^H D^H}{\beta + \beta^H D^H} + \frac{c_0}{(1+\theta)} + \frac{k}{(1+\theta)} P_{RAW} + \varepsilon \quad (17)$$

3.93 Genesove and Mullin estimate (17) using a non-linear IV estimator. Estimates for the demand parameters β, α, β^H and α^H are obtained by estimating the demand equation (16). In this case θ is identified. The results of the estimation of (17) are reproduced in the Figure 3 below.

Figure 3: Estimates of pricing equation parameters

	Linear		Direct Measure
	(1)	(2)	(3)
$\hat{\theta}$	.038 (.024)	.037 (.024)	.10
$\hat{c}_u$	.466 (.285)	.39 (.061)	.26
$\hat{k}$	1.052 (.085)		1.075

Source: Genesove and Mullin (1998).

3.94 For the linear case, the econometric results (see column (1) and (2)) show that θ has a very low value (0.038 and 0.037). In fact, it is closer to perfect competition ($\theta = 0$) than the monopoly outcome ($\theta = 1$). The monopoly (or perfect collusion) hypothesis is rejected by the data, however perfect competition is not.

Switching models

3.95 As noted in paragraphs 3.27 to 3.39, a firm's expectations about rival's **future** conduct are central to the mechanism that enables firms to reach and sustain a collusive outcome. Because a conjectural variation model is static by nature it can only measure **current** conduct, but it does not include the dynamic elements that explain how collusion is sustained through repeated interaction between firms.

3.96 Nonetheless, empirical conjectural variation models can still be used to estimate market power As Bresnahan (1989) argues, because firm's observed behaviour are a function of their expectations, the CPM can still be used to measure average market power that prevails under collusion **if the collusive outcome rarely breaks down** (for example there are very few punishment phases observed in the data).

3.97 However, Green and Porter's (1984) model suggests that the collusion might actually break down quite frequently. It is therefore quite possible that during the period examined sequences of collusive conduct are followed by period of price war. In this case, when estimating market power the analyst mixes the level of market power under collusion with that during periods of price war. Obviously market power is not estimated accurately. The challenge is to measure separately market power in the collusive phase and the price war periods.

3.98 By using a 'switching model' approach Porter (1983) shows that the analyst can assess market power in the collusive regime. Switching models are relatively straightforward extensions of the CPM **if** there is a variable available that indicates when firms actually switch behaviour. If the analyst assumes that during the price war period, firms adopt a specific conduct (for example perfect competition), then she can recover the **level** of market power under collusion.

3.99 However, if the analyst does not observe when firms alter their behaviour, then she cannot set up a binary variable to indicate when firms switch from collusion to price war. This is the situation faced by Porter (1983). However, he shows that by making some assumptions about the error term of the supply relation and assuming a specific form of conduct during the price war phase, he is able to estimate the level of market power under collusion.

3.100 Below we describe the switching model that Porter applied to the late 19th century US railroad cartel.

Porter's (1983) switching model: Identifying conduct with unobserved regime switches

3.101 Porter (1983) examines how firms pricing behaviour changed during the period in which the Joint Executive Committee (JEC) railroad cartel was in place. He employs a simultaneous equation switching regression model to assess whether firms altered behaviour during the cartel period and, if so, whether, as predicted by the Green and Porter model, in collusive periods the firms collectively set price above marginal cost but lower than the joint profit maximising price.[67]

3.102 Porter considers a static oligopoly model in which **N** firms supply a perfectly homogenous product. He assumes that each firm knows the functional form of the industry demand curve as well as each others' cost function. The constant price elasticity industry demand curve in each period t is given by:

$$\ln Q_t = \alpha - \epsilon \ln P_t + Z_t'\gamma + v_t, \qquad (18)$$

where $Q$is industry output, $P$is the industry price, $Z$is a vector of exogenous demand shifters, $\gamma$is the corresponding set of unknown coefficient, $\epsilon$is the industry price-elasticity of demand, and v_t is the error term. $t$indexes time.

3.103 On the supply side, firms have different costs of production. Each firm's cost function is given by:

$$C_i(q_{it}) = a_i q_{it}^{\delta} + F_i, \qquad (19)$$

where $i$indexes firms, q_i is firm **i**'s output, and F_i represents each firm's fixed costs.[68] Entry decisions are not modelled but are accounted for by a shift in the supply curve.

3.104 Porter assumes that firms maximise per-period profits by choosing quantity. Each firm conjectures about the response of its rivals when it selects its quantity. Firm **i**'s first order condition is given by:

[67] This results from the fact that larger profits in the cooperative periods provide a greater incentive to secretly cut prices. Hence, by setting prices below the joint profit maximising level, firms trade off short run profits for increased future cartel stability.

[68] The benefit of this functional form is that it enables a range of models of competition.

$$p_t\left(1+\frac{\theta_{it}}{\epsilon}\right) = a_i \delta q_{it}^{\delta-1}, \quad (20)$$

where θ_{it} is the individual conduct parameter, and the right-hand side is firm *i*'s marginal cost. The conduct parameter is equal to zero when firms set price at marginal cost, it is equal to one when firms maximise joint profits. Alternatively, when firms produce the Nash-Cournot output level, $\theta_{it} = {}^{q_{it}}/_{Q_t}$, which is firm *i*'s market share in period *t*.

3.105 Porter estimates an industry level model, which is given by the following system of equations:

Demand equation
$$\ln Q_t = \alpha - \epsilon \ln P_t + Z_t^{'}\gamma + v_t \quad (21)$$

Industry Supply equation
$$-(\delta - 1)(Q_t) + \ln P_t = \mu + \beta I_t + W_t^{'}\emptyset + u_t \quad (22)$$

where $\mu = \ln D, \beta = -\ln\left(1+\frac{\theta_t}{\epsilon}\right)$, I_t is an indicator which takes the value 1 when the industry is in a cartel regime and 0 otherwise.[69] W_t is the set of exogenous explanatory variables that capture aggregate supply shifts (that is, the entry of new firms) and β is an unknown parameter that measures the extent to which prices converge to the monopoly level under a cartel regime.

3.106 Porter (1983) assumes that the indicator variable is not observable to the researcher, but it is to the firms. As such it is treated as unobserved and it is therefore part of the supply equation's error term. Clearly, without additional stochastic assumptions neither μ or β can be separately identified. To this end, Porter introduces non-normality in the error term of the supply equation. He assumes that the demand and supply error terms, v_t and u_t, are *i.i.d* normal and that the unobserved

[69] Here Porter assumes that the firm conduct in the price war period (or punishment regime) corresponds to static Nash-Bertrand conduct.

regime indicator follows an *i.i.d* Bernoulli process.[70] It is the non-normality of the error term of the supply equation that allows him to identify β empirically. The identification of the switching model hinges on the assumption that the demand and supply errors are $i.i.d$normal. If not, then there is more than one explanation for non-normal errors and the model is no longer identified.

3.107 With these assumptions, Porter identifies periods in which firms switched behaviour and then he estimates the market supply and demand functions. Table 5 below reproduces Porter's estimation results.

[70] In other words, the probability that the observed data are generated by collusive conduct is $k \in [0,1]$ and the probability that the data are generated by a competitive conduct (the punishment regime) is $1 - k$.

Table 5: Porter's estimates of the structural model

Supply Relation		Demand Equation	
Parameter	**Estimates (se)**	**Parameter**	**Estimates (se)**
μ	-2.416 (0.710)	α	9.090 (0.149)
β	0.545 (0.032)	ϵ	-0.800 (0.091)
$\emptyset_1$	-0.165 (0.0240	γ	-0.430 (0.120)
$\emptyset_2$	-0.209 (0.036)		
$\emptyset_3$	-0.284 (0.027)		
$\emptyset_4$	-0.298 (0.073)		
$\delta - 1$	0.090 (0.068)		

3.108 We draw two main conclusions:

- The results show that firms changed conduct during the cartel period. The null hypothesis that no change in behaviour is observed (that is, $H_{0:}\beta = 0$) is overwhelmingly rejected.[71] The coefficient estimate of the switching dummy variable is considerably greater than 0 and is statistically significant. Accordingly periods of collusion involved substantially higher prices. Specifically, the estimate implies that in equilibrium the price was 66 per cent higher whilst quantity was 33 per cent lower in cooperative periods than otherwise.
- The pricing behaviour in the collusive periods was consistent with the predictions of the Green and Porter model. That is, the results

[71] The coefficient on the behaviour switching dummy variable in the estimated supply equation is both considerably greater than 0 ($\beta = 0.545$) and is significant (the t-statistic for this coefficient is 0.545/0.032 = 17.03125).

provide evidence that firms' pricing behaviour in the cooperative periods was roughly consistent with Nash-Cournot behaviour,[72] which implies that whilst firms did collectively raise prices by a significant amount they did not charge the joint profit maximising price.

Wider application of switching models

3.109 Porter's study shows that switching models may extend the application of CPM when firms' conduct vary across periods or across markets. Switching models can be used to identify collusive conduct whenever observed data contains a mix of conducts across periods and/or markets. In Porter's model, firm conduct is allowed to vary between periods of collusion and of price war. In other applications, firms supply the same product, but they behave differently depending on the geographic market. For example, Salvo (2010) set to test whether coastal cement markets in Brazil are constrained by the threat of imports, whilst inland cement markets are not (for more detail see paragraphs 3.118 to 3.123 below).

3.110 Whilst the flexibility of switching models makes them more attractive than the CPM, it should be noted that they are more demanding in terms of data. In particular, to allow the analyst to estimate accurately market power that stems from collusive conduct, the data must contain a sufficient number of data points for markets in which collusion prevails and the same requirement applies for markets in which firms compete. Salvo (2010) states that his data sample may contain insufficient information to distinguish between Nash-Cournot and monopoly conduct.

[72] As shown by the first order condition for profit maximisation above, this is given by $\beta = -\ln\left(1 + \frac{\theta_t}{\epsilon}\right)$ and the value of θ_t implied by the regression results is 0.336. This is roughly consistent with Nash-Cournot behaviour in cooperative periods.

Misspecification and inference issues when applying the CPM

3.111 To recover a value for the conduct parameter the CPM consists in the application of econometric techniques to estimate a supply relation such as equation (2). However to guarantee that market power is measured accurately, two conditions must be met:

- the functional form assumptions on demand and marginal cost must be correct, and
- the observed market outcomes must be generated by a conjectural variation model.

3.112 If neither condition is met, then the structural econometric model on which the CPM is based is said to be misspecified. As a result, the estimated market power (or conduct) parameter is biased. However, the nature of the misspecification is slightly different in each case.

3.113 First, the analyst may select a functional form for the demand and marginal cost that is a poor approximation of the data. This is a standard problem in most empirical studies. In this particular case, and as highlighted in paragraphs 3.70 to 3.82 and by Reiss and Wolak (2007), functional form assumptions allow the analyst to separately identify marginal cost and the conduct parameter in the supply relation.[73]

3.114 The problem remains that these assumptions cannot be directly tested. This means that when the conduct parameter departs from value that correspond to a well-understood static model (see Table 1), the analyst cannot rule out that this is the result of the functional form assumptions. For example, if the industry level conduct parameter estimate is 0.4

[73] Reiss and Wolak (2007) stress that without any parametric assumptions for the demand and supply equations in the structural model, the analyst can only retrieve join density of prices and quantities given exogenous demand and supply shifters using non-parametric smoothing techniques. Therefore, to separately identify and estimate the demand and supply equations from observed industry data the analyst must make parametric assumptions.

whereas the Nash-Cournot is 0.2 (in a five-firm market), the difference may simply be due to this sort of misspecification. For this reason, many CPM studies report estimates of the conduct parameter under different functional form assumptions so as to assess the sensitivity of the conduct parameter estimate.

3.115 Second, the other source of misspecification is arguably more complex, yet it also applies to most empirical studies. Nevertheless, we discuss this issue in more depth in the remainder of this section. In a nutshell, when the underlying economic model that generates the price and quantity data observed by the analyst is poorly approximated by a conjectural variation model, then the CPM model may fail to estimate accurately market power.

3.116 We discuss two illustrations in turn:

- First, the analyst considers an oligopoly model with domestic firms whilst ignoring the impact that the threat of foreign imports bears on the price level. When the threat of imports actually constrains the domestic price, Salvo (2010) shows that the CPM understates market power.

- Second, the equilibrium outcome of some repeated oligopoly games cannot be reproduced by a conjectural variation model. In these cases, as Corts (1999) shows, the CPM may not measure accurately market power.

3.117 Finally, we report the results of a handful of studies that assess empirically the accuracy of the CPM. In some cases, the estimated conduct parameter diverges widely from the adjusted Lerner index.

Omitting the impact of foreign import threat

3.118 The CPM fails to accurately measure market power when competitive forces that affect the equilibrium price and quantity are not taken into account (that is, they are not included in the structural econometric model).[74] In particular, we show that this is the case when the analyst incorrectly omits the threat posed by foreign imports. Intuitively, when the analyst considers that UK-based firms compete in autarky, in so doing she fails to realise that the actual market price level is constrained by the threat of imports and not by domestic competitive forces. Consequently, the price is set so that no foreign imports take place. In this case the CPM understates market power.

3.119 Salvo's (2010) study of the Brazilian cement industry illustrates this problem. He shows that when the domestic price level is actually limited by the threat of foreign imports, the supply relation based on the theory of conjectural variation is misspecified. In this case the identification strategy suggested by Bresnahan (1982) and Lau (1982) does not work: the observed price is not generated by an oligopoly model with domestic firms, but is set at a point so that no imports enter the Brazilian market. As Salvo points out, imports need not materialize to impact the domestic price level. In fact, foreign imports have accounted for 1-2 per cent of Brazilian cement consumption.

3.120 Figure 4, taken from Salvo (2010), graphically illustrates the identification problem facing the analyst who is unaware that the equilibrium price is being constrained by a latent threat of imports. In this example, the supply of foreign imports is assumed to be perfectly elastic. As the graph shows, the import threat prevents the analyst from determining which of the following two alternative models generate the data (they are observationally equivalent): (i) a competitive industry with high marginal cost, $\overline{c}$, and (ii) a monopoly with low marginal cost $\underline{c}$, facing a price limit at $\overline{c} = p^I$, where p^I is the price level above which imports would take place.

3.121 When the import threat matters, the optimal monopoly price level, p^*, is above the price at which importers would start supplying the domestic market, p^I. In other words, p^*, would be the equilibrium price without

[74] Note that this problem also affects the menu approach that we discuss in the second part of this chapter.

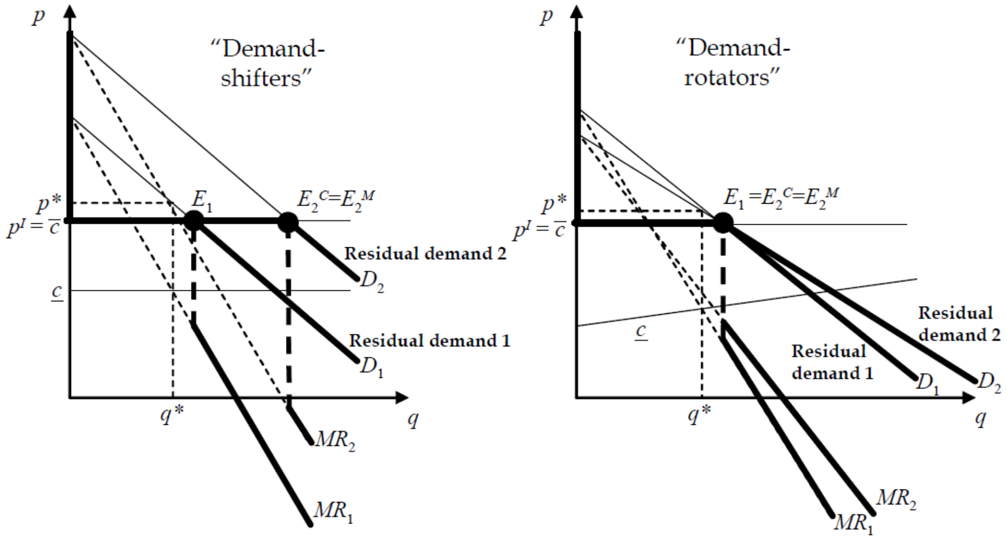
the import constraint. The equilibrium E_1 in both panels shows that the threat of imports affect the domestic price, which is set to p^I.

- The left panel in Figure 4 considers the case of demand shifters. As can been seen, after demand shifts outwards (D_1 to D_2) price remains at the same level at the new equilibrium E_2. The problem the analyst faces is that the new equilibrium is consistent with the constrained low cost monopoly and the perfectly competitive industry with high marginal cost, $\bar{c}$. Consequently, the observed outcome resulting from a shift in demand cannot identify firm conduct.

- The right panel in Figure 4 considers the case of demand rotators, which is the solution proposed by Bresnahan (1982) (see paragraphs 3.70 to 3.82 above). After demand rotates around E_1 the equilibrium remains at the same point, that is, $E_2 = E_1$. As was the case in the left panel, the new equilibrium is the same under a high cost perfectly competitive industry and a constrained low cost monopoly. As a result, the analyst cannot identify firm conduct by using a rotation of demand.

3.122 This example illustrates Salvo's argument. That is, unaware that the prices are constrained by outside forces, the analyst may perceive the lack of price variation in response to exogenous demand shocks as evidence that the market is intensely competitive (that is, in a perfectly competitive market, price remains at the level of marginal cost, therefore neither a shift nor a rotation in the demand curve affect the price level). In reality, the domestic firms earn positive profit margin, but due to the threat of imports, they are unable to change prices in response to a shift or a rotation in demand.

Figure 4: Price-cost margins are no longer identified when the entry threat binds



Source: Salvo (2010)

3.123 Salvo (2010) shows that estimating the typical CPM pricing equation without accounting for the latent import threat leads the analyst to understate market power. In the case of the Brazilian cement industry, the CPM yield estimates of θ close to zero. In fact, Salvo cannot reject the hypothesis of perfect competition. However, in his study, even when the empirical model accounts for the latent import threat, the estimated parameter conduct remains very close to zero. One possible explanation is that the empirical model is still not rich enough to capture the competitive interaction between Brazilian cement producers. In particular, in periods when foreign imports do not constrain the domestic price (this is the case when the R$/US$ exchange rate is low, making imports less competitive), it cannot be excluded that domestic firms adhere tacitly to a mutually beneficial strategy, yet, they are unable to set the monopoly output without causing the collusive arrangement to breakdown. In this case, as we will see just below, the CPM may yield biased and inconsistent estimates of market power.

The Corts' critique

3.124 The empirical model that forms the basis of the CPM is based on the theory of conjectural variations. The problem is that conjectural variation models cannot represent all dynamic oligopoly models in which a collusive outcome may emerge. This is the essence of the Corts' critique, which is summarised as follows:

> 'Without stipulating the true nature of the behaviour underlying the observed equilibrium, no inference about the extent of market power can be made from analysis of the observed variables'.

3.125 In other words, when the underlying economic model that generates the data observed by the analyst is not a conjectural variation model, the econometric estimation of the conduct parameter is unlikely to provide a reliable estimate of market power.

3.126 In the following paragraphs, we first introduce the Corts' critique. Then we illustrate, based on Corts' simulation results, the extent to which the CPM fails to measure market power when industry behaviour corresponds to a dynamic oligopoly that cannot be reproduced by a conjectural variation model. Finally, we present a proposed solution to remedy the Corts critique whose scope of application remains limited.

An introduction to the Corts' critique

3.127 In some situations, a conjectural variation model generates the same outcome (in terms of price and quantity) as that of a repeated oligopoly model. For example, in some repeated oligopoly models, firms achieve the perfect collusive outcome (that is, the monopoly price and quantity level), but this outcome is also reproduced by a conjectural variation model with symmetric firms and $\theta = N$. In this particular case, the dynamic oligopoly game and the conjectural variation model are observationally equivalent. However, there are many cases when collusion is not perfect (that is, firms have to settle for less than the monopoly price level as this renders collusion more sustainable), and no conjectural variation model can reproduce the same outcomes (see the next subsection for an example of such a dynamic game). In that context, the CPM fails to measure accurately market power.

3.128 To assess the accuracy of the CPM, Corts (1999) compares the adjusted Lerner index (or as-if conduct parameter) defined in equation (3) with the estimated conduct parameter. Following Corts' notation we define the 'as-if' conduct parameter as $\tilde{\theta}_i$. Assuming N symmetric firms ($Nq = Q$), it is equal to:

$$\tilde{\theta}_i = \frac{p-c}{p} N\varepsilon = \frac{p-c}{-P'q} \qquad (23)$$

where $-P'$ is the slope of the inverse demand function, and ε the price elasticity of demand whilst $p-c$ is the price cost margin. The adjusted Lerner index measures price-cost margin on **average**.

3.129 The estimated conduct parameter, $\hat{\theta}_i$, measures something different. Corts shows that it gauges how responsive the price-cost margin is to changes in equilibrium quantity driven by demand-fluctuations. Recall from paragraphs 3.16 to 3.22 that the analyst employs an IV/GMM estimator to estimate the CPM model as the quantity variable is endogenous. Typically, the analyst uses demand shifters as instruments to estimate the slope of the supply relation, one of whose components is the conduct parameter. This implies that the estimated conduct parameter is a function of how equilibrium quantity varies with demand shifters (that is, the instruments). Corts shows that in the linear case (assuming a linear demand curve, a linear marginal cost function and a linear response between equilibrium quantity and demand shifters), the conduct parameter measures how responsive the price-cost margin is to demand fluctuations. Formally this is:

$$\hat{\theta}_i = \frac{1}{-P'} \frac{d(p-c)}{dx} \Big/ \frac{dq^*}{dx} \qquad (24)$$

where x represents demand shifters and q^* is the equilibrium output. The 'as-if' conduct parameter and the estimated conduct parameter are the same only when:

$$\tilde{\theta}_i = \hat{\theta}_i \text{ when } \frac{p-c}{x} \Big/ \frac{q^*}{x} = \frac{d(p-c)}{dx} \Big/ \frac{dq^*}{dx} \quad (25)$$

3.130 That is, it must be the case that the average and marginal responsiveness of price-cost margin to demand fluctuations are exactly the same. This is not true unless the underlying model that generates equilibrium price and quantity is also a conjectural variation model.

3.131 Again, the dynamic oligopoly model and the conjectural variation model that yield the monopoly outcome are observationally equivalent as they generate the same price and quantity level. This implies that the average and marginal responsiveness of the price-cost margin is the same, and formally: $\tilde{\theta}_i = \hat{\theta}_i = N$. In this case, it does not matter which model generates the collusive outcome.

3.132 However, when the underlying economic model is not a conjectural variation model, the average and marginal responsiveness are different. For example, when the discount factor is sufficiently low that the monopoly outcome cannot be achieved, yet collusion takes place, and demand shocks are short-lived, the estimated conduct parameter does not detect any collusive behaviour (this will be shown in more detail below with the simulation results developed by Corts). In this case, in every period the equilibrium quantity is the Cournot quantity less a function of the punishment incurred by deviation. The punishment is the difference between future profit under collusion and future profit when collusion breaks down (see Corts for more details). When demand shocks are short-lived, they do not impact future demand, and thus future profit. As a result, profit under punishment remains unaffected by today's change in demand. This also means that demand shocks affect only the Cournot component of equilibrium quantity, and clearly price-cost margin responds in a Cournot fashion to demand fluctuations. Because the estimated conduct parameter measures the marginal responsiveness of the price-cost margin to demand-driven fluctuations, $\hat{\theta}_i = 1$, which is consistent with Cournot behaviour. Yet, the adjusted Lerner index $\tilde{\theta}_i$ measures price-cost margin that are consistent with a collusive outcome, as firm sustain an equilibrium quantity that is less than the Cournot level. In this particular case, $\tilde{\theta}_i > \hat{\theta}_i$, that is, the estimated conduct parameter understates market power.

3.133 In general, the Corts critique can be summarized as follows: the conduct parameter $\tilde{\theta}_i$ provides a measure of the average degree of market power, whereas the estimated conduct parameter $\hat{\theta}_i$ yields a measure of conduct at the margin. These two are equivalent only when the market outcome can be replicated by a conjectural variation model.

Illustrating the effects of the Corts critique: evidence from simulation

3.134 To show how severe the problem could be, Corts compares the estimated conduct parameter with the 'as if' parameter using data generated by a dynamic oligopoly model. Specifically, this is a duopoly model, where the firms look to set the monopoly price and share industry profits. They play the so-called 'grim-trigger' strategy whereby a firm selects the static Cournot quantity forever after one firm is found cheating the agreement.

3.135 Corts introduces two important parameters that condition the extent to which collusion is sustainable:

- **A common discount factor, $\boldsymbol{\delta}$:** firms are highly myopic when discount factors are low ($\delta \to 0$) and highly patient when discount factors are high ($\delta \to 1$). All else equal, more patient firms are more likely to sustain a collusive outcome as they value future profits more, which makes short-run gains from deviating from the collusive output less attractive.

- **The persistence of demand shocks,** λ: demand shocks are increasingly short-lived as $\lambda \to 0$. In this case current demand contains little information about future demand. In contrast, when $\lambda \to 1$ demand shocks are long-lasting. In this situation, the current level of demand is a better predictor of future demand conditions. All else equal, increased certainty over future demand conditions increase the likelihood that collusion can be achieved and maintained.

3.136 When collusion is sustained at the monopoly price level, the conduct parameter is equal to 2 (recall that perfect collusion implies $\theta = N = 2$). Instead, when collusion breaks down and firms compete *à la* Cournot, the conduct parameter is equal to 1.[75] For some values of the discount rate, the collusive price is set below the monopoly price level to avoid a breakdown in the collusive arrangement.[76] In these cases, the conduct parameter ranges from 1 to 2.

3.137 Corts generates data by assuming a linear demand and constant marginal cost. He computes the 'as if' conduct parameter as in equation (3) (that is, the elasticity-adjusted Lerner index). This represents the actual degree of market power. Then he applies the CPM to the data generated by the simulation to estimate a conduct parameter. The difference between the 'as-if' conduct parameter and the estimated conduct parameter provides an indication about the extent to which market power is measured accurately.[77]

3.138 Figure 5 shows the results of the comparison when demand shocks are assumed to be positively correlated. The conduct parameter is plotted on the vertical axis and the discount factor is plotted on the horizontal axis.

3.139 The figure shows that the 'as-if' conduct parameter is equal to 1 when the discount factor is zero (that is, since neither firm values the future

[75] Recall that when the market power is consistent with Cournot the conduct parameter is 1. When two symmetric firms engage in collusive conduct and achieve the monopoly outcome, the conduct parameter is 2.

[76] The incentive constraint does bind, which means that the monopoly price is too high given the discount factor. The players must settle for a less profitable scheme to ensure that collusion is sustainable.

[77] Combining quantity and the demand and cost shifters the CPM can recover the estimated CV parameter using 2-stage least squares.

they select the static Cournot quantity in every period), and it is equal to 2 when the discount factor is greater than 0.6 (that is, both firms are sufficiently patient so that they achieve the monopoly outcome). The other lines in the figure show estimated conduct parameters resulting from the application of the CPM with differing degrees of persistence of the demand shocks.

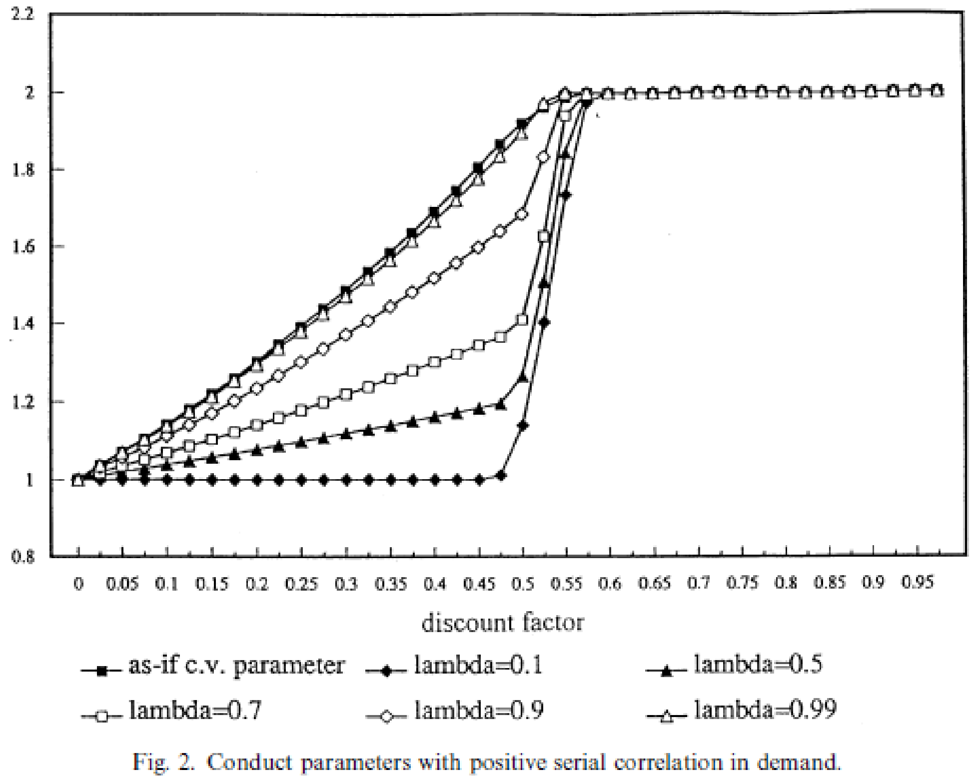
3.140 Corts' simulations reveal that under certain circumstances there is a wide gap between the 'as-if' conduct parameter (or the adjusted Lerner index) and the estimated conduct parameters. In particular, Corts finds that:

- when firms are patient (the discount factor is above 0.55), the CPM accurately measures market power
- when the discount factor is relatively low (less than 0.5) and demand shocks are not enduring ($\lambda \to 0$), the CPM understates market power, and find an estimate that is more consistent with Cournot competition, when in fact firms collude, albeit imperfectly
- the CPM provides an increasingly accurate measure of market power when the demand shocks become more long-lasting (the reader can see that the line labelled $\lambda = 0.99$ is similar to the 'as-if' parameter line).

3.141 The results of these simulations clearly show that the estimated conduct parameter does not always provide an accurate estimate of market power.

3.142 To see why, consider the following example based on the figure below. Let us suppose that CPM is applied to two different industries: one with highly persistent demand shocks ($\lambda = 0.9$) and the other with less permanent demand shocks ($\lambda = 0.5$). Further suppose that in both cases the estimated conduct parameter is 1.2. Without heeding the warnings of the Corts critique, we might take the estimated conduct parameters as evidence that the firms in both industries wield the same degree of market power. However, and in contrast to the estimated conduct parameter, Corts' simulations show that the 'as-if' conduct parameter (or the true degree of market power) is very different in the two industries. In the industry where demand shocks are highly persistent the 'as-if' parameter is 1.3. This is quite close to the estimated conduct parameter. However, where demand shocks are less enduring, the 'as-if' parameter is 1.9. This is far greater that the estimated conduct parameter of 1.2 and is closer to the collusive level of market power. In short, the estimated conduct parameter can provide a misleading measure of market power.

Figure 5: Conduct parameters with positive serial correlation of demand shocks



Source: Corts (1999)

3.143 The reliability of the above simulation results are mitigated by the fact that the CPM fails to measure accurately market power when firms are implausibly impatient (the discount factor is below 0.55). In this case, the interest rate would be at least 81 per cent, and that rate augment as the discount factor declines.[78]

3.144 Corts' also repeats the simulations assuming that demand shocks are negatively correlated. The results are shown in Figure.

3.145 The key result from these simulations is that the estimated conduct parameter is negatively correlated with the 'as-if' parameter. In other words, it implies that the estimated conduct parameter suggests that the industry is even more competitive than Cournot when the actual level of market power exerted increases. This is especially unusual since the simulation assumes one shot Cournot is played forever after cheating is detected.

3.146 These simulation results suggest that in industries that experience demand shocks that are negatively correlated (that is, seasonal fluctuation in demand) applying CPM to identify conduct could lead the analyst astray. She may be making inaccurate inferences about market power. In particular, the estimated conduct parameter might be indicating that the industry is highly competitive when, in reality, firms are achieving monopoly mark-ups through collusion.

[78] A discount factor of 0.55 implies an interest rate greater than 81 per cent. In the context of weekly, monthly or even annual observations, this would appear to be implausibly high. We thank Peter Davis for highlighting this point.

Figure 6: Conduct parameters with negative serial correlation of demand shocks

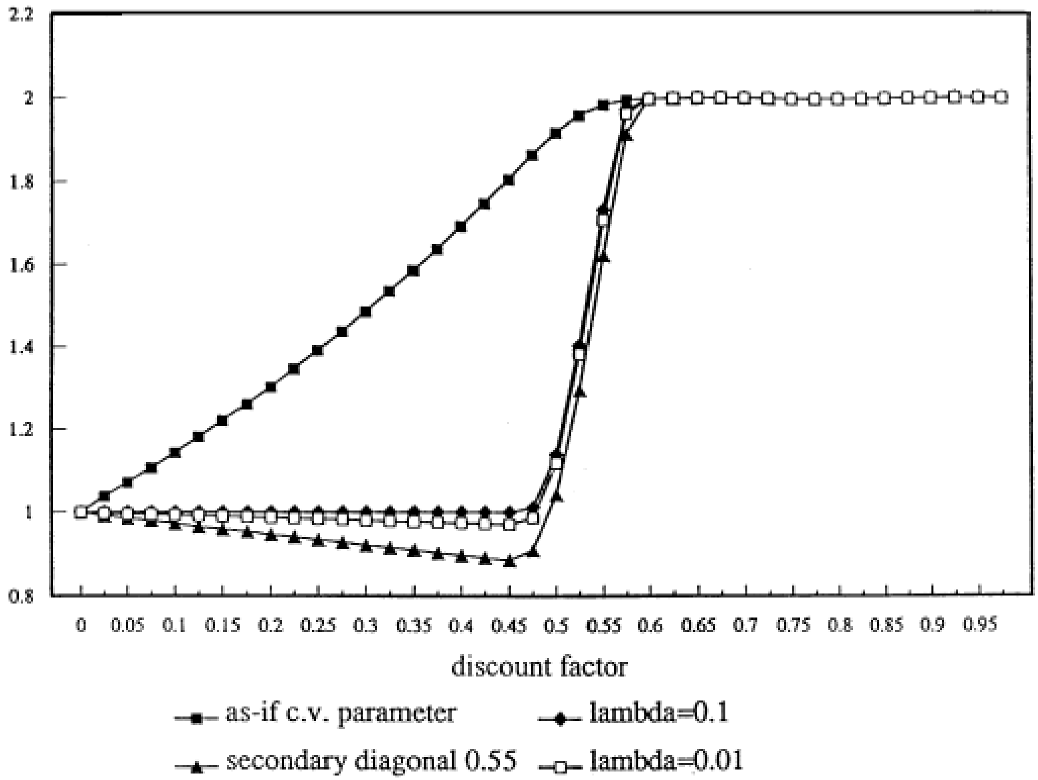


Fig. 3. Conduct parmeters with negative serial correlation in demand.

Source: Corts (1999)

3.147 In summary, these simulations highlight the issue at the heart of the Corts critique. Namely, if the underlying economic model that generates the market outcome is poorly approximated by a conjectural variation model, then the CPM is misspecified and it provides severely biased estimates of market power.

3.148 In some circumstances, however, the results of the above simulation results show that the CPM may perform quite well. First, when the discount factor is high (and thereby the interest rate at reasonable value), the CPM estimates accurately the elasticity-adjusted Lerner index. Second, when demand shocks are permanent, then the CPM also replicates the adjusted Lerner index. The analyst might therefore be tempted to rely on this method in industries that exhibit this feature.

3.149 While the example above would appear to be encouraging, it is important to recognise that this represents only one specific situation where the CPM might perform adequately in practice. Corts simulation results are based on an efficient super-game, but collusion may emerge in other settings. Furthermore, there may be omitted factors for which the conjectural variation model fails to account. For example, Salvo (2010) shows that the conjectural variation model grossly understates market power when the credible threat of imports is incorrectly omitted from the model (see paragraphs 3.118 to 3.123). In this case applying the CPM to estimate market power is likely to provide severely biased estimates.

Can the Corts' critique be solved?

3.150 Puller (2009) purports to solve the Corts' critique by proposing a methodology that estimates consistently the conduct parameter. For example, Corts shows that when firms are engaged in an efficient tacit collusion game (that is, whenever possible they jointly maximise profit to achieve the monopoly outcome), firms may sometimes have to settle for a sub-optimal outcome. When this is the case, the CPM may seriously understate market power as shown by the simulation results above.

3.151 Using this efficient tacit collusion game, Puller recasts the Corts critique as an omitted variable problem. When the incentive compatibility constraint binds, firms do not achieve the monopoly outcome – though they may be close to it. In this case, the static first-order condition, which forms the basis of the supply relation that is estimated by the analyst, contains an extra term (the effect of the incentive compatibility constraint on firm conduct). This extra term is common to all firms, yet it may vary over time and remain unobserved by the analyst. If the omitted term is correlated with the firm quantity, estimates of the conduct parameter are biased and inconsistent. One way to alleviate the problem is to include time fixed-effects, which is the solution proposed by Puller.

3.152 This approach, however, does not constitute a general remedy for the Corts' critique as Puller (2009) recognises. First, the analyst needs to acquire a panel of firm level data to estimate the model. Second, and more importantly, this proposed methodology is designed to work with efficient pricing dynamic games, that is when firms are efficiently colluding. It is unclear whether this method is robust to other forms of dynamic pricing. As a result, the Corts' critique must still be carefully considered before using the CPM to measure market power.

Evidence of bias using CPM to measure the market power

3.153 To test empirically the accuracy of the CPM some studies compare the estimate of the conduct parameter with direct estimate of the elasticity-adjusted Lerner index. Few studies can actually implement this comparative assessment because access to data that accurately describes marginal cost remains a luxury. Recall that to compute the adjusted Lerner index, the analyst must have reliable data on price and marginal cost as well as some information on the price elasticity of demand. The latter can be obtained through the estimation of a demand equation or by reference to existing studies. In this section, we report the results of three empirical studies that compare estimates from the CPM with a direct estimate of market power in homogenous product industries.

3.154 The Genesove and Mullin (1998) sugar study provides the first comparison (see paragraphs 3.83 to 3.94). The results imply that the CPM understates market power, however, the difference between with the direct measure of market power is not economically significant.

3.155 Wolfram (1999) uses detailed marginal cost data from the UK Electricity Industry to compare the industry level elasticity-adjusted mark-ups. Using previous studies, Wolfram calibrates the demand for UK electricity generation assets and finds that market power is very low (that is, the calibrated conduct parameter is 0.05 – equivalent to a symmetric 20 firm Nash-Cournot model). Then and in line with the approach taken by Genesove and Mullin (1998), she applied the CPM using rotations of demand to estimate the industry conduct parameter. The results reveal an industry conduct parameter very close to 0. However, Wolfram notes that she is unable to reject the hypothesis that it is significantly different to the calibrated industry conduct parameter (0.05).

3.156 Clay and Troesken (2003) follow a similar approach as that used by Genesove and Mullin, in particular they adopt similar demand and cost function, to the US Whiskey Trust in the late nineteenth century. In spite of the fact that the Trust was a hard-core cartel, their results suggest that it did not exercise much market power. They found a relatively low level of market power. Depending on the functional form of the demand equation, the direct estimate of market power ranges from 0.052 to 0.103 (see Table V in their study). In this work, the CPM somewhat overestimates market power relative to direct estimates of the adjusted Lerner index. The conduct parameter estimates vary from 0.120 to 0.346 (see Table VII in their study). The problem stems largely from the fact that their implementation of the CPM underestimates marginal cost, widening the price-cost margin.

3.157 Kim and Knittel (2006) apply the CPM to the California electricity market. They also compare direct estimates of the adjusted-Lerner index that they construct using actual data on marginal cost with the estimated conduct parameter that result from applying the CPM.[79] To recover the elasticity of demand, they estimate a demand model for strategic firms, that is, firms that possess market power. They leave aside non-strategic firms that are price-takers and only bid their marginal cost curves. To test the robustness of the results, they assume that the demand curve takes different functional forms. Their results are reproduced in the table below:

[79] They use price data as well as short-run marginal cost data from Borenstein, Bushnell and Wolak (2002).

Figure 7: Direct measures of Lerner and elasticity-adjusted Lerner indexes

	LI	Linear Model Adj LI	Log-log Model Adj LI	Linear-Log Model Adj LI	N
Entire Sample	0.128	0.070	0.073	0.071	21104
	(0.191)	(0.139)	(0.096)	(0.090)	
1998	0.099	0.066	0.068	0.063	5037
	(0.164)	(0.147)	(0.101)	(0.091)	
1999	0.088	0.072	0.066	0.064	8748
	(0.139)	(0.140)	(0.094)	(0.089)	
2000	0.196	0.072	0.085	0.085	7319
	(0.237)	(0.131)	(0.094)	(0.090)	
Weekday Peak	0.228	0.097	0.103	0.099	4340
	(0.243)	(0.148)	(0.094)	(0.085)	
Weekday Offpeak	0.108	0.058	0.066	0.064	10474
	(0.168)	(0.122)	(0.092)	(0.086)	
Weekend	0.093	0.074	0.064	0.064	6290
	(0.162)	(0.154)	(0.099)	(0.097)	

Numbers in parentheses represent standard deviations.

Source: Kim and Knittel (2006)

3.158 Their analysis shows that the CPM estimate tends to overstate market power. For example, in the linear demand case, the direct estimate of market power is 0.070 whilst the conduct parameter estimate from the CPM is 0.123. The comparison becomes even less favourable for the linear-log and log-log models. For these models the conduct parameter estimates are 0.188 and 0.229 respectively,[80] while the direct estimates are 0.071 and 0.073. Kim and Knittel attribute the lack of accuracy of the CPM to the inability of the model to estimate precisely marginal cost.

3.159 Adding Salvo's (2010) findings that the application of the CPM to the Brazilian Cement industry that understates market power (see paragraphs 3.118 to 3.123), we have a small body of literature that has evaluated the accuracy of the CPM in homogenous product industries. The conclusions from this literature are reproduced in Table 6 below.

[80] These are not shown in the Table above. They are taken from Table VI on page 463 in Kim and Knittel (2006).

Table 6: Summary of accuracy of CPM as a measure of market power

Authors	Industry	Type of paper	Conclusion
Genesove and Mullin (1998)	Sugar	Cartel effect	CPM understates market power
Salvo (2010)	Cement	Nature of competition	CPM understates market power
Wolfram (1999)	Electricity (UK)	Nature of competition	CPM not statistically different from market power
Clay and Troesken (2003)	Whiskey	Cartel effect	CPM overstates market power
Kim and Knittel (2006)	Electricity (California)	Nature of competition	CPM overstates market power

3.160 The available evidence is mixed: two out of the five studies show that CPM understates market power, two studies show that CPM understates market power, and one shows no discernable difference. Moreover, it does not appear that the reliability of the CPM is function of the issues that is being investigated. For example, Genesove and Mullin (1998) and Clay and Troesken (2003) both examine the CPM's ability to recover estimates of market power in hard-core cartels, yet they find bias in opposing directions. Similarly, Kim and Knittel (2006) and Salvo (2010) use the CPM to estimate the degree of market power exerted in two homogenous product industries and also they find different directions for the bias.

3.161 The literature evidence is scant, and shows no obvious ways to help the analyst determine the direction of the bias.

The case of differentiated products

3.162 Up to now we assumed that each firm supplies a homogenous product. However, in most industries, products are differentiated along one or several dimensions: physical characteristics, quality, branding, etc. Even suppliers of commodity products may be seen as differentiated when transportation costs matter. Because consumers do not view the different offerings as perfect substitutes, when a firm raises its price, it loses some sales, but not all. As a result, product differentiation is a source of market power, in the sense that firms have an incentive to set price above marginal cost.

3.163 When assessing market power and firm conduct in differentiated products industries, it is crucial to separate market power that is the result of anti-competitive conduct from that that stems from product differentiation. In principle, the conjectural variation approach can be applied to differentiated products industries, but in practice its implementation must overcome significant obstacles. We discuss these in turn.

3.164 First, when products are differentiated, firms form a conjecture about the reaction of each individual rival. That is, $\theta_i = 1 + \sum_{i \neq j} r_{ij}$, where $r_{ij} = \partial q_j / \partial q_i$. In the case, when firms select price to maximise profit (as in a Bertrand game), Slade (1995), shows that $r_{ij} = -s_j \epsilon_{ji} / s_i \epsilon_{ii}$, where s_j is firm *j*'s market share and the ϵs represent the partial own and cross-price elasticities for product *i* and *j*. In other words, r_{ij} can be viewed as the diversion ratio from firm *i* to firm *j*. In practice, to compute θ_i, the analyst has to estimate market shares and all relevant own and cross-price elasticities for the products sold in the industry.

3.165 The analyst can recover the price-elasticity of demand by estimating a demand equation. However, it is far more challenging to estimate consumer demand in differentiated products industries than in the case of homogenous products. In homogenous product industries, the analyst has to recover a single price-elasticity of demand. In contrast, in differentiated product industries, the number of elasticities depends on the number of existing products. When the market contains J products, in principle there are J^2 elasticities. For example, in a 10 product-market, the analyst must obtain 100 elasticities. However, significant progress has been made in the estimation of demand systems involving differentiated products, reducing the height of this obstacle.[81] As we will see in the next section, a number of studies estimate consumer demand in differentiated product industries to obtain all relevant own and cross-price elasticities.

3.166 It is also worth noting that in the case of differentiated product there is no simple formula such as the elasticity-adjusted Lerner index.

3.167 Second, for the implementation of CPM, Nevo (1998) shows that a very large number of sources of exogenous variation is necessary to identify all the conduct parameters. While it is theoretically possible to identify these parameters, Nevo states it will be difficult, if not impossible, to find such a large number of exogenous variables in practice.[82]

3.168 Recognising the difficulties involved with identifying all of the conduct parameters in a differentiated product market, Nevo suggests that a 'menu approach' is the best way to investigate firm conduct in such industries. We discuss the menu approach in paragraphs 3.169 to 3.249.

The menu approach

3.169 The objective of the conduct parameter method (CPM) is to estimate the degree of market power held by each firm and infer firm conduct. In

[81] See Berry (1994), Berry, Levinsohn, Pakes (1995) and Hausman, Leonard and Zona (1994) for examples of popular techniques that are often used to estimate differentiated product demand systems.

[82] If there are J products in the market, $J(J-1)$ CV parameters have to be estimated - significantly more than in the homogeneous case at the firm level, where there would be J parameters.

particular, through the use of conjectural variation, the analyst can nest a range of conduct in a single empirical model. The CPM has some obvious advantages over the SCP approach that was used before, but it also has some limitations.

- The CPM treats the conduct parameter θ_i as a free parameter. Some economists view this as an issue. If θ_i equals 2, this does not correspond to any specific firm conduct, as a result, it is unclear what kind of interpretation should be given.

- Another stumbling block relates to the application of the CPM to differentiated products industries. Even if the analyst believes that the conjectural variation model is appropriate, she has to overcome enormous practical hurdles to estimate the conduct parameter that makes the task hardly feasible. In particular the estimation of all the conduct parameters in a differentiated products market requires data that is highly unlikely to be available (see Nevo (1998)).

3.170 In this section we present the 'menu approach' that provides an alternative to the direct estimation of conduct. Instead of treating the conduct parameter as a free parameter, the menu approach evaluates an array of economic models in which the firm conduct is made explicit. That is, the analyst considers a menu of models that differs in the firms' assumed behaviour.[83] Then the analyst selects the 'winning' economic model, which provides the best fit to the data.

3.171 In the simplest application, the analyst may estimate one model in which firms are assumed to compete as in a Bertrand-Nash game and one model in which the firms are assumed to perfectly collude and achieve the monopoly price level. If one model clearly fits the data better than

[83] Typically the analyst selects a range of static oligopoly models. When the analyst has additional information on subsets of the data where firms were known to, or at least strongly suspected, to have different conduct (i.e. price wars in industries prone to collusion or regional models of local competition with latent import), then the analyst might take this into account by estimating two or more sets of oligopoly models (or more formally a regime switching model, see Salvo (2010)).

the other, the analyst concludes that the conduct assumed by the 'winning' model is most consistent with the prevailing price level. In practice the analyst can choose from an array of economic models, expanding the possibilities in terms of firm conduct. For example, the analyst may consider that firms behave as Stackelberg leader or engage in collusion over a subset of products (partial collusion).

3.172 For example, suppose a competition authority suspects that a number of multi-product firms, which supply differentiated products, are colluding in the high-end segment whilst they face significant competition in the low-end segment from a myriad of producers. To test this theory, the analyst might estimate a demand system and check whether a model in which collusion takes place in the high-end segment provides a better fit than a model in which there is no such collusion. As we will see below, depending on the type of data available, she can either test or compare the fit of this model against a competitive benchmark.

3.173 In general, economic studies that have adopted the menu approach have estimated a wide range of oligopoly models. In practice, the features of the industry under investigation as well as the competition concerns provide some guidance to select the economic models that the analyst ought to test (that is, suspected collusion among firms, brand-leadership of the most popular brands etc).

3.174 In summary, the menu approach is based on the following two-step process:

- **Step 1**: the analyst specifies a number of economic models, each of which assumes a specific type of firm conduct. The analyst estimates each model separately.

- **Step 2**: the analyst examines which model best fits the data. Broadly speaking there are three methods that can be employed to select the 'winning' model.

    - First, the predicted outcome of each model can be **compared against (reliably) observed counterparts**. For example, the analyst could compare the price-cost margin predicted by each model with the observed price-cost margin. The reliability of this approach depends on the accuracy of the observed margin. In particular, the use of accounting data may not provide the best measure of economic profit margin.

- Second, the analyst uses '**natural experiments'** such as the introduction of a new product or a change in regulation to determine which of the models best predict the changes caused by this event. Naturally this approach requires that such an event actually occurs and that data are available before and after the event.

- Finally, the analyst can perform **non-nested hypotheses testing** to establish which, if any, of the models is best supported by the data. The implementation of this approach requires that the analyst has supply side variables so they can directly estimate the supply side relation. In principle, it could be applied in all cases and in combination with the first two methods.

3.175 To illustrate the menu approach, we review a number of academic studies that have employed these methods to identify firm conduct. The rest of this section is organised as follows:

- Paragraphs 3.176 to 3.201 review studies that compare the models' predictions against observed outcomes in order to evaluate the fit of each model. Naturally, the success of this approach depends on the quality and reliability of the data that is used to test the models' predictions. This approach is straightforward and is frequently made in conjunction with more formal tests (that is, Slade (2004), Villas-Boas (2007), Rojas (2008), Salvo (2010)). To illustrate ideas, we review Nevo's (2001) study of the ready-to-eat cereal and Slade's (2004) analysis of market power in the UK beer market. Both papers compare predicted against observed price-cost margins. The results of Nevo's analysis show that the Ready-to-Eat Cereal industry is actually very competitive, in spite of concentration and relatively large price-cost margin. Equally, Slade's study of the UK beer market shows that the industry is highly competitive and that product differentiation and multiple-brand ownership account entirely for observed price-cost margins.

- In paragraphs 3.202 to 3.220 we present two studies that rely on a 'natural experiment'. Hausman and Leonard (2002) uses the introduction of Kleenex Bath Tissue by Kimberly Clark in the bath tissue market. Their results show that the Nash-Bertrand model's predictions are closer to the actual estimate of the price reduction caused by the entry of the new brand. Rojas (2008) relies on a 100 per cent increase of the excise tax of beer in the US to determine which of three models, Bertrand-Nash, Stackelberg leadership and collusion, best predict the price rise caused by the tax increase. His results show that collusion can be ruled out.

- Finally, paragraphs 3.221 to 3.249 presents the non-nested hypothesis testing approach. The literature commonly uses two types of non-nested tests: Vuong's test and Cox-type tests.

  - To illustrate Vuong's non-nested testing framework we show how it has been applied by Salvo (2010) and Gasmi, Laffont and Vuong (1992). As noted in paragraphs 3.118 to 3.123, Salvo examines the role that the threat of imports plays in the Brazilian Cement industry. When the model allows the import threat to constrain the domestic price, he can reject the hypothesis of perfect competition. However, his results are not consistent with accounting data that appear to suggest that domestic firms have considerable market power. In an earlier study, Gasmi, Laffont and Vuong (1992) use the Vuong test to determine which models of competition best fit the carbonated soft drink industry. Their results show that collusive models better fit the data than models of competition in which Coca-Cola and Pepsi are assumed to play a Nash game or a Stackelberg game.

  - To show how the Cox-type tests can be applied we present a study by Villas-Boas (2007). She relies on the menu approach to determine which is the best model. Each model provides for different vertical retailer-manufacturing relationships in the yogurt market in the United States. Villas-Boas finds evidence that non-linear tariffs best described the vertical relationship between retailers and manufacturers. In general, she finds that retailers are supplied at wholesale cost and retail prices are set in between Nash-Bertrand and collusive level.

Comparing predicted and observed outcomes

3.176 In this section we present how Nevo (2001) and Slade (2004) use observed margins to assess the fit of a menu of oligopoly models. In practice, they estimate a demand system to recover all price-elasticities (own and cross), then they posit different types of firm conduct. Using the estimated price-elasticities they predict the price-cost margin implied by each form of conduct, which they then compare with the actual price-cost margin.

Market power in the ready-to-eat cereal industry (Nevo (2001))

3.177 Nevo (2001) investigates whether firms in the ready-to-eat (RTE) cereal industry have engaged in collusive behaviour. This industry is characterised by high profit margins and a high degree of market concentration, and large firms own a multitude of brands. Nevo seeks to identify the source of the high price-cost margins that prevail in the industry. In particular, because of product differentiation, firms set price above marginal cost. It is of interest to separate the part of market power that stems from product differentiation from that of anti-competitive conduct. To this end Nevo specifies three distinct models of competition in which firm conduct depends on the structure of the brand ownership matrix:

- In the first model, each brand is owned by a single product firm. That is, the price of each brand of cereal is selected by maximising only the profit for that brand. The extent to which a cereal product is differentiated from its rivals may be one of the reasons that contribute to explain price-cost margin.

- Instead, the second model assumes that multi-product firms set the prices of their products by maximising the profit that stems from selling their product portfolio. When a firm is selling two imperfect substitute products, it charges a higher price than if the two products were each sold by a single- product firm. This is because the firm takes into account the cannibalisation (or diversion of sales) between the brands it sells. If the firm sets prices too low, it steals sales from other products that it is selling. This model seeks to determine whether the portfolio effect (or multi-brand ownership) is one of the reasons behind high price-cost margins.

- In the third model, the price of each brand is selected so as to maximise the joint industry profit. This model corresponds to monopoly or perfect price collusion, and prices are selected as if the industry was under the control of a single firm. This model seeks to determine whether price collusion would explain high-price cost margin.

3.178 These three models can be nested into one single framework that we present below. Consider that demand for brand *j* is written as $q^j(p_j, p_{-j})$ where p_j is the price of brand *j* and p_{-j} is a vector containing the price of substitute products. In the first model, the first-order condition for brand *j* can be written as:

$$q^j(p_j, p_{-j}) + (p_j - MC_j)\frac{\partial q^k}{\partial p_j} = 0 \qquad (26)$$

3.179 It shows that the firm supplying brand *j* selects p_j by only considering the profit it earns by selling that brand. Instead in the second model, firms may own multiple brands. As a result, firms seek to maximise the sum of profits from each single brand that belongs to their portfolio. For brand j the first-order condition becomes:

$$q^j(p_j, p_{-j}) + \sum_{k \epsilon F}(p_k - MC_k)\frac{\partial q^k}{\partial p_j} = 0 \qquad (27)$$

where F is the set of all products supplied by the multi-product firm that supplies brand j. The difference between (26) and (27) rests in the fact that the multi-product firm takes into account the effect that a price change of brand j has on the profit it draws from its other brands. In other words, when setting prices, the firm factors in the cannibalisation effect between its brands. In each model, there are J first-order conditions, one for each product.

3.180 Finally, in the third model in which only one single firm is assumed to select the price of all brands, the first order condition for product j becomes:

$$q^j(p_j, p_{-j}) + \sum_{k \epsilon J}(p_k - MC_k)\frac{\partial q^k}{\partial p_j} = 0 \qquad (28)$$

where J is the set of all products sold in the market. The difference between (27) and (28) is that when selecting the price level of each brand the single firm takes into account the cannibalisation effect with all substitute products in the market. Under this model, brand prices are set at the highest level.

3.181 The three models can be summarized into a single framework. In matrix form the J first order conditions for the three models can be written as:

$$Q + (p - MC)\Omega = 0 \qquad (29)$$

where Ω is a $J \times J$ matrix defined as follows: $\Omega = S \circ \Theta$.[84] S is a matrix of derivatives, in which $S_{jr} = (\partial q_r / \partial p_j)$, that is, the effect of a change in the price of brand j on quantity sold by substitute brand r. The cross-derivatives are positive whilst the own-derivatives are negative. Because it only depends on consumer behaviour, S is the same for the three models of competition. Θ represents the product ownership matrix as defined above. The supply relation (29) can be solved for each product's price-cost margin:

$$(p - MC) = \Omega^{-1}q \qquad (30)$$

3.182 The advantage of this approach is that the analyst can estimate price-cost margin without actually observing costs. It is clear from (30) that the price-cost margin depends on the matrix Ω, and more specifically on S and Φ. For each model of conduct the analyst assumes a particular ownership matrix Φ. For example, in the first model that portrays single-

[84] Where $\circ$ represents the element-by-element matrix multiplication.

product firms playing a static Nash-Bertrand game, the ownership matrix is a $J \times J$ identity matrix. For the second model, the ownership matrix is block diagonal, reflecting the fact that each firm may own several brands. Finally, in the third model where firms are assumed to perfectly collude, Φ is a matrix whose elements are ones.

3.183 The main challenge of this approach is to estimate the matrix S, which summarises consumer substitution patterns. S consists of J^2 elements, which means in practice that if the industry under investigation has 10 products, the analyst has to estimate 100 parameters. The number of parameters to estimate can thus be very large, which is often not practical. To overcome this problem, many researchers adopt a discrete choice approach, which combined with some assumptions about consumer heterogeneity leads to the well-known logit model. However, the analytical tractability of the Logit model comes at the cost of imposing substitution patterns that are not necessarily appropriate for the industry being analysed.[85]

3.184 Berry, Levinsohn and Pakes (1995) (hereafter, BLP) have developed the random coefficient model, which relaxes the restrictions on consumer substitution patterns – though this comes at considerable computational cost (see Dube, Fox, and Su (2011)). The advantage of this approach however is that consumer substitution pattern is driven by product characteristics. That is, all else equal, a children's cereal is more likely to be substitute to another children's cereal than to a wholesome, simple and nutritional cereal. In this report we do not present the details of

[85] The advantage of the logit demand model is that the analyst estimates a limited number of parameters to recover own and cross-price elasticities. However, this advantage comes with a serious drawback: the logit model places restrictions on the pattern of substitution between products (for more details see Berry (1993)). These restrictions imply that when the price of a particular brand of cereal increases, consumers would substitute towards other brands in proportion of market shares, regardless of the attributes of each brand. As Nevo puts it, this means that if Quaker CapN Crunch (a kid cereal) and Post Grape Nuts (a wholesome simple nutrition cereal) have similar market shares, then substitution from General Mills (a kid cereal) towards either of them will be the same.

demand estimation under the logit and random coefficient method. The interested reader is referred to Nevo (2001) for an introduction.

3.185 Nevo adopts the BLP approach to estimate a demand system for the RTE industry. The parameter estimates of the demand model allows Nevo to determine the elements of the matrix S, and using (30) he predicts the price-cost margin for each brand under each model of competition. In Figure, below, we reproduce the median margin (see Table VIII in Nevo (2001)).

Figure 8: Predicted median margins

MEDIAN MARGINS[a]

	Logit (Table V column ix)	Full Model (Table VI)
Single Product Firms	33.6%	35.8%
	(31.8%–35.6%)	(24.4%–46.4%)
Current Ownership of 25 Brands	35.8%	42.2%
	(33.9%–38.0%)	(29.1%–55.8%)
Joint Ownership of 25 Brands	41.9%	72.6%
	(39.7%–44.4%)	(62.2%–97.2%)
Current Ownership of All Brands	37.2%	—
	(35.2%–39.4%)	
Monopoly/Perfect Price Collusion	54.0%	—
	(51.1%–57.3%)	

[a] Margins are defined as $(p - mc)/p$. Presented are medians of the distribution of 27,862 (brand-city-quarter) observations. 95% confidence intervals for these medians are reported in parentheses based on the asymptotic distribution of the estimated demand coefficients. For the Logit model the computation is analytical, while for the full model the computation is based on 1,500 draws from this distribution.

Source: Nevo (2001)

3.186 Nevo estimated two demand models:

- the Logit model corresponds to the simple logit with restrictive and unrealistic substitution patterns, and
- the Full model corresponds to the random coefficient estimation, which in this case appears to yield more realistic substitution patterns.

3.187 In the latter model, Lucky Charms, a children's cereal, is most sensitive to a change in the price of Corn Pops and Fruit Loop, also children's cereals. It is also less sensitive to a change in the price of Corn Flakes, which is aimed at a different segment of the population. The results of the demand estimation show that the Full model overcomes the restrictive patterns of substitution imposed by the simple Logit model.[86]

3.188 As expected, the price-cost margins tend to be higher under the second model (current ownership of multiple brands) than the first model (single-brand firm), while the margins predicted by the third model (perfect price collusion) are larger. The predicted margins vary with the demand model. In particular, there is a striking difference between the Logit and Full model margins under perfect price collusion. The Logit model predicts a median margin of 41.9 per cent whilst the Full model's median margin is 72.6 per cent. The difference in the results stems from the restrictive substitution pattern of the Logit model that we described above.

3.189 To assess which oligopoly model best fits the data Nevo uses the more flexible Full model by comparing the margins predicted by each model with observed price-cost margins. From accounting data he measures a margin for a typical brand, which corresponds to 46 per cent of the retail price. The results suggests that the observed price-cost margins are consistent with the second oligopoly model estimated using BLP, in which multi-product firm is assumed to behave non-cooperatively, that is, in a static Nash-Bertrand fashion.

Market power and joint dominance in the UK brewing industry (Slade (2004))

3.190 Slade (2004) applies the menu approach to assess the sources of market power in the UK brewing industry. As in Nevo (2001), her study depends on the estimation of a demand model to recover the price-elasticities. Using two periods of bimonthly data on UK beer sales in pubs in London and Anglia in 1995, Slade estimates a nested Logit model and a distance-metric (DM) demand model.[87] She then uses the

[86] See section 4.2 in Nevo (2001) for more details.

[87] See Pinkse and Slade (2004) for more details on spatial demand models applied to differentiated products.

estimates from the demand models and imposes different forms of competition to predict price-cost margins. Each model's predicted margins are then compared to observed margins.

3.191 As in Nevo (2001) she considers three sources of market power:

- one that is due to product differentiation
- one that is due to market structure, that is, multi-brand ownership, and
- one that is due to collusion.

3.192 Like Nevo (2001), Slade uses a single product firm Nash-Bertrand model to measure the amount of market power that stem from product differentiation. The margin predicted by this model is attributed to product differentiation.

3.193 The market power arising from the ownership of multiple brands is assessed by estimating a Nash-Bertrand model that assumes the current ownership structure (termed by Slade 'the status quo' model). The difference between the margins predicted by this model and those by the single product firm model gives a measure of market power that arise from multi-brand ownership.

3.194 Finally, Slade considers that the difference between the observed margin and the margin implied by the 'status quo' model is a measure of market power arising from collusion (explicit or tacit). She calls this 'excess margins'.

3.195 Figure9 below shows the results of Slade's study. The leftmost column lists the different demand models and the second column labelled 'equilibrium' reports the form of competition that she assumes. The right–hand-side of the table shows the average price predicted by each model, the standard deviation of those prices, the difference with the observed price, and the average margin.[88]

3.196 The results from the DM model show that under the single-product firm model the average margin is 23.5 per cent. Therefore, approximately three-quarters of the observed margins, which she estimates at 29.9 per cent, can be attributed to product differentiation. If the brands are assigned to the firms owning them (the status quo model), the predicted average margin is 30.4 per cent. The increment in the margin reflects the market power stemming from the market structure and accounts for the remaining quarter of the observed margin. With the whole margin accounted for, the excess margin is zero and there is no evidence that collusion is a source of market power.

Figure 9: Predicted equilibrium prices and margins

Demand Equation	Equilibrium	Mean Price	Standard Deviation	% Difference[a)]	Margins (L)
Nested Logit	Status Quo	211.0	38.1	31.4	45.1
Distance Metric	Marginal-Cost Pricing	129.1	5.2	– 23.1	0.0
	Single-Product Firms	159.4	19.8	– 5.1	23.5
	Status Quo	168.4	29.5	0.4	30.4
Observed Prices & Margins		167.8	20.2		29.9

[a)](Predicted–Observed)/Predicted.

Source: Slade (2004)

3.197 Slade also conducts statistical tests of 'excess margins'.[89] Using these tests, she cannot reject the hypothesis that the average predicted margin under the 'status quo' model with a DM demand is different from the observed margins. However, as Slade notes, this finding does not eliminate the possibility that some firms behave collusive while others do not, after all the test result only concern average margins.

[88] The predicted price is calculated by adding the predicted margin to the observed cost. The percentage margin is the (price – cost)/cost.

[89] Since the excess margins are calculated using a combination of random variables they too have a distribution and can be subjected to standard statistical testing.

3.198 To test for this possibility, the 'excess margin' implied by the DM 'status quo' model is regressed on an array of product characteristics in order to determine whether some firms or some products that share specific characteristics explain 'excess margins'.

3.199 Slade's results are shown in the figure below. She sets out three distinct specifications to explain excess margins:

- The first regression assesses whether the brand belonging to national brewer (NAT) have higher excess margins than others.

- The second regression consider in addition to the type of brewer, whether the market share of the product (LCOV), its classification as a premium or standard product (PREM), and whether or not it is sold in multiple establishments (MULT) has an impact on excess margins. The regression also allows the excess margin to differ by type of beer (lager, stout, keg ale and real ale).

- The third regression is similar that the second one except for the fact that it allows the alcohol content to affect excess margin. In this specification, the actual alcohol content of the beer (ALC) is included instead of the dummy variable indicating whether or not the product is classified as a standard or premium beer.[90]

[90] Beers with more than 4.2 per cent alcohol content are classified as premium beers.

Figure 10: Excess margins, actual – status quo 2-step estimates using the DM demand equation

Equation	1[a)]	2	3
NAT	0.005 (0.2)	−0.002 (−0.1)	−0.003 (−0.1)
LCOV		0.038 (3.7)	0.037 (3.4)
PREM		0.062 (3.8)	
ALC			0.047 (3.6)
MULT		0.052 (2.9)	0.052 (2.9)
$PROD_1$ (lager)		−0.142 (−4.1)	−0.315 (−4.6)
$PROD_2$ (stout)		−0.028 (−0.6)	−0.218 (−2.3)
$PROD_3$ (keg ale)		−0.113 (−2.8)	−0.270 (−3.7)
$PROD_4$ (real ale)		−0.204 (−6.9)	−0.374 (−6.1)

[a)]Includes a constant.
t-statistics in parentheses.
Standard errors corrected for heteroskedasticity and spatial correlation of an unknown form.

Source: Slade (2004)

3.200 The results show that despite not finding any statistical evidence that the average excess margin is greater than zero, the results from the second and third regressions suggest that some products with higher market shares, higher alcohol content and those sold in multiple establishments are 'less competitively priced'.

3.201 Finally, Slade reports that, unlike the report published by the UK Monopolies and Mergers Commission in 1989, the intensity of competition is similar across the different types of beer. Combined with the fact that the 'status quo' Nash-Bertrand model is a good fit, this leads Slade to conclude that there is no evidence that lager prices are set collusively.

Relying on 'natural experiments'

3.202 In some industries events such as the entry of a new product or a change in regulation affect the market outcome. For example, when a new product is introduced in the market, it steals business away from incumbent products, leading competitors to reduce prices. The analyst can take advantage the impact of such a change in the market to determine which models of competition predict best the price reduction that typically follows the introduction of new competing product. This is the strategy that Hausman and Leonard adopt in the bath tissue market. We first discuss their study and then present another study that relies on the change in the excise tax of beer to identify which models of firm conduct better represent the US brewing industry.

Entry of a new brand in the bath tissue market (Hausman and Leonard (2002))

3.203 Hausman and Leonard (2002) investigate the competitive impact of the entry of a Kleenex brand in the bath tissue market. They use the change in price that results from this entry to assess which model of competition best fits the industry. They do so by comparing the actual price reduction on existing brands that resulted from this entry with the price reduction as predicted by different oligopoly models. Naturally, they select the oligopoly model that generates a price reduction that is closest to the actual one.

3.204 Hausman and Leonard have market-wide information on weekly sales of bath tissue products in different cities across the US from January 1992 to September 1995.[91] During this period, Kimberley Clark introduced the Kleenex Bath Tissue (KBT) in three waves across different cities. By using observations on the price of existing products before and after the introduction of this new brand in each city, they estimate the incumbent's price reduction due to this entry. These estimates serve as benchmark against the price reduction predicted by each oligopoly model.

3.205 For each oligopoly model, Hausman and Leonard follow a three-step procedure to simulate the price change due to the entry of Kleenex.

[91] The data does not contain disaggregated information on private label products.

- Step 1: they estimate a demand system using data **after** the introduction of KBT. They adopt a two-stage budgeting model (Gorman (1995)) in which the lowest level of the model is estimated using the 'almost ideal demand system' (Deaton and Muellbauer (1980)).[92]

- Step 2: using the demand estimates for each specific oligopoly model they recover the implied marginal costs for the period after KBT entered. This gives them an estimate of the price-cost margin for each brand that is consistent with the assumed oligopoly model.

- Step 3: for each oligopoly model, they use the demand estimates and the implied marginal costs to simulate the market outcome without KBT.[93] By comparing the predicted price level without entry with the observed prices (with KBT in the market) they obtain the predicted impact of KBT's entry on the price of existing brands.

3.206 By comparing the predicted effect with the actual estimates of the price reduction, they assess the validity of different oligopoly models. If the demand system is correctly specified, marginal costs are constant over the relevant range of output, and the assumed oligopoly model approximate firms' conduct, then the predicted and actual estimates should be approximately the same.[94]

[92] One of the reasons to select this model is that it provides a flexible functional form for demand within a segment.

[93] Formally, this requires that the analyst solves the first order conditions derived under the assumed oligopoly model for all products except Kleenex and set the demand for Kleenex to zero.

[94] Hausman and Leonard argue that the misspecification of demand is unlikely to be significant for two reasons. First, the use of a flexible functional form to estimate demand within a segment (for example the AIDS model) reduces the risk of misspecification. Second, the price effects being used to test the validity of the assumed oligopoly model are small and the effect of misspecification, if present at all, is not substantial. Similarly, they argue that for relatively small changes in quantity marginal movements are unlikely to be large.

3.207 Figure11 shows the actual (direct estimate) and predicted price (indirect estimate) reduction for each incumbent brand as well as the results of the test statistics. Hausman and Leonard (2002) assess three different oligopoly models:

- Nash-Bertrand model (columns 2 and 3 in Figure11)
- Premium cartel without KBT: before the introduction of KBT the model considers that the incumbent brands operate a cartel, but after its entry KBT does not participate in the cartel. As a result, the cartel breaks down and the firms play a Nash-Bertrand game (columns 4 and 5 in Figure11), and
- Premium cartel with KBT: before and after the entry of KBT the industry operates as a cartel (column 6 in Figure 11).

3.208 Overall, whilst the evidence is mixed, the Nash-Bertrand model provides estimates for the price reduction that are relatively close to the actual estimates. Indeed, under Nash-Bertrand, the predicted price effects for Charmin, Northern, Angel Soft, ScotTissue are similar to their actual estimates. Furthermore the two sets of estimates are not statistically different. However, for Cottonelle and private label the predicted estimates are well below the actual estimates, and the test statistics reject the hypothesis that these two estimates are the same.

3.209 The Premium cartel model, in which KBT does not participate, generates price reductions that are generally much larger than the actual estimates. This is because under this model, KBT's entry breaks up an existing cartel, and thus prices fall from perfect collusion to Nash-Bertrand level. The only exception is Cottonelle for which the actual and predicted price effects are similar. Consequently, assuming a cartelised industry prior to the introduction of KBT is clearly inferior to the Nash-Bertrand assumption.

3.210 Finally, as can be seen in Figure11, the price effects predicted by the model in which KBT joins a premium brand cartel are generally lower than both the Nash-Bertrand model and the actual estimates.

3.211 In sum, Hausman and Leonard conclude that the Nash-Bertrand model is also superior to the two models in which firms behave as in a cartel. While the results of the statistical tests in the Nash-Bertrand model do not provide unambiguous support for it, they conclude that it provides a better fit to the industry than the other two models examined.

Figure 11: Comparison of direct and indirect estimates of the price effects of the Kleenex bath tissue introduction

Brand	(1) Direct Estimate	(2) Indirect Estimate Nash-Bertrand Model	(3) *t*-test	(4) Indirect Estimate Premium Cartel w/o KC	(5) *t*-test	(6) Indirect Estimate Premium Cartel w/ KC
Cottonelle	−8.2%	−3.6%	3.4	−7.8%	0.2	−1.8%
	(1.3%)	(0.3%)		(1.2%)		
Charmin	−3.5%	−2.8%	0.7	−6.8%	2.3	−1.5%
	(0.9%)	(0.1%)		(1.1%)		
Northern	−2.3%	−3.4%	1.4	−7.6%	3.8	−1.3%
	(0.8%)	(0.2%)		(1.2%)		
Angel Soft	−3.5%	−2.4%	1.6	−6.9%	2.7	−1.1%
	(0.6%)	(0.3%)		(1.1%)		
ScotTissue	−0.6%	−1.5%	1.3	−3.1%	3.1	−1.4%
	(0.5%)	(0.4%)		(0.6%)		
Private Label	−3.8%	−0.7%	2.7	−1.5%	1.9	−0.5%
	(0.9%)	(0.7%)		(0.8%)		

Notes: (1) Standard errors in parentheses.
(2) For the column (6) estimates, the delta method did not provide reliable standard errors.

Source: Hausman and Leonard (2002)

A change in the excise tax of beer (Rojas (2008))

3.212 Rojas (2008) uses a 100 per cent change in the excise tax of beer in the US to assess the validity of different oligopoly models. The US government's decision to double per barrel production levies on alcohol in all states in January 1990 effectively increased brewers' marginal cost. Rojas' analysis proceeds in a similar vein as Hausman and Leonard (2002).

- First, the price effects of this natural experiment are directly estimated using simple regression analysis on quarterly brand level data across up to 58 cities from 1988 to 1992. The direct estimates serve as benchmark to assess the prediction of oligopoly models that assume different forms of firm conduct.

- Second, Rojas uses a two-stage budget demand model.[95]

- Third, for each specific oligopoly model, he backs out the implied marginal cost. Using the demand estimates, and the implied marginal costs, he simulates the price effect of a change in tax under each oligopoly model.

3.213 Rojas considers three different oligopoly models.

- Bertrand-Nash Model – two versions of the model are estimated.

  - Single-product firms: although this ownership structure does not reflect the reality of the in US beer industry, it is estimated to assess the degree of mark-up that is due to product differentiation alone.

  - Multi-product firms: this reflects the competitive benchmark for industry. By comparing implied margins in this model to the single-product version of the Bertrand-Nash model, the mark-up attributable to product differentiation can be separated from the mark-up arising from the concentration of ownership of brands.

- Stackelberg Model – two versions of the model are estimated:

  - Anheuser-Busch leads with its whole portfolio of products as a leader, and

  - Anheuser-Busch leads with its largest product, Budweiser.

- Collusion – three versions of the model are estimated:[96]

[95] To estimate the lower level of demand he uses Pinkse, Slade, and Brett's (2002) distance metric model – a semi parametric version of the AIDS model.

[96] Detailed descriptions of the performance metrics can be found in the notes to Figure 42.

- Collusion between three firms
- Collusion between three brands, and
- Full collusion.

3.214 To select the model that best corresponds to the US brewing industry, Rojas creates a set of performance metrics to compare the direct estimates of the price effects from the tax increase to that of the simulated price effects under each model listed above. Figure 12 below reproduces the performance metrics and summary statistics for each of the oligopoly models. The left-hand-side of the table contains the summary statistics of the actual and predicted price increases following the tax increase. The right-hand-side of the table reproduces the performance metrics for each of the oligopoly models. We discuss each part of the table in turn.

Figure 42: Summary statistics of actual and predicted price increases and performance metrics of models

	Summary Statistics[a]			Performance Metrics		
	Mean	Median	St. Dev.	# No-Reject[b]	Weighted Increase[c]	SSD[d]
Actual Increases	1.38	1.37	0.65	N/A	64.74	N/A
Predicted Increases						
Single-Product Bertrand-Nash	0.95	0.81	1.07	20	89.74	3587
Bertrand-Nash	1.02	0.90	1.02	21	86.91	3643
A-B Stackelberg Leader[e]	1.00	0.92	0.98	21	76.80	3441
Budweiser Stackelberg Leader	0.99	0.89	0.99	21	78.97	3442
Collusion 3 firms[f]	1.21	1.11	1.01	22	87.48	4328
Collusion 3 brands[g]	1.03	0.93	1.00	23	84.45	3621
Full Collusion	18.19	13.40	15.88	0	1014.95	> 1E6

[a] Computed with absolute price increases for each brand: the absolute price difference between the first quarter of 1991 and the fourth quarter of 1990, over 46 cities (1748 observations).
[b] Number of brands for which mean of predicted increases falls within the confidence intervals of mean of actual increases (as in Figure 3).
[c] Sum of weighted absolute price increases; weight = volume of brand sold in city/total volume of all brands in all cities in the first quarter of 1990 (1748 observations).
[d] Sum of squared deviations over all brands and all cities; deviation = predicted-actual (1748 obs.).
[e] A-B = Anheuser-Busch.
[f] Anheuser-Busch, Adolph Coors, Miller (Philip Morris).
[g] Budweiser, Coors, Miller Genuine Draft.

Source: Rojas (2008)

3.215 Some general points emerge from the summary statistics. First, by comparing the actual price increase (in the top row of the leftmost column) to each model's predicted price increases we can see that with the exception of the three-firm collusion model the other oligopoly models understate the price impact of the tax increase. However, Rojas states that for this particular model the result is driven by the large over-predictions of the price effects for Anheuser-Busch's and Miller's brands rather than by small under-predictions of other brands.

3.216 Second, the difference between single and multi-product Bertrand-Nash mark-ups is small. This suggests that the majority of mark-up is explained by brand differentiation and not concentration of ownership.

3.217 Finally, all of the measures strongly reject the 'Full Collusion' model. The predicted margins are implausibly high and this model performs poorly under the various metrics.

3.218 Rojas also analyses the fit of the different models by analysing the three performance metrics.

- The first performance metric counts the number of brands whose simulated mean price lies within the 95 per cent confidence interval of the observed mean price increase. The model that has the large number of brands that fall within this confidence interval is viewed as providing the better fit. According to this measure, the model that assumes collusion among three brands is the better alternative.

- The second performance measure sums the weighted absolute price increases. This has the added benefit of weighting errors in the price increase by the volume of sales. A selected oligopoly model is deemed to fit better the data when the performance measure is closer to the actual weighted absolute price increase presented the top row of the table. In this case, the Stackelberg models outperform all other models.

- The final performance metric is the sum of squared deviations, where a deviation is the difference between the actual and simulated price increases. When this measure is small, it indicates that the model predicts well the observed price increases. Again, the Stackelberg models outperform the other models.

3.219 In sum, the first performance metric counting the number of brands whose predicted price lies within the actual confidence interval suggests that the model with collusion among three brands appears to best explain industry conduct. In contrast, the other two measures suggest that the Stackelberg models outperform the other models.

3.220 While the performance metrics have the advantage of being simple to calculate, Rojas stresses that their major drawback is that they are not formal statistical tests. In particular, when the difference between the performance metrics is small, it is far from clear that a statistical test would be able to reject the hypothesis that the oligopoly models fit the data equally well. Consequently, Rojas suggests that performance metrics should be cautiously interpreted.

Non-nested hypothesis testing of firm conduct

3.221 Non-nested hypotheses tests have been used in the academic literature to evaluate economic models of firm conduct. The general idea is to compare economic models in pairs to determine which one fits the data best. To implement this approach, the analyst estimates the oligopoly models' supply relations. This requires that the analyst has data on variables that affect marginal cost, that is, he has data on factor prices such as electricity, wages, ground rents etc.

3.222 Using the likelihood of each model's estimated supply relations, the analyst can construct pair-wise non-nested tests.[97] For each pair if one model survives rejection by the other model, then it is judged to provide the best explanation of firm conduct. If not, the analyst must carefully analyse the results and see which models perform best. The results of the non-nested tests might then be combined with less formal performance measures to find the model that provides the best description of firm conduct.

3.223 Next, we illustrate how the menu approach applies non-nested tests. We examine in more detail three studies: Gasmi, Laffont and Vuong (1992) (hereafter GLV), Salvo (2010), and Villas-Boas (2007). They employ different non-nested hypothesis tests:

- Salvo and GLV uses Vuong's symmetric non-nested test (paragraphs 3.225 to 3.241), and

- Villas-Boas uses Smith's (1992) Cox-type non-nested testing framework (paragraphs 3.242 to 3.249).

3.224 We review each study in turn.

[97] The two of the most commonly used non-nested testing frameworks are attributable to Vuong (1989) and Cox (1961). Annexe A provides more details of these statistical tests and highlights their relative merits.

Implementing the menu approach: Vuong's non-nested tests

Conduct in the Brazilian cement industry (Salvo (2010))

3.225 As noted in paragraphs 3.118 to 3.123, Salvo (2010) adopts the menu approach to investigate firm conduct in the Brazilian cement industry. In particular, he examines how taking into account the threat posed by foreign import impacts the empirical identification of firm behaviour.

3.226 To illustrate how, if left unaccounted for, latent imports can lead a researcher to draw incorrect inferences about the degree of market power wielded by a domestic oligopoly, Salvo estimates five models. These are as follows.

- Autarkic models (these models ignore the threat posed by foreign imports):
  - Model a1: Autarkic monopoly
  - Model a2: Autarkic Nash-Cournot oligopoly
  - Model a3: Autarkic perfectively competitive industry
- 'Integrated' models (these models account for the import threat):
  - Model i1: integrated domestic monopoly
  - Model i2: integrated domestic Nash-Cournot oligopoly

3.227 Noting that there are no (or negligible) imports currently observed, the analyst might not realise that the import threat set a price ceiling in some domestic markets. As such, she estimates a range of models that assumes that imports play no role. These are the autarkic models, which consider three distinct forms of behaviour: monopoly, Nash Cournot, and perfect competition.

3.228 If, however, the analyst considers that the import threat may affect prices, then she estimates an 'integrated' model. The integrated model allows for the possibility that imports constrain some, but not all, local cement markets (that is, coastal markets may be likely to be more constrained by imports than those inland). Using the variation in prices between unconstrained and constrained markets, the integrated model can, in principle, identify the model that best describes industry outcomes.

3.229 To assess how each model fit the data, Salvo uses Vuong's non-nested tests. The results are shown in Figure 13.

3.230 The models listed in the first column of the table are assumed to be true under the null hypothesis. They are tested against the models listed in the top row. The table present the test statistic results and the respective p-values are reported in brackets.

3.231 The content of the figure is interpreted as follows:[98]

- Test statistic < -1.96: the model under the alternative hypothesis (listed in the top row of the table) is preferred to the model under the null hypothesis (listed in the first column) at a five per cent level of significance.

- Test statistic > 1.96: the model under the null hypothesis (listed in the first column) is preferred to the model under the alternative hypothesis (listed in the top row of the table).

- -1.96 < Test statistic <1.96: the data cannot tell apart which model is a better fit (that is, they are observationally equivalent).

3.232 If one model is preferred to all other models, then it is the 'winning' model.

[98] Please see Annexe A for a more detailed description of the Vuong test.

Figure 13: Pair-wise Vuong tests for non-nested models: test statistics and *p* values

Different degrees of freedom not corrected	$a2$: autarkic Cournot	$a3$: autarkic competition	$i1$: integrated monopoly	$i2$: integrated Cournot
$a1$: autark. monopoly	-36.030 (0.000)	-49.605 (0.000)	-50.176 (0.000)	-50.176 (0.000)
$a2$: autark. Cournot		-35.975 (0.000)	-36.581 (0.000)	-36.581 (0.000)
$a3$: autark. competition			-4.856 (0.000)	-4.856 (0.000)
$i1$: integr. monopoly				-0.001 (0.500)
Correction according to Schwarz (1978)	**$a2$: autarkic Cournot**	**$a3$: autarkic competition**	**$i1$: integrated monopoly**	**$i2$: integrated Cournot**
$a1$: autark. monopoly	-36.030 (0.000)	-49.605 (0.000)	-49.756 (0.000)	-49.756 (0.000)
$a2$: autark. Cournot		-35.975 (0.000)	-36.221 (0.000)	-36.221 (0.000)
$a3$: autark. competition			-2.636 (0.004)	-2.636 (0.004)
$i1$: integr. monopoly				-0.001 (0.500)

Notes: Positive (negative) test statistic: Model in row (model in column) displays better fit.

Source: Salvo (2010)

3.233 Salvo's results contain several interesting aspects:

- First, had he not estimated any of the integrated models, he would have found that the autarkic model of perfect competition is preferred over the two other autarkic models in which firms have some market power.

- Second, the monopoly integrated and Nash-Cournot integrated models are preferred over a model of perfect competition in autarky. These results suggest that the threat posed by foreign imports is important to evaluate industry conduct. Its omission results in biased results. Moreover, since both integrated models involve some market power, the hypothesis that domestic firms wield market power cannot be rejected.

- Finally, the non-nested tests cannot distinguish between the two integrated models. This can arise if:

  - all markets are constrained by the threat of imports and the actual form of conduct cannot be identified, or

  - the form of domestic oligopoly is more complex than the two static oligopoly models included in the menu (that is, dynamics can support an industry outcome between Nash-Cournot and monopoly).

3.234 In summary, the test results lead Salvo to reject all models that fail to take into account the competitive constraint from foreign imports. However, without clear-cut support for the integrated monopoly model over its Nash-Cournot counterpart, he cannot claim to have shown that the Brazilian Cement industry has considerable market power by pricing up to the cost of the fringe of latent imports – as suggested by detailed margin data. Confident that the 'true' model of the Brazilian cement industry would reflect this market power held by domestic firms, he finds that the static model may be missing important dynamic features or that the data does not contain the required variation to identify monopoly outcomes.

Competition in the carbonated drinks market (Gasmi, Laffont, Vuong (1992))

3.235 GLV investigate the carbonated soft drink market and, in particular, they assess whether Coca-Cola and Pepsi-Cola engaged in collusive behaviour between 1968 and 1986. They consider that the two companies compete in price and in advertising. In other words, Coca-Cola may steal Pepsi customers by either undercutting Pepsi and/or boosting its advertising activities. To discriminate between competitive and collusive conduct, GLV postulate six models that we describe below:

- M1: the two firms are Nash players in prices and advertising
- M2: Coca-Cola is the Stackelberg leader in both prices and advertising
- M3: Pepsico is the Stackelberg leader in prices only
- M4: the two firms collude on prices and advertising
- M5: the two firms collude on advertising and compete in prices, and
- M6: the two firms collude on prices and compete in advertising.

3.236 In summary, GLV specify three models in which Coca-Cola and Pepsi compete (M1-M3), and three models of in which they are engaged in some form of collusion (M4-M6). They estimate separately each model and apply the Vuong testing procedure described in Annexe A to determine which model of competition is most likely to explain the data. The test results for the model selection are reproduced in the table below (see Table VII of GLV).

Figure 54: Adjusted LR statistics for model selection

	M2	*M3*	*M4*	*M5*	*M6*
M1	−0.12	−0.09	−4.55[b]	−2.73[a]	−1.13
M2		−0.08	−4.57[b]	−2.73[b]	−1.13
M3			−1.77[a]	−1.73[a]	−0.22
M4				−0.01	5.11[b]
M5					2.51[b]

[a]Significant at the 10% level in a one-sided test and at the 20% level in a two-sided test.
[b]Significant at the 5% level in a one-sided test and at the 10% level in a two-sided test.

Source: Gasmi, Laffont, and Vuong (1992)

3.237 The idea behind the Vuong test is to determine between each pair of models, which one of the two models is the most likely (that is, which one best fits the data). For example, when comparing M1 and M2, the Vuong test result is -0.12. The result is not statistically significant, which indicates that there is not enough evidence to decide between the two models.

3.238 Applying the Vuong test may be cumbersome. Indeed, the analyst must compare each pair of models. In the case of six models as in GLV, the analyst will have to perform 15 pair-wise tests. As the number of models increases, the testing procedure will become less manageable. For 10 models, this involves 45 pair-wise tests. In general, for N models, the analyst will perform $\sum_{i=1}^{N-1} N - j$ tests.

3.239 In the case of GLV, the test results show that the non-collusive models cannot be discriminated between themselves. Indeed, the pair-wise tests (M1, M2), (M1, M3) and (M2, M3) are all statistically insignificant. The results are provided in the first and second columns and rows of the above table.

3.240 However, the three models in which Coca-Cola and Pepsico are assumed to compete (M1, M2 and M3) are rejected in favour of M4 and M5. For example, the pair-wise test result for M1 and M4 is -4.55, which is statistically significant, leading GLV to prefer M4 over M1. The Vuong test results, however, do not favour M6 over each of the three models in which the firms are assumed to compute (M1-M3). M4 and M5 are also preferred over M6, which means that these models best fit the data, but the data does not allow GLV to distinguish between M4 and M5.

3.241 In sum, GLV conclude that their analysis support some form of collusion between Coca-Cola and Pepsi. GLV refine their analysis by allowing a regime change in the sample period, which was marked by wild price fluctuation due to the sugar crisis of the mid-1970s. They eventually conclude that during the sample period, some form of collusion in advertising took place between the two leading suppliers of carbonated soft drinks. The evidence on price collusion is less clear-cut.

Implementing the menu approach: Cox-type non-nested testing

3.242 Villas-Boas (2007) uses scanner data on yoghurt sales from three stores in a midwestern US city to examine the vertical relationship between manufacturers and retailers.[99] Since wholesale prices are not observed, Villas-Boas uses links between retail prices and the underlying product and cost characteristics to develop testable restrictions of different vertical contracting models.

[99] Villas-Boas appears to choose yoghurt sales because it has a short shelf life. The impact of this is that that short-run marginal costs changes can, in principle, feed through into wholesale prices. Consequently, she finds that the input costs, retail prices and wholesale prices are likely to correlated – a necessary for identification of the demand model.

3.243 She considers a number of economic models that describe different vertical relationship between manufacturers and retailers. To test which of the economic models is best supported by the data, Villas Boas adopts a two-step procedure. In the first step, like Nevo (2001) she estimates a random coefficient logit demand model. Then, taking the demand estimates as given, the fit of competing supply models is investigated in the second step using two approaches: informal tests and a more formal set of tests using the menu approach.[100] We focus on the latter.

3.244 To perform non-nested hypothesis testing, Villas-Boas (2007) uses Cox-type tests suggested by Smith (1992). These one-sided pair-wise tests compare the fit of a model assumed to be true under the null hypothesis to the fit of an alternative model. If the fit of the alternative model is significantly better than that under the null then the test statistic is high. If the test statistic exceeds the critical value, then we can reject the model assumed true under the null against the alternative. If a model cannot be rejected against any other model, then it is the 'winning' model.

3.245 Villas-Boas examines six different models of vertical relationships between manufacturers and retailers:

- **Scenario 1 – Simple linear pricing model**. Manufacturers sell to retailers with a mark-up and then the retailers set their mark-up.

[100] Villas-Boas uses are two different informal tests of the supply models. First, the retail price is regressed on marginal costs components, the implied retail margin, and the implied wholesale margin. In principle, if the supply model used to calculate the implied margin is correct, the estimated parameters on the implied margins should be equal to 1. Therefore, the null hypothesis of the 'informal' specification test is that the estimated parameters on the implied margins are not different from 1. In addition to this specification test, Villas Boas also assesses the fit of each supply model checking whether the implied marginal costs are always positive.

- **Scenario 2 – Hybrid model**. This is similar to the scenario as above, but in this case the retailers set the price of private label products as a vertically integrated firm.

- **Scenario 3 – Nonlinear pricing models**

  - **Zero wholesale margin**: manufacturers sell to retailers at cost and the retailers sets the price, and

  - **Zero retailer margin**: manufacturers set retail prices and incur retail costs.

- **Scenario 4 – Wholesale collusion**: manufacturers collude over wholesale prices and retailer price mark-ups.

- **Scenario 5 – Retailer collusion**: retailers collude to set and manufacturers continue to supply retailers competitively.

- **Scenario 6 – Monopolist**: retailers and wholesalers collude and act as a monopoly firm.

3.246 Figure 15 reports the results of Villas-Boas (2007) non-nested hypothesis testing. The models listed in the first column are assumed to be true under the null hypothesis and they are each tested against an alternative model listed in the top of the table. The numbers in the table are the p-values of the test statistic. The top panel of the table shows the results of the model where manufacturers are assumed to set one price for each store. The bottom panel shows the results of the analysis when manufacturers are allowed to treat chain stores differently to individual stores.[101]

3.247 The top panel of this table shows that only the wholesale collusion and monopolist models are not rejected against any of the other models. The non-collusive double mark-up models (simple linear pricing and hybrid)

[101] See notes at the bottom of Figure 6 for further details of the differences between the two tables.

and the retail collusion model reject one another. Similarly the non-linear tariff models (zero wholesale and zero retail margins) reject one another at the five per cent level.

3.248 If we allow the manufacturers to treat chain stores differently to individual stores, the results of the non-nested tests are that all models are rejected by at least one other model at the five per cent level of significance. In particular:

- the simple linear model and the zero retail margin model is rejected against three of the six alternatives at the five per cent level
- the hybrid model is rejected by wholesale collusion model at the five per cent level
- both wholesale and retail collusion models are rejected by all models except the zero retail margin model at the five per cent level, and
- the zero wholesale margin and the monopolist models reject five out the other six models at the five per cent level and are only rejected by one another.

Figure 65: Non-nested tests of different vertical pricing models

p-Values for pairwise non-nested comparisons

	Alternative models						
H_0 model	1	2	3·1	3·2	4	5	6
1: Simple linear pricing	–	0·50	0·00	0·50	0·24	0·00	0·50
2: Hybrid	0·00	–	0·50	0·50	0·12	0·00	0·50
3.1: Zero wholesale margin	0·41	0·29	–	0·05	0·50	0·39	0·07
3.2: Zero retail margin	0·39	0·40	0·05	–	0·50	0·39	0·17
4: Wholesale collusion	0·49	0·48	0·50	0·50	–	0·48	0·50
5: Retail collusion	0·00	0·00	0·50	0·50	0·22	–	0·50
6: Monopolist	0·34	0·35	0·17	0·31	0·48	0·34	–
Chain size weighted							
1: Simple linear pricing	–	0·08	0·01	0·06	0·08	0·00	0·00
2: Hybrid	0·17	–	0·15	0·22	0·00	0·06	0·14
3.1: Zero wholesale margin	0·08	0·15	–	0·11	0·15	0·12	0·00
3.2: Zero retail margin	0·01	0·07	0·00	–	0·09	0·01	0·00
4: Wholesale collusion	0·00	0·05	0·04	0·09	–	0·00	0·02
5: Retail collusion	0·00	0·02	0·03	0·11	0·02	–	0·00
6: Monopolist	0·10	0·20	0·00	0·15	0·20	0·14	–

Notes: *p*-Values reported from non-nested, Cox-type (Smith, 1992) test statistics of the null model in a row being true against the specified alternative model in a column. Bottom part is a robustness check. It has the same format as above, but the non-nested comparisons are based on estimates for the case when the portion of the manufacturer's profit due to each retailer is weighted by the retailer's chain size.

Source: Villas-Boas (2007)

3.249 Noting that both the zero wholesale margin and the monopolist models have zero wholesale margin and only differ in the mechanism by which the retail price is set (Nash-Bertrand vs. Collusion), leads Villas-Boas to conclude that the non-nested test results provide some evidence in support of the view that wholesale margins are zero and retail prices fall somewhere between the Nash-Bertrand and collusive levels.

Policy applications

3.250 Competition authorities are expected to determine whether firms hold significant market power and in some cases to identify the source of this power, which may not be the result of anti-competitive conduct. Sometimes, competition authorities need only assess whether a particular firm holds significant market power so as to be deemed dominant, in other words whether the firm exercises monopoly levels of market power. In other cases, competition authorities have to determine whether market power stems from collusive behaviour. In all cases, linking market power to firm conduct is at the core of the investigation.

3.251 In many investigations, the set of evidence gathered by competition authorities is not always clear-cut. As a result, in that context discriminating between collusive and non-collusive conduct is a challenge. When such situation arise we recommend that competition authorities consider applying some of the empirical methods that we have presented in this Chapter to gauge market power and to infer firm conduct. We have presented two approaches:

- the empirical conjectural variation model, and
- the menu approach.

3.252 As we have shown none of these approaches is perfect. In fact, they are based on static models of competition, whilst collusive conduct is best explained by taking into account repeated firm interactions. That these models are imperfect is however not a reason to discard them. First, they can prove useful to explain and predict some of the observed market outcomes. And second, the empirical estimation of dynamic oligopoly models is still the subject of academic research, and more progress must be achieved before it becomes practical to apply these models in competition policy investigations.

3.253 Where it is possible to do so we believe that using the approaches presented in this Chapter may provide useful evidence. However, best practice suggests that the analyst:

- assess the empirical results in light of the limits of each approach
- contrast the results with the other evidence collected in the course of the investigation. When the results and the qualitative evidence are inconsistent, both the assumptions that underpins the economic modelling that the analyst has adopted and the reliability and interpretation of the qualitative evidence should be carefully reviewed
- perform sensitivity analysis to assess the robustness of the results.

3.254 In paragraphs 3.255 to 3.276 we present the pros and cons of the empirical conjectural variation models and the menu approach respectively. Paragraphs 3.277 to 3.283 conclude.

Empirical conjectural variation models

3.255 In paragraphs 3.1 to 3.4, we introduced how empirical conjectural variation models can be used to gauge market power and to identify firms' conduct. The method is based on the estimation of a 'free' parameter (also known as the conduct parameter). The value of this parameter provides the analyst with an estimate of the degree of market power and it can be used to draw inferences about firms' behaviour.

3.256 We showed two ways to estimate the conduct parameter:

- calibrating the conduct parameter – the elasticity-adjusted Lerner Index (paragraphs 3.44 to 3.60), and
- estimating a supply relation model to recover the conduct parameter (the Conduct Parameter Method (paragraphs 3.61 to 3.94)).

3.257 In the following paragraphs we introduce the strengths and weaknesses of each method in turn.

Calibrating the Elasticity-Adjusted Lerner Index (EALI)

3.258 The analyst can directly compute the Elasticity-Adjusted Lerner Index, if she has access to the four necessary inputs: price, marginal cost, the price elasticity of demand and the firm's market share. Once the analyst has gathered the relevant information about each of these inputs, it is very simple and quick to calculate the conduct parameter. However, the ease of computing a precise value for the conduct parameter should not obfuscate a number of conceptual and practical difficulties.

3.259 First and foremost, it is far from trivial to obtain accurate estimates of all four inputs. Because the information that is used to calibrate the EALI is likely to be better approximated using a range of estimates for one or more inputs, the analyst should perform a sensitivity analysis. In particular, it seems reasonable to use a range of plausible values for marginal cost and the elasticity of demand, which are notoriously difficult to estimate:

- The marginal cost is not typically observed by the analyst. Even if accounting measures are sometimes used because they are readily available, the analyst has to bear in mind that marginal cost and the chosen accounting cost measure (that is, average variable cost in the case of gross margins) need not coincide. In fact, the NEIO literature emerged in part because marginal cost is simply not observed and must be estimated.

- The industry price elasticity of demand is typically not readily available. The analyst could infer consumer price sensitivity from marketing studies or take estimates of the aggregate elasticity of demand from academic studies. If, on the other hand, the analyst has enough data to estimate a consumer demand function, it might make sense to extend the model and implement the CPM.

- Market shares depend on the precise definition of the relevant market. Because market definition is often the subject of debate, the market shares used to compute the EALI might also be controversial.

3.260 Second, the analyst must be careful not to mix inputs that are not compatible with each other. For example, consider that the analyst seeks to determine whether an upstream manufacturer holds significant market power. If she relies on accounting information (which might not be correct) to compute the upstream firm's price-cost margin but considers using the price elasticity of demand at the retail level, this approach is inappropriate when upstream and downstream are engaged in bargaining to set prices. Although the retailer's demand is also a function of consumer demand, when firms negotiate prices, the upstream producer's margin is also determined by its bargaining strength. In this context, the conduct parameter is likely to be unreliable.

3.261 Third, most of the time the analyst is likely to obtain a non-zero value for the conduct parameter, which indicates that firms exercise some market power (that is, they set price above marginal cost). If the value is close to zero, this indicates that market power is negligible. However, even if the value is above zero in a market in which several firms supply a product, this does not imply that these firms do not compete. Market power is not always the result of collusive conduct. For example, to name but two alternative sources of market power, firms can achieve market power by supplying differentiated products or by having production processes requiring large upfront fixed costs.

3.262 Finally, the analyst may want to gauge based on the value of the conduct parameter whether firms are actually competing or have engaged in collusive conduct, whether tacitly or explicitly. For example, if there are five firms in the market and the market level conduct parameter is 0.5, the result might give rise to suspicion that firms are colluding. If instead, the value is 0.01, then the analyst might consider that the market outcome is close to perfect competition. These results could be compared with the benchmark value given by a Cournot game with five symmetric firms, which is 0.2. So in the first case, when the conduct parameter is 0.5, firms would appear not to compete vigorously, whilst in the second case, when the conduct parameter is 0.01, the analyst could conclude that firms are actively competing.

3.263 Overall, although computing the conduct parameter appears easy, we recommend that the analyst exercise caution before relying on this result as evidence that collusion has taken place. This is because there is considerable uncertainty about relying on a relatively imprecise measure of marginal cost and the elasticity of demand. It seems to us that this 'back-of-the-envelope' calculation may be most useful to form an 'initial view' about the extent to which market power is being exercised. In particular, policy makers could use it alongside other type of evidence to decide whether or not to devote resources to further investigate the links between market power and anticompetitive conduct.

Implementing the CPM

3.264 The analyst may elect to adopt a more formal approach and estimate the conduct parameter using the CPM. This requires the econometric estimation of a structural economic model. Although it is significantly more challenging to implement this method, it has a number of advantages over the calibration approach described above.

- One advantage is that marginal cost and the elasticity of demand are estimated using econometric techniques.[102] This allows the analyst to ascertain the precision of these estimates.

- Further, whilst the calibration approach could be viewed as a 'black-box', the CPM imposes upon the analyst to make explicit all the assumptions that support the structural economic model that is estimated. In particular, the CPM is based on a supply relation, which itself requires that the analyst sets up demand and marginal cost functions.

- In addition, the analyst can apply standard statistical tests to assess whether the conduct parameter estimate is significantly different from the value given by static oligopoly model benchmarks. For example, the analyst may be able to reject the hypothesis that firms behave in a non-coordinated manner (Nash-conduct), yet she may fail to reject the hypothesis that firms are perfectly colluding (that is, they achieve the monopoly outcome). In this case, the analyst may conclude that this result is evidence that anti-competitive conduct has given rise to monopoly levels of market power.

3.265 However, like the calibrated approach, the analyst should be wary of a number of potential shortcomings. Below, we highlight the major pitfalls the analyst might encounter:

- First, as stressed by Reiss and Wolak (2007), the identification of the conduct parameter relies entirely on functional form assumptions. Consequently, it would appear to be prudent to examine the robustness of the results to different functional form assumptions.

[102] The estimation of the marginal cost function does not require accounting cost data. For example, the analyst may have data on the price of key inputs.

For example, the analyst could estimate different demand curves as in Genesove and Mullin (1998) to assess how sensitive the results are to various functional forms.

- Second, the CPM assumes that products are homogenous. While this may be a suitable assumption in some industries, in others, where products are differentiated, this assumption is more difficult to sustain. For example, if the analyst has incorrectly assumed that products are homogenous, then she might wrongly assign market power that stems from product differentiation to collusive conduct.

- Third, the analyst must also heed structural misspecification highlighted by Corts. The so-called Corts critique arises when firms' behaviour cannot be replicated by a conjectural variation model. In this case the CPM yields unreliable results.[103] This is a serious issue as the analyst cannot determine ex-ante whether the firms' choice of price or output is also predicted by a conjectural variation model.

- Finally, the analyst must exert some caution about the interpretation of the estimated conduct parameter. Outside of a few specific values that link the conduct parameter to specific models of firm's conduct (that is, perfect competition, Nash, Stackelberg, and perfect collusion), the value of the conduct parameter does not correspond to a form of behaviour that can be rationalised in a static oligopoly model.

3.266 Some economists have put forward that conjectural variation models could represent a reduced form of a more elaborate dynamic oligopoly game in which collusion may emerge as an equilibrium (see Chapter 5). Re-cast in this manner, the conduct parameter can be viewed as a measure of market power of the collusive equilibrium that can be sustained in that industry. In particular the advantage of this approach is

[103] Since the Corts critique is essentially that the first order conditions are incorrect, it will also affect the calibrated elasticity adjusted Lerner index.

that the model also estimates 'imperfect' collusive equilibrium outcomes, and not just the monopoly outcome.

3.267 Whatever the analyst's view, it is important to note that the value of the estimated conduct parameter still hinges on assumptions needed to achieve identification. Therefore, the analyst will always be confronted by the possibility that values that do not correspond to static form of conduct are the result arbitrary functional form assumptions, not collusive conduct.

Conclusion

3.268 As the discussion above reveals relying on empirical conjectural variation models to link market power and firm conduct is the subject of debate. Reiss and Wolak (2007) states:

> 'If one wants to describe where price is in relation to a firm's marginal cost, then θ_i provides a descriptive measure of that, but not a statement about behaviour.'

3.269 However, this does not mean that these models are not useful when investigating a market. Like all models, using empirical conjectural variation models may be helpful in developing the analyst's understanding of the key parameters that govern the competitive interaction between firms.

3.270 To see how, suppose the analyst's estimation yields a firm level conduct parameter of 1.2, which is statistically different from 1. Rather than concluding that the industry exhibits 'softer' than Cournot competition, this finding may cause the analyst to revisit the underlying assumptions of the model. For example, she may consider that market power might be due to a first-mover advantage and test whether a Stackelberg model might be more appropriate. Alternatively, she might revisit the assumption of homogeneity and/or the functional forms imposed.

3.271 A second use for such models might be to rule out some form of firm conduct. As highlighted by the example in paragraphs 3.44 to 3.60, having calculated the elasticity-adjusted Lerner Index that is close to zero the analyst might feel confident that there is no 'smoking gun'. As such, she may feel comfortable in not assigning costly resources to investigate a market in which firms do not seem to exercise much market power.

The menu approach

3.272 The menu approach has the attractive feature that in each model the firms' conduct is made explicit. In practice, the analyst ranks all the models, and selects the one that best fits the data. She can then use the 'winning' model to simulate counterfactual market outcomes. Because the model is based on a clear theory of the firms' behaviour some economists view this as a major advantage over the empirical application of conjectural variation models. Reiss and Wolak (2007) state that if:

> '... one wants to use the estimated parameters to predict what would happen if the firms' economic environment changes, then one must have a theory in which beliefs and equilibrium behaviour coincide, or one must ask which of a small set of values of θ_i, corresponding to perfect competition, monopoly, Cournot and the like, best explains the data.'

3.273 However, if the purpose of the investigation is to detect market power and collusive conduct, then the advantage of the menu approach over CPM is arguably diminished, especially when products are homogenous. Note, however, that the Corts' critique continue to cast some doubt about the reliability of the CPM.

3.274 Furthermore, unlike the menu approach the CPM cannot realistically be applied in differentiated product industries whilst the menu approach. In particular, by applying the menu approach the analyst can distinguish between market power stemming from firms' conduct and that from product differentiation, which is a very useful feature.

3.275 However, as is the case with the CPM, the analyst must also make functional form assumptions. For example, the analyst has to assume a particular structure for the demand systems, which affects in particular the curvature of the demand function and the pattern of substitution. In addition, the analyst must also assume the shape of the marginal cost function.

3.276 Finally, it is highly desirable to test the specification of the selected model. Therefore, not only should the analyst check that the selected model is the one that best fits the data, it is important to also determine that the model is not grossly misspecified. For example, if the analyst adopts a simple logit demand system, this might restrict unrealistically the pattern of substitution between the products in the industry. One way to assess the model's specification consists in implementing the Cox-type non-nested tests. Although these non-nested tests are more demanding to compute than the Vuong non-nested tests, they do have the advantage of also testing the model's specification as well as whether one model is a better fit than another.

Conclusion

3.277 As we have shown above each approach has strengths and weaknesses. In spite of their shortcomings we believe that competition authorities could employ these empirical methods to measure the degree of market power and identify firms conduct. Obviously, in order to draw reliable conclusions, the implementations of these approaches must follow best practice. In particular, the economic model's assumptions should not blatantly contradict basic facts of the industry. Furthermore, the analyst should perform various sensitivity analyses to test the robustness of the results. Finally, the empirical results should be compared with other types of evidence.

3.278 In homogenous product industries, both EALI and the CPM may be useful policy tools for measuring market power. For example, EALI may be employed as a quick and simple 'back of the envelope' calculation to form an initial view on how much market power is being exercised.

3.279 With more data, the analyst might consider implementing the CPM to estimate the conduct parameter. The CPM allows the analyst to test the conduct parameter against well understood static oligopoly models and avoid the measurement issues of the EALI components. In addition, there is no risk of mixing and matching economic measures that are not directly connected (for example, combining the price elasticity of downstream consumer demand with upstream firms' margins). These additional benefits may give the analyst some confidence about applying the CPM approach. However, the Corts' critique continues to cast some doubts about the reliability of the results.

3.280 In differentiated products industries, EALI and the CPM cannot realistically be applied. In these industries, the menu approach is better suited to investigate the source of market power, and in particular whether it stems from product differentiation or from collusive conduct. The menu approach can also be applied in homogenous product industries. In particular, it is not subject to the Corts' critique.

3.281 This Chapter focused on the implementation of empirical economic models 'looking backward'. That is, the empirical analysis' objective is to assess the degree of market power and firms' conduct in the past. However, it is worth briefly discussing the case when the analyst is considering applying these economic models to predict market outcomes when the economic environment changes (that is, merger simulation or the impact of regulatory intervention in market investigations).

3.282 For example, if the policy maker is planning to implement the CPM, and then to use the results to perform policy simulations, she must be prepared to confront the problem that the conjectural variation model is unable to rationalise formally all kinds of firm conduct. In some cases, the results may lead to the conclusion that firms are colluding, but the model is unable to explain how firms sustain collusion. In this case, it is difficult to fathom how the economic model could help predict market outcomes following a change in the economic environment.

3.283 In sum we are sceptical about using economic models which do not explicitly rationalise firms' conduct to predict market outcomes based on some policy experiments. Recognising that no model is perfect, it would seem advisable to at least use a model that has solid economic foundations.

4 UNILATERAL EFFECTS – A SURVEY OF PRICE PRESSURE INDICES WHEN FIRMS HAVE CONJECTURAL VARIATIONS

4.1 In this Chapter we discuss a more **forwards-looking** approach to how conjectural variations can be used by policy makers, particularly with respect to unilateral effects analysis in merger control. Specifically, considering both empirical and theoretical issues, we examine the role that conjectures can potentially play with respect to the initial screens based on simple simulations that the OFT often uses to assess whether or not proposed mergers (especially retail mergers) may give rise to a realistic prospect of a substantial lessening of competition. We find that recent research by Jaffe and Weyl (2011) outlines an interesting and useful approach to incorporating conjectures in just this way, and highlight the key implications of their work. However, we also emphasise that the time and data constraints faced by competition authorities may significantly limit the extent to which their approach can be applied in practice.

Existing short cut approaches to analysing unilateral effects

4.2 In this section we discuss several standard short-cut approaches that have been developed to aid the assessment of the likely unilateral effects of a horizontal merger. In particular we highlight three measures that have attracted particular attention from antitrust practitioners.

- Upwards pricing pressure ('UPP')
- Gross upwards pricing pressure index ('GUPPI')
- Illustrative price rise ('IPR')

4.3 We provide a brief summary of these below.

Upwards pricing pressure (UPP)

4.4 Influential US economists have recently proposed 'an economic alternative to market definition' which they dub 'upward pricing pressure' or UPP.[104] They advocate this approach as representing a simple indicator which can be used as an initial screen of whether a horizontal merger between rivals in a differentiated products industry is likely to raise prices through unilateral effects. They present this as substantially more informative than a traditional approach (still prevalent in US courts) to screening mergers based on market concentration measures, which may have well-documented weaknesses in assessing differentiated products.[105]

4.5 In deriving their UPP measure, Farrell and Shapiro consider the effect of merger in a novel way. They explain how pre-merger competition between two single product firms producing substitute goods gives rise to a negative externality between firms (that is, one party's lower price harms the other's profits).

4.6 Specifically, Farrell and Shapiro note that an increase in sales by one of the merging parties will effectively cannibalise some of the sales of its partner. This can be conceived of as an opportunity cost of lowering the price – if one party lowers price to gain volumes, some of the gain comes at the expense of the other party. Farrell and Shapiro then explain that the owner of the two merged firms could allow the firms to continue to operate independently but internalise the externality by the

[104] Farrell and Shapiro (2010a).

[105] For example, market shares may not adequately capture the closeness of substitution between the parties' products. Furthermore, the process of market definition requires that substitute products must be somewhat artificially ruled either 'in' or 'out' of the market, a discrete choice that may in some cases play a significant role in determining the outcome of an investigation (this is sometimes dubbed the 'binary fallacy').

imposition of an internal tax on each division. The tax would raise production costs, making each division less keen on lowering their price.[106]

4.7 For example, suppose that pre-merger there are two firms, 1 and 2, respectively selling products 1 and 2. Following a merger of these firms, Farrell and Shapiro explain that the appropriate tax on product 1 would equal the opportunity cost of lowering the price of product 1. This is then compared against the merger specific reduction in the marginal cost of producing product 1 to give rise to their UPP index.[107] Specifically, Farrell and Shapiro calculate UPP for firm 1 as:

$$UPP_1 = D_{12}(p_2 - c_2) - E_1 c_1$$

4.8 Where D_{12} is the (quantity) diversion ratio from product 1 to product 2, p_2 is the price of product 2, c_1 and c_2 represent the marginal costs of firms 1 and 2 respectively, and E_1 is the percentage reduction in firm 1's marginal costs that result from merger-specific synergies.[108] The use of this approach as a merger screen would seek to examine whether UPP is greater than zero for both parties, a positive finding in this regard would

[106] This approach builds on earlier work by Werden (1996) who calculates the required marginal cost reductions to restore pre-merger prices when firms compete in a differentiated Bertrand setting. Similarly, Froeb and Werden (1998) calculate these critical efficiencies in a Cournot setting. See also O'Brien and Salop (2000) who derive several measures of the economic pressure to change prices in response to a change in ownership structures, each of which they term a Price Pressure Index (PPI).

[107] This provides a **first-round** estimate of the necessary internal tax. Farrell and Shapiro (2010a) note in their Proposition 2 that for UPP the true value of the internal tax depends on variables being measured at post-merger levels.

[108] The opportunity cost of selling an additional unit of product 1 is the product of the diversion ratio (from 1 to 2) and the absolute margin earned on product 2. To see this, note the following. Suppose a small increase in the price of product 1 would lead to 100 lost units of which 30 switch to product 2 (*for example* the diversion ration from 1 to 2 is 30 per cent). This implies that a small decrease in the price of product 1 would lead to a gain of 100 units, of which 30 are won from product 2. Those units switched from product 2 entail an opportunity cost per unit equal to the margin earned on product 2.

indicate that the merger may lead to higher prices and should be subject to closer scrutiny.[109]

4.9 Ultimately, Farrell and Shapiro's approach does not attempt to predict the change in prices that will result from a merger, as they comment that this will depend on various complex issues such as the curvature of demand. Rather, their measure simply seeks to estimate the direction of the price change, that is, they consider only whether prices will increase or decrease. Intuitively, if the additional cannibalisation 'cost' (or 'tax') that results from the merger is greater than the reduction in marginal cost through synergies then overall (effective) marginal costs will rise, leading to higher prices.

UPP – a more conventional explanation

4.10 Farrell and Shapiro's approach to deriving the UPP test through the lens of internal taxes, while innovative and in many cases insightful, may be unfamiliar to many antitrust practitioners. A more conventional approach to understanding how a merger may give rise to higher prices is simply to note that (i) a price increase that leads to the loss of sales to rivals becomes less costly following a merger, because the sales that divert to the other merging party are now effectively recaptured by the firm in question and (ii) merger specific efficiencies make increasing the price less attractive because lost sales are more 'costly' because the lost margin is higher.[110]

[109] More specifically, in Proposition 1 of Farrell and Shapiro (2010a) they find that, if prices are increasing in a firm's own marginal cost, and non-decreasing in the marginal cost of its merging partner, if for both firms UPP is greater than zero then the merger will lead to an increase in prices. However, it is less clear what the appropriate approach to a merger should be if UPP is positive for only one of the merging parties, the approach in the UK in this regard has been to investigate whether either price may increase post-merger.

[110] In this spirit, see Bailey, Leonard, Olley and Wu (2010)'s alternative derivation of the UPP test.

4.11 By bearing this more traditional interpretation in mind, the three elements of the UPP formula can be explained as follows. Prices are more likely to rise if:

- Firm 2 is a major constraint on Firm 1. This relates to the closeness of substitution between firm 1 and firm 2, and in particular what proportion of consumer purchases switched away from product 1 as a result of a price increase would be recaptured by product 2. This is given by the diversion ratio from product 1 to 2, which measures the percentage of 1's lost volumes captured by firm 2 following the price increase of product 1 (and holding other prices constant). For example, suppose firm 1 increases price and loses 100 units as a result, if 2 captures 30 of those lost units then the diversion ratio, D_{12}, is 30 per cent. Intuitively, the more of 1's lost volumes that 2 captures, the more firm 2 constrains firm 1.

- Firm 2 has a high absolute margin. The higher is firm 2's absolute margin, the greater the value of the sales that will be recaptured at 2 following a price increase.

- Efficiency reductions in Firm 1's marginal cost are small. Other things being equal, if firm 1's costs fall it has a greater incentive to lower prices because it becomes more costly for it to lose volumes. So firm 1 is more likely to increase its price if it does not benefit from substantial marginal cost reductions as a result of the merger.

UPP context

4.12 Farrell and Shapiro seek to develop a screen that is both informative and easy for a judge to understand. In our view, the UPP approach is best understood in a US context, where mergers are frequently assessed by courts, the definition of the relevant market is generally considered crucial and the structural presumption that mergers leading to high market shares are anticompetitive remains strong.

4.13 In that regard, the main advantages of the UPP test highlighted by Farrell and Shapiro are the facts that it is theoretically more appealing than market share screens, it is simple and intuitive, and it only relies on a small amount of pre-merger data, particularly when compared to much more data-intensive and complex merger-simulation techniques. In particular, it requires only information on margins, which may be available from firms' accounts, and the standard 'Bertrand' diversion ratio, which it may be possible to estimate from a survey. These advantages arise because, as Farrell and Shapiro themselves note, the UPP approach is a less ambitious exercise as it does not seek to calculate the post-merger equilibrium, but simply to understand whether that equilibrium is characterised by higher or lower prices.[111] Because the formulas do not present an equilibrium result, but rather an approximation, UPP tests are often dubbed 'first-order' approaches.

4.14 The point to emphasise here – which is important when we come to discuss the role of conjectural variations in UPP type tests – is that the aim of UPP was to establish a simple initial screen that is better than a market share screen for horizontal mergers involving differentiated products. It does not purport to be an accurate predictor of the competitive effects of a merger or a screen that trumps a detailed investigation of the strength of existing competition, potential competition and buyer power.

Gross upwards pricing pressure index (GUPPI)

4.15 One variation on the UPP test which has garnered particular attention recently is the Gross Upward Pricing Pressure Index, or GUPPI, introduced by Salop and Moresi (2009a and 2009b) and Moresi (2010). In particular, this test has been adopted by the recently published US Horizontal Merger Guidelines.[112] GUPPI is defined as

$$GUPPI_1 = \frac{D_{12}(p_2 - c_2)}{p_1}$$

[111] Farrell and Shapiro (2010b).

[112] Horizontal Merger Guidelines, U.S. Department of Justice and the Federal Trade Commission, 19th August 2010.

with an equivalent expression for product 2. As the above formulation makes clear, GUPPI is UPP excluding the efficiency credit, and then scaled by the price of the product in question, here product 1.

4.16 A possible strength of the GUPPI lies in the fact that it can be more directly related to market definition by simulating a post-merger price rise to shed light on the question of whether a SSNIP would be profitable for the merging firms. This requires measuring (or assuming) the pass-through rate, defined as $\rho_1 = \frac{\Delta p_1}{\Delta c_1}$. Note that this is the single firm pass-through rate, that is, the amount by which a firm's price would increase relative to the increase in its marginal cost, holding the marginal cost of all other firms in the industry constant.[113]

4.17 The approximation for the percentage price increase arising from a merger is then calculated as

$$\frac{\Delta p_1}{p_1} = \rho_1 \frac{D_{12}(p_2 - c_2)}{p_1} = \rho_1 GUPPI_1$$

4.18 Intuitively, recall the discussion above of how a merger can be thought of as creating an opportunity cost of lowering price, approximately equal to $D_{12}(p_2 - c_2)$. This cost 'increase' is passed through by an amount equal to ρ_1. Thus the **change** in price equals $\rho_1 D_{12}(p_2 - c_2)$. Dividing through by p_1, yields a prediction for the percentage price rise.[114] Indeed, we understand that in the UK the approach that has typically been adopted is along these lines, viewing it as the value of business internalised by the merger calibrated as a potential price rise.

[113] To be precise, one needs to be careful what is meant by the pass-through rate, for example there is a difference between the pre-merger pass-through rate and the post-merger pass-through rate. Jaffe and Weyl (2011) show that what is relevant in the context of a merger is neither of these, though it may be close to them. Also see Kominers and Shapiro (2010).

[114] Jaffe and Weyl (2011) go further and use the pass-through matrix to derive an expression for the change in consumer welfare.

4.19 As applied to horizontal mergers, the hypothetical monopolist test is often implemented by a SSNIP test. Under this approach, the products supplied by (say) two firms constitute a relevant market when, if they were under joint ownership, the owner would be able to profitably institute a 'small but significant and non-transitory increase in price' (holding other prices constant). In practice the SSNIP threshold is often interpreted to be either five per cent or 10 per cent. With reference to GUPPI, if the formulation given above indicates that the merger would result in a price increase greater than a given SSNIP threshold (say five per cent or 10 per cent), then the two firms alone would constitute a relevant market.[115] In other words, the GUPPI test suggests a narrow market consisting of only the two merging parties if

$$GUPPI_1 \geq \frac{SSNIP\ threshold}{\rho_1}$$

Illustrative price increase (IPR)

4.20 One limitation of using a first order approach such as GUPPI to estimate the price effect of a merger is that fact that it only examines a change in the price of one of the merging products at a time and therefore it ignores feedback effects between the merging firms' two products. In order to gain a more theoretically consistent (albeit not necessarily accurate) estimate of the impact of a merger on price which accounts for such feedback effects it is necessary to make more assumptions regarding the nature of oligopoly conduct and the structure of demand – in particular the 'shape' of the demand curve.

[115] Of course, this assumes that the parameters are measured correctly. Note that technically GUPPI is a first order approximation to a 'profit-maximising' SSNIP test (which examines whether the **optimum** price rise is at least 5-10 per cent), as opposed to a 'profitable' SSNIP test (which examines whether a price rise of 5-10 per cent is profitable, even if it is not optimum). However, if the two firms form a relevant market under a profit-maximising SSNIP test then they must also constitute a relevant market under a profitable SSNIP test.

4.21 This illustrative price rise ('IPR') approach follows the work of Shapiro (1996), who provided simple formulas that, under certain strong assumptions (such as symmetry and particular forms of the demand curve), estimate the percentage price increase that would result from a merger as a function of only the diversion ratio and the margin. For example, with linear demand the increase is given by

$$IPR(linear) = \frac{DM}{2(1-D)}$$

And with constant elasticity (isoelastic) demand this is given by

$$IPR(isoelastic) = \frac{DM}{1-M-D}$$

4.22 The preceding formulae are restrictive. They assume that firms have the same prices and marginal costs pre-merger and that the diversion ratio from product 1 to product 2 is exactly equal to that from 2 to 1. Put another way, there is no scope for asymmetric diversion patterns or for firms to have different prices and costs – usually unrealistic in practice. Further expressions have subsequently been derived to allow for more 'realistic' assumptions. For example, assuming linear demand, Hausman, Moresi and Rainey (2010) demonstrate that if the cross price effects are equal, so we have $\frac{\partial Q_2}{\partial p_1} = \frac{\partial Q_1}{\partial p_2}$, then the illustrative price increase allowing for asymmetries in prices, marginal costs and diversion ratios would be:

$$IPR_1 = \frac{D_{12}(p_2 - c_2) + D_{12}D_{21}(p_1 - c_1)}{2(1 - D_{12}D_{21})p_1}$$

4.23 This highlights a recurrent theme as regards the use of UPP screens, there is a trade-off between simplicity and accuracy in theory (that is, even before we consider how to measure the various parameters appropriately). For example, one can debate whether additional feedback effects should be incorporated, such as how to take into account likely reactions of other firms. If other firms would increase their prices following a price rise by the merging parties, then UPP screens understate upwards pressure, on the other hand, if new entry or product repositioning would occur post-merger, the screens might understate the likely impact. We discuss this further in the following section.

Implications of conjectural variations for the analysis of unilateral effects

Link between existing approaches and conjectural variations

4.24 One way to take into account responses by rivals is to adopt a conjectural variations approach. Before discussing this, however, we note an important distinction between conjectural variations and what we dub 'partial approaches' such as those associated with UPP, GUPPI and IPR.

4.25 There are different approaches to measuring price impacts depending on what else is held constant. In the following we refer to firms 1 and 2 as simply '1' and '2' respectively.

- If 1 and 2 merge, we may calculate a basic UPP measure holding constant 2's price (and cost).
- If 1 and 2 merge, we may calculate a price pressure measure allowing the prices of 1 and 2 to change, holding non-merging parties' prices constant. (The above UPP and GUPPI formulae consider the change in 1's price holding 2's constant. The IPR formulae shown above allow the prices of the merging parties to change, but not the prices of their rivals.)
- If 1 and 2 merge, we might in principle calculate a price pressure measure allowing the prices of 1 and 2 to change and also allowing non-merging parties' prices to change as well. Even here, it is typical to assume no new entry and product repositioning occurs. However, models can be extended to allow for these features as well (albeit at the expense of added complexity).

4.26 Thus the preceding models can be thought of as partial approaches – partial in the sense that certain competitor reactions (for example, their prices or scope for new entry) are not addressed.

4.27 In all of the above cases, it is normal to model firms as setting prices just **once** and **simultaneously** – that is, there is no opportunity for firms to respond to each other's prices, by changing their own price. For this reason, we derive equilibrium on the basis that each firm assumes that as it changes its price, the prices of all of its rivals are held fixed. More formally this can be expressed as $\frac{dp_j}{dp_i} = 0$, or in other words these approaches implicitly assume a conjectural variation of zero.

4.28 However in practice, competition between firms is often a process that takes place over time, and is not in fact a simple, simultaneous move, one-shot game as assumed in a standard static differentiated Bertrand model. There are various ways to deal with this issue. One would be to model the dynamic game explicitly. Though in many cases this may be a difficult exercise, it may at least be possible to shed some light on the dynamic process which serves to shape market outcomes. Another way is to model the game as being played once but assume that when firms set prices they form an expectation as to how rivals will react to those prices – that is, they have a non-zero conjectural variation.

4.29 The extent to which such an approach is appropriate in theoretical or empirical terms is addressed in Chapter 2 and Chapter 3 of this report respectively. Furthermore, in Annexe B we outline a simple modelling exercise where we compare the actual impact of a merger in a market characterised by dynamic competitive interaction (specifically a Stackelberg model) to the price increase that would be predicted by a calibrated static conjectural variations model. This exercise demonstrates that, in the specific example considered, the CV model overestimates the price increase that would emerge from the merger by 50 per cent. This represents a significant overstatement, and serves as a general caution that trying to model complex dynamic interactions in a simple static framework runs the risk of failing to accurately capture the true nature of competition.

Conjectural variations and UPP – the theoretical approach

4.30 Farrell and Shapiro (2010a, b) discuss how the fundamental logic underlying the UPP test is in fact relatively general, and does not depend on the specific form of competition. Essentially, as outlined by Bailey, Leonard, Olley and Wu (2010), UPP considers how a merger affects a firm's first order condition. As noted in Chapter 2, with conjectural variations firms' first order conditions are modified to take into account a perception that a change in their own actions will lead to responses from rivals. In principle, the two approaches can be combined so that we allow for mergers when firms have non-zero conjectural variations in price.

4.31 Jaffe and Weyl (2011) consider the more general case of UPP where each merging firm is assumed to have a non-zero conjecture as regards how its rivals would respond to a change in its own price. With conjectures of zero this simply collapses into the standard UPP formulation. They ultimately conclude that we can still use a measure similar to the standard UPP formula if we use a different estimate of the diversion ratio. They put aside the issue of efficiencies and outline a measure called Generalised Pricing Pressure, or GePP, which expressed in their notation is:

$$GePP_1 = \widetilde{D}_{12}(p_2 - c_2) - (\mu_1 - \tilde{\mu}_1)$$

4.32 Here $\widetilde{D}_{12}$ is the alternative measure of the diversion ratio which Jaffe and Weyl argue is appropriate to use in this context. This measure examines the level of switching to product 2 in response to an increase in the price of product 1, holding constant the price of product 2, and the **strategies** of all other firms, which here means assuming that rivals do not change the way that they (are perceived) to respond to changes in the prices of the merging parties. In particular, although their approach does not specifically rely on this assumption, Jaffe and Weyl (2011) note that considering the case of consistent conjectures allows the use of real-world data to inform the value of conjectures, thereby making their measure easier to estimate.[116]

[116] Broadly speaking, a consistent conjecture means that firm 1 conjectures accurately what firm 2 would do if firm 1 changed its price. Thus, having observed how firm 2 actually responds to firm 1's price, one can infer firm 1's conjecture.

4.33 The additional term, $\mu_1 - \tilde{\mu}_1$, represents the fact that post-merger the first order condition changes. If firm 1 owns product 2, then firm 1 no longer has to form a conjecture as to how firm 2 will react to a change in firm 1's price. Instead, 1 controls 2's price and so, when maximising profits, the first order condition relevant for determining the price of product 1 will treat the price of firm 2 as **constant,** that is, post-merger we have $\frac{dp_2}{dp_1} = 0$, whereas pre-merger $\frac{dp_2}{dp_1} > 0$, which we denote 'accommodating price reactions'.[117] With such accommodating price reactions, that is, so that rivals (are perceived to) increase their prices as firm 1 increases its price, there is an offsetting effect on upwards pricing pressure. Compared to the case of zero conjectural variations, firm 1 would have had a greater incentive to increase price pre-merger (as this would in turn induce a price increase from 2, which would act to reduce the number of customers that 1 would lose from its price rise), however this incentive to price at a higher level is removed by the merger. Put another way, the accommodating responses pre-merger soften competition between firm 1 and firm 2 such that the removal of competition between 1 and 2 post-merger has a reduced impact on raising price: if pre-merger the two merging firms would effectively have not been competing very aggressively, there is little scope for loss of competition post-merger. Jaffe and Weyl (2011) dub this the 'end of accommodating reactions' term.[118] [119]

[117] In principle $\frac{dp_2}{dp_1} < 0$ is also possible, although, as discussed below, in Bertrand price-setting models best response functions slope upwards suggesting a presumption that $\frac{dp_2}{dp_1} > 0$ may be more appropriate.

[118] Jaffe and Weyl's approach is related to the earlier analysis of Baker and Bresnahan (1985) who consider the impact of a merger using residual demand curves which capture the responses of rivals to any price changes by the parties. Their work therefore potentially provides a means to estimate the effect of a merger on prices, however, as outlined by Davis and Garces (2009), several practical limitations have been identified with this approach. In particular, their methodology has very strong data requirements, requiring information on all variables that may affect the costs of, or demand for, all third party firms to accurately solve for the parties' prices.

[119] See also Jaffe and Weyl (2011b) for a less technical version.

4.34 Given the OFT's interest in the application of conjectural variations to UPP and other practical measures, we outline a derivation of GePP from first principles using an alternative notation that may be more familiar to most practitioners and which may serve to help to make the underlying intuition clearer.[120]

Conjectural variations, single product firms and UPP

Pre-merger

4.35 Pre-merger firm 1 maximises the following standard profit function

$$\pi_1 = (p_1 - c_1)q_1(\boldsymbol{p})$$

4.36 These profits are maximised by taking the derivative of the above expression with respect to p_1, and setting the expression equal to zero – this is known as the 'first order condition'. With zero conjectural variations on price, there is no difference between taking the **total** and the partial, derivative of the above expression for profit, with respect price. However, when we allow for non-zero conjectures, we must consider the total derivative. This gives us the following first order condition

$$\frac{d\pi_1}{dp_1} = q_1 + (p_1 - c_1)\frac{dq_1(\boldsymbol{p})}{dp_1} = 0$$

4.37 This can also be written as follows (where, for convenience, we write q_1 instead of $q_1(\boldsymbol{p})$

$$q_1 + (p_1 - c_1)\left(\frac{\partial q_1}{\partial p_1} + \sum_{k=2}^{n}\frac{\partial q_1}{\partial p_k}\frac{dp_k}{dp_1}\right) = 0$$

4.38 Note that $\frac{dp_k}{dp_1}$ is the conjectural variation of the price of product k with respect to the price of product 1. The term $\left(\frac{\partial q_1}{\partial p_1} + \sum_{k=2}^{n}\frac{\partial q_1}{\partial p_k}\frac{dp_k}{dp_1}\right)$ represents

[120] The following section is our interpretation of Jaffe and Weyl (2011). We are grateful to Glen Weyl and Sonia Jaffe for very helpful correspondence, which has informed the approach set out below.

the impact on the sales of product 1 of a change in its price. As the expression makes clear, this is the sum of direct switching in response to a change in the firm's own price, $\frac{\partial q_1}{\partial p_1}$, and indirect switching from the resulting changes in prices of all rival products, $\sum_{k=2}^{n} \frac{\partial q_1}{\partial p_k} \frac{dp_k}{dp_1}$. This indirect switching in turn depends on both the magnitude of the price conjectures, $\frac{dp_k}{dp_1}$ (that is, how accommodating they are assumed to be), and the switching rates from these firms to product 1, given by $\frac{\partial q_1}{\partial p_k}$.

4.39 Note that an alternative way to write this expression (which will be useful further below) is given by taking firm 2 out from the summation term, which now starts from k = 3, as follows:

$$q_1 + (p_1 - c_1)\left(\frac{\partial q_1}{\partial p_1} + \sum_{k=3}^{n} \frac{\partial q_1}{\partial p_k} \frac{dp_k}{dp_1}\right) = -(p_1 - c_1)\frac{\partial q_1}{\partial p_2}\frac{dp_2}{dp_1}$$

4.40 This expression therefore must hold when evaluated at pre-merger prices.

Post-merger

4.41 Post-merger firm 1 now also controls the price of product 2, and maximises profits across the two products. The profit function of the merged firm is now:

$$\pi_{1+2} = (p_1 - c_1)q_1 + (p_2 - c_2)q_2$$

4.42 Again we take the derivative of the above expression for profit with respect to the price of product 1 to give rise to the new first order condition. This gives the following expression:

$$\left.\frac{d\pi_{1+2}}{dp_1}\right|_{p_2} = q_1 + (p_1 - c_1)\left.\frac{dq_1}{dp_1}\right|_{p_2} + (p_2 - c_2)\left.\frac{dq_2}{dp_1}\right|_{p_2} = 0$$

4.43 The vertical bar indicates that p_2 is held constant (joint profit maximisation requires that when differentiating with respect to the price of product 1, we hold the price of product 2 constant, and vice versa). Thus, the total derivatives here are different to those in the pre-merger situation. We can decompose both total derivative terms in a similar fashion as above, except here the fact that p_2 is held constant means that the summation terms start at k = 3. We therefore obtain the following expression:

$$\left.\frac{d\pi_{1+2}}{dp_1}\right|_{p_2} = \left[q_1 + (p_1 - c_1)\left(\frac{\partial q_1}{\partial p_1} + \sum_{k=3}^{n}\frac{\partial q_1}{\partial p_k}\frac{dp_k}{dp_1}\right)\right] + (p_2 - c_2)\left(\frac{\partial q_2}{\partial p_1} + \sum_{k=3}^{n}\frac{\partial q_2}{\partial p_k}\frac{dp_k}{dp_1}\right)$$

4.44 We are interested in how the merger affects pricing relative to pre-merger levels. We can therefore evaluate the above at pre-merger prices (which amounts to substituting in the expression from paragraph 4.39 above for the term in square brackets). This gives rise to the following:

$$\left.\frac{d\pi_{1+2}}{dp_1}\right|_{p_2} = (p_2 - c_2)\left(\frac{\partial q_2}{\partial p_1} + \sum_{k=3}^{n}\frac{\partial q_2}{\partial p_k}\frac{dp_k}{dp_1}\right) - (p_1 - c_1)\frac{\partial q_1}{\partial p_2}\frac{dp_2}{dp_1}$$

4.45 The first term, $(p_2 - c_2)\left(\frac{\partial q_2}{\partial p_1} + \sum_{k=3}^{n}\frac{\partial q_2}{\partial p_k}\frac{dp_k}{dp_1}\right)$ is positive if, as we have assumed, $\frac{dp_k}{dp_1} > 0$, given that the n products in the market are all substitutes.[121] It is increasing in the margin earned on product 2, as well as the extent to which a higher price of product 1 increases demand for product 2. It is also increasing in the extent to which a higher price of product 1 is perceived to cause the non-merging parties to increase their prices and how, in turn, these latter price increases lead to higher demand for product 2.

4.46 The second term on the other hand is negative, that is, $-(p_1 - c_1)\frac{\partial q_1}{\partial p_2}\frac{dp_2}{dp_1} < 0$. It is more negative the larger the margin earned on product 1, and the more that a higher price of product 1 caused the price of 2 to go up (pre-merger), thereby increasing demand for product 1.

4.47 If the second term were sufficiently negative to offset exactly the first term, then there would be no change in price as a result of the merger. However, if the overall expression is positive, the first order condition

[121] In the following we take as given that $p_i > c_i$, *for example* that margins are positive.

would not be satisfied post-merger and so the price of product 1 would have to be increased (compared to its pre-merger value). On the other hand, if the overall expression were negative, the price of product 1 would fall.

4.48 It is of interest to consider the impact of incorporating positive conjectural variations on rivals' prices, compared to the case of zero conjectures. Consider, for example, the case of 3 firms, where firms 1 and 2 merge. On the one hand, the conjecture on how 3 responds to 1's price gives rise to an additional incentive to increase the price of product 1 (since it induces the price of product 3 to go up, thereby shifting some demand to product 2). On the other hand, prior to the merger, firm 1 was already taking into account the fact that increasing the price of product 1 would induce a higher price of product 2, in turn reducing the volume of sales lost on product 1. This incentive to price higher is removed by the merger; in other words to the extent that competition between 1 and 2 pre-merger was relatively soft, this reduces the incentive to increase price further post-merger. In the extreme case, where firms 1 and 2 were previously perfectly colluding, the merger will have no impact at all.[122]

4.49 The sign of the expression above therefore can be thought of an index that (approximately) represents whether or not there is upwards pressure on the price of product 1. Linking this to Farrell and Shapiro's approach, see above, we can estimate the per-unit internal tax that the merged firm would have to levy on its hypothetical separately run divisions (that is, which independently set the prices of product 1 and product 2) in order to prevent them lowering prices too much and cannibalising each other's sales.[123] In other words, we divide through by the absolute value of $\left.\frac{dq_1}{dp_1}\right|_{p_2}$, as this is the relevant change in volumes of product 1 given the change in its price (and any responses of rivals) holding the price of

[122] More precisely, this would be the case where firms 1 and 2 were perfectly colluding against the residual demand given by their conjectures of outside firm reactions.

[123] As discussed above, this provides a **first-round** estimate of the necessary internal tax.

product 2 constant. This gives us what we understand to be Jaffe and Weyl's alternative formulation of UPP, GePP, as follows:

$$GePP = \frac{\left(\frac{\partial q_2}{\partial p_1} + \sum_{k=3}^{n} \frac{\partial q_2}{\partial p_k} \frac{dp_k}{dp_1}\right)}{\left|\frac{\partial q_1}{\partial p_1} + \sum_{k=3}^{n} \frac{\partial q_1}{\partial p_k} \frac{dp_k}{dp_1}\right|}(p_2 - c_2) - \frac{\frac{\partial q_1}{\partial p_2} \frac{dp_2}{dp_1}}{\left|\frac{\partial q_1}{\partial p_1} + \sum_{k=3}^{n} \frac{\partial q_1}{\partial p_k} \frac{dp_k}{dp_1}\right|}(p_1 - c_1)$$

4.50 Note that when conjectures are zero, $\frac{dp_j}{dp_i} = 0$, this expression simply collapses down to the standard UPP expression (excluding efficiencies).

$$GePP\left(\frac{dp_j}{dp_i} = 0\right) = \frac{\frac{\partial q_2}{\partial p_1}}{\left|\frac{\partial q_1}{\partial p_1}\right|}(p_2 - c_2) = D_{12}(p_2 - c_2)$$

4.51 Intuitively, and as noted by Jaffe and Weyl, the introduction of a conjectural variation parameter has two offsetting effects.

4.52 Firstly, accommodating reactions raise the (modified or 'conjectured') diversion ratio, and therefore make prices rises more likely, for two reasons. They reduce the sales lost by firm 1 following an increase in its price, because rivals also increase their prices meaning customers are less likely to switch away. They also increase the sales gained by firm 2 as a result of this price change, as it becomes relatively cheaper compared to third party competitors. Broadly speaking, the numerator of the diversion ratio is increased while the denominator is reduced.

4.53 Secondly, and offsetting this increased diversion, is the fact that positive conjectures increase the end of accommodating reactions term, which tends to reduce the incentive to raise prices post-merger. Therefore, because these two effects to some extent offset one another, Jaffe and Weyl argue that the size of GePP may therefore not differ too significantly over alternative values of the conjectural variation parameter. They highlight this as a strength of GePP, as it potentially means that it can be applied under assumptions such as consistent conjectures that are easier to estimate in place of potentially more realistic (but harder to estimate) ones.

4.54 However we note that, to the extent that they are right that conjectural variation parameters do not have a significant impact on the likelihood of unilateral effects arising, this potentially implies that practitioners may not actually need to concern themselves with conjectural variations much at all as the failure to account for these may not represent a significant additional limitation of existing measures such as IPRs and UPP.[124]

Implications for practical implementation

Formal implementation

4.55 As the expression laid out in the previous Section makes clear, in order to formally and precisely estimate GePP in practice would require not only information on the prices and costs of both merging parties, but also estimates of all of the relevant conjectural variation parameters and the switching patterns relating to how increases in the prices of non-merging firms' products lead to higher sales of product 1 and product 2.

4.56 One approach to identifying conjectures is to assume that they are consistent with pre-merger observed patterns. Although Jaffe and Weyl's approach is more general, this is one particular case that they focus on.[125] That is to say, if (and this is potentially a 'big if') we could find a situation where an idiosyncratic cost shock for product 1 led to the price of product 1 going up, we might then 'observe' (that is, estimate controlling for other impacts on prices and volumes) how other prices reacted. We might then presume that these estimated reactions by firm 1's rivals match exactly firm 1's conjectures as to how its rivals react to a change in its price. Specifically, we would estimate $\frac{dp_2}{dp_1}$ and

[124] It is important however to appreciate that these measures still rely on a range of restrictive assumptions, as discussed in paragraphs 4.20-4.23; for example predicted price rise formulae may require restrictive and non-transparent assumptions on the pass-through rate. Our analysis takes as given that the Authorities are applying a price pressure index, it is beyond the scope of our report to opine on the merits of applying such tests as phase 1 screens.

[125] For example Jaffe and Weyl (2011b) argues that '(e)stimates of pre-merger accommodating reactions could either be based on data from the industry or information from industry experts, or on internal documents indicating the firms' expectations about rivals' reactions to price changes combined with an assumption that those expectations are correct.”

assume this to be firm 1's conjecture on how 2 responds to a change in its price.

4.57 Further, we could (in principle) estimate switching patterns as well. We would thus obtain information on $\frac{dq_1}{dp_1}$ and $\frac{dq_2}{dp_1}$.

4.58 Unfortunately, formally implementing GePP may be more complicated than this because the appropriate diversion measure requires the price of product 2 to be held constant, while an observed cost shock would likely also lead to the price of product 2 changing. More specifically, if the price of product 2 increases with that of product 1, we would be likely to observe lower rates of switching to firm 2 as a result of the cost shock than we would from a post-merger price increase, holding the price of product 2 constant.

4.59 A possible way to gauge the necessary derivative holding the price of product 2 constant would be to estimate the partial derivative $\frac{\partial q_1}{\partial p_2}$, and adopt the following approximation:

$$\left(\frac{\partial q_1}{\partial p_1} + \sum_{k=3}^{n} \frac{\partial q_1}{\partial p_k} \frac{dp_k}{dp_1}\right) = \frac{dq_1}{dp_1} - \frac{\partial q_1}{\partial p_2} \frac{dp_2}{dp_1}$$

4.60 In principle, some of the relevant parameters could be gauged by survey evidence (for example the partial derivatives required), although this leaves open the fundamental question of how to measure conjectures. Attempting to econometrically estimate the necessary parameters by using a structural model is a difficult process that can take several weeks, even if it is possible at all given the likely data restrictions. Furthermore, if a practitioner were to estimate such a model it is not clear that they would want to apply the results in a UPP-style framework, rather than simply estimating the impact of the merger more directly.

4.61 In Annexe C we outline one, though not the only, possible approach to formally implementing GePP, using information from observing separate cost shocks for **each** firm in the market. By combining this information it is possible to observe the size of the price responses of each firm, and thereby imply all of the switching rates, which can then be used to estimate the impact of the merger. It is important to realise that the cost shocks must be single-firm shocks, so that the price changes by rival firms occur only in response to the initial price change made by the firm experiencing the increase in costs.

4.62 However, in practice it is highly unlikely that such detailed cost shock information will be available in the context of the use of such measures as an initial screen. Even to the extent that notable cost shocks do occur, they may well affect several firms given that they are likely to all purchase similar inputs for their production processes. Furthermore, in reality there is likely to be a significant volume of noise in the data, as other market conditions change which will affect pricing and volume levels – in other words it is likely that the practitioner would need to observe certain types of idiosyncratic demand shocks as well. These issues in estimation are similar to those that emerge in the NEIO literature and are discussed further in Chapter 3.

4.63 Jaffe and Weyl (2011) are more optimistic and note that it is actually possible to implement their approach simply using clean instruments for the costs of the two merging firms, rather than that of all firms, which they argue is strictly less than that which is required in any other demand estimation exercise.[126] They also make the point that any econometric technique that purports to measure cross-price elasticities will need clean shocks to the prices of good 1 and 2 so no additional data burden is imposed here. Further they highlight that the cost shocks need not be entirely single-firm, rather it is necessary that they only affect the two merging parties and are not collinear, also they need not be identified, measurable shocks, just any demand shifter.[127]

[126] See for example Baker and Bresnahan (1985).

[127] They argue that 'Under the N-i-p concept, in order to predict the behaviour of even a single firm, enough instruments must be variable to hold fixed all other firms' prices (as they do not in equilibrium stay fixed in response to a single-firm cost shock), leading to the classic curse of dimensionality (Ackerberg et al., 2007) in empirical industrial organization. Under consistent conjectures only shocks to the firms whose incentives one wishes to identify are necessary'.

4.64 Nevertheless, we still note that the GePP approach gives rise to a significant data burden, especially in the context of the formal use of these unilateral effects measures as simple first phase screens for anticompetitive effects. Moreover, the outcome is not only an approximation for pricing pressure but its implementation may rely on two questionable assumptions. That is, while the measure itself in general does not rely on any specific assumptions on the nature of conjectures, if it were to be applied formally using observed data this would generally require an assumption that conjectures are consistent and that the merger has no impact on those conjectures. In the latter case, we note that it is not necessarily appropriate to presume that firms' pricing conjectures would remain unchanged post-merger – to do so is to assume that $\frac{dp_k}{dp_1}$ is independent of ownership structure (for $k > 2$), which may not be an innocuous assumption.

4.65 Therefore, it appears that in practice it may be difficult (and arguably undesirable) to fully implement GePP in the majority of cases, especially in the context of using such measures as a simple data-light first phase screen for anti-competitive mergers. Indeed, Jaffe and Weyl themselves admit that 'the full force of our general formula is only likely to be used in exceptional cases', though they argue that simplified variants may be used in specific cases – we turn to an assessment of these in the next two subsections.

Informal implementation

4.66 Even where it cannot be formally implemented, there still may be some scope to apply GePP in a more informal manner, and in a way that does not rely on an assumption of consistent conjectures. As Jaffe and Weyl argue, measures of the diversion ratio that are obtained in practice to some extent may actually reflect competitors' responses to price changes. For example, this may be the case for information obtained from firms' internal documents considering the impact of a proposed price change, though note that this is specifically not the case for information obtained from surveys which may be more likely to measure the pure Bertrand diversion ratio (that is, taking prices as given, although it would depend on the precise question asked). Although such ad hoc measures would typically not provide precise estimates of the desired conjectured diversion ratio, specifically they will likely not hold the price of product 2 fixed, it could be argued that in some cases they may potentially better estimate this than the standard diversion ratio. Where previously such 'contamination' of the observed diversion ratio (as a result of rivals' prices **not** being held constant in observed data) may have been seen as a problem, the work of Jaffe and Weyl highlights that the fact that such a measure to some extent incorporates rivals' responses may be in some ways an advantage.[128]

4.67 The implication is that an observed diversion ratio might incorporate conjectures. If so, Jaffe and Weyl's work also highlights that this should not be blindly incorporated into the standard UPP formula as this may create an issue of mixing models. In particular, if an estimate of the modified diversion ratio were to be used, it would also be necessary to obtain an estimate of the end of accommodating reactions term in order to allow GePP to be fully implemented. Without this the approach would fall between UPP and GePP and risk not being internally consistent, and also being biased. Indeed, if it is not possible to incorporate an estimate of this term then the practitioner looking to implement a price pressure test may be better off sticking with a standard UPP measure in place of GePP (or, indeed, other approaches to assessing the impact of the merger).

Implementation using simplified measures

4.68 We noted above that the general form of GePP outlined by Jaffe and Weyl is complex and difficult to implement because of the significant amount of data required. However, to address this point the authors outline steps that could be taken to simplify the expression to make it more implementable in practice. For example, they note that by applying

[128] Moreover, given that the evidence on diversion available to the Authorities may in some cases have been generated by firms who do in fact consider how their rivals are going to react, it may well be useful to have quantitative measures available which utilise this.

some form of symmetry between the merging and/or the non-merging firms and making specific assumptions regarding conduct may make practical implementation easier. In particular, they themselves outline two versions of GePP which are easier to implement, derived by making several simplifying assumptions.

4.69 First, consider a simple example with n identical firms each of which is charging an absolute mark-up of $p-c$ in the pre-merger equilibrium. If the aggregate diversion ratio to the $n-1$ other firms following a price increase by any one firm is equal to $\overline{D}$, and if each firm holds conjectures about the responses of their rivals equal to λ then we have

$$GePP_{Symmetric} = D(p-c)\frac{1+\tilde{\lambda}(n-3)-\overline{D}(n-1)\frac{\tilde{\lambda}^2}{1-\tilde{\lambda}}}{\left(1-\overline{D}\tilde{\lambda}\right)(n-1)+\overline{D}\tilde{\lambda}}$$

where we have $\tilde{\lambda}=\frac{\lambda}{1+\lambda}$. This expression only requires the number of firms, an estimate of the aggregate diversion ratio, mark-ups and a single conjectural variation parameter, and can be computed using a simple back of the envelope calculation.

4.70 However, while far easier to apply in practice than the more general GePP expression, this formulation has the significant weakness of assuming equal diversion to all rival firms in response to price changes. In other words, this simplified approach actually assumes away what is often the key issue that is under investigation, which is the closeness of competition between the parties relative to other firms in the market. This is often the primary focus of merger investigations in differentiated product industries, with short-cut formulas used to quantify the implications of this closeness for likely changes in prices. It therefore seems that the symmetric expression outlined above may be of limited usefulness in assessing the likely competitive impact of mergers.

4.71 A second simplification outlined by Jaffe and Weyl attempts to address the issue of closeness raised above by considering a partially asymmetric model. Here they assume that the two merging parties are symmetric, and that there is a single asymmetric third firm which can be interpreted to represent a reduced form for the rest of the industry. They firstly assume that pre-merger quantities and the slopes of the demand curves are the same for all three firms and that the merging parties are charging an absolute mark-up of $p - c$. They also assume that the (symmetric) diversion ratio between the merging parties is δ, while from the third firm to each of the merging parties (and vice versa) is d. Finally they assume that conjectures are in proportion to diversion, with the merging parties anticipating a reaction of $\lambda\delta$ from each other and λd from the third firm, and the third firm expecting λd from each of the two merging parties. In this case the simplified GePP expression is:

$$GePP_{3\,firms} = (p-c)\frac{\delta + \hat{\lambda}(d^2 - \delta^2) - (d^2 + \delta^2)\dfrac{\hat{\lambda}^2}{1 - \delta\hat{\lambda}}}{1 - d^2\hat{\lambda}}$$

where we have $\hat{\lambda} = \frac{\lambda}{1+\delta\lambda}$. Because this formulation is still able to capture closeness of competition between the parties relative to the rest of the industry it has some appeal, and assuming symmetry between the two merging firms in terms of mark-ups and diversion ratios is potentially not excessively restrictive.[129]

4.72 However, given that the third firm is meant to represent the rest of the industry it does seem like a strong assumption to assume that it is the same size as the two merging firms. Also, assuming that the diversion ratios from the merging parties to the rest of the industry is the same as that from the rest of the industry to each of the merging firms also appears quite restrictive, as in practice we may expect these to be asymmetric. Finally, assuming that conjectures are simply proportional to diversion ratios means that these cannot be varied independently, which significantly reduces the flexibility of this measure. Overall, this three firm simplification of GePP may be useful in certain specific cases, though it would be necessary to carefully confirm the extent to which these particular assumptions can be shown to approximately hold, as indeed is the case whenever any such shortcut model is used.

[129] The OFT has historically made similar symmetry assumptions when employing IPR formulae for example.

4.73 The discussion of these two simplified measures reemphasises one of the key points that keeps re-emerging in the discussion of these short-cut unilateral effects formulas, which is that there is a significant trade-off between these measures being more general and therefore realistic and their data requirements and therefore ease of use. In order for any such measures to be of significant use to practitioners an appropriate balance must be struck between these two competing demands, so that they are both practically implementable but yet still sufficiently general to capture the key economic issues under consideration.

4.74 We earlier noted that the general GePP expression, while robust enough to cover a range of scenarios, may be too difficult to implement in practice. The two simplified measures outlined here on the other hand, while significantly easier to implement, are, as we have discussed, potentially simplified to the extent that they are no longer general enough to accurately capture the key competitive dynamics of the market.[130] Having said that, they must be evaluated in the context of the existing approaches used by the OFT, in particular IPR formulae, which themselves rely on arguably even stronger assumptions. We highlight that a potentially interesting avenue for future research to explore is to try and develop further variants on these simplified formulas which are both sufficiently flexible to address the key economic issues of interest, but for which the data requirements would not be excessively onerous. To the extent that several such measures could be developed relying on a range of different assumptions, practitioners could then potentially examine the likely impact of the merger in a range of different scenarios.

The use of standard UPP

4.75 Even if the only information available were an estimate of the Bertrand diversion ratio, and so standard UPP must be used, Jaffe and Weyl's work is still useful in that it highlights the qualitative conditions under

[130] More specifically, they may be relatively easy to implement taking it as given that an Authority is applying a measure which incorporates conduct parameters because only one or two conjectures need to be estimated, though of course in practice this may still be difficult.

which the standard UPP formula will tend to overstate or understate the actual level of upwards pricing pressure. In particular we note that their work emphasises that UPP will tend to overstate the likelihood of a merger resulting in higher prices when pre-merger there is a significant degree of accommodation in the pricing of the two merging parties between one another (and relatively little accommodation of the merging parties' prices by other firms in the relevant market). For example this would be the case if the parties have significant positive conjectures about their responses to each others' pricing decisions, while conjectures involving other firms were close to zero (that is, close to the standard Bertrand assumption presumed in UPP and GUPPI models).[131]

4.76 A potential example of this is provided by the takeover of Julian Graves by NBTY, examined by the UK Competition Commission in 2009. This merger concerned the market for nuts, seeds and dried fruit, with the key issue being whether supermarkets constrained the pricing of the parties, which were the two main specialist retailers of these products. The Competition Commission noted evidence that the parties monitored each other's pricing, but yet supermarkets did not monitor the actions of the parties. On this basis it could be reasonable to assume that here the modified diversion ratio will in fact be equal to the Bertrand diversion ratio, as there will likely be no responses from rivals (supermarkets) if the parties were to increase prices. On the other hand, given that the parties are two specialist providers and do monitor each other's pricing, there could be an end of accommodating reactions effect. The implication therefore is that here the use of a standard UPP measure may

[131] In other words this is when the numerator of the right hand term in the GePP expression above is relatively high. Note that some care must be taken when analysing the qualitative implications of the GePP formula presented above. For example one may be tempted to conclude that UPP would tend to overstate the parties' incentives to increase prices as a result of the merger when firm 1's margin is high. However, although this may indeed lead to firm 1's incentives to increase prices being overstated, much like UPP, GePP must be applied both ways. When firm 1's margin is high this may lead to firm 2's incentive to increase prices being understated by UPP. Overall, therefore, it seems that no clear prediction can be made for whether UPP under- or overstates the true extent of upwards pricing pressure on the basis of firms' margins.

serve to overstate the true pricing pressure created by the merger, as it appears that GePP would be strictly lower than UPP. More generally, we note that even though it may often be unclear whether the magnitude of these two effects would be likely to offset one another in any particular case, the fact that they run in opposite directions tends to imply that the use of standard UPP does not introduce a large inherent bias into merger control (given a desire to use price pressure tests as screens). That is, while not explicitly accounting for rivals' responses would clearly reduce the accuracy of any measure of the impact of a merger, it appears that this may not result in the applied standard being consistently too strict or too lenient.[132]

4.77 A final point we highlight is that it is unclear if there may be legal or economic issues raised by firms putting forward an argument related to the end of accommodating reactions term. Firms may potentially be reluctant to raise, and authorities to accept, reasoning that may at least appear to rely on firms not competing strongly pre-merger due to their conjectures about each others' behaviour. For example, some may interpret this as being suggestive of pre-merger tacit coordination, and would therefore argue that this is not a reason to clear a merger.

Conjectural variations and non-price reactions

4.78 The major limitation of the short-cut unilateral effects measures discussed above is the fact that they fail to consider supply side responses of rivals, for example in terms of product repositioning and entry.[133] In many instances these factors are critical in shaping the competitive effects of a merger. Such a point is explicitly recognised by Shapiro (2010), who comments that 'other supply responses by rivals,

[132] All of which must also be seen in the context of the competition authorities taking decisions based upon all the evidence in the round and not attaching undue prominence to any one piece of evidence.

[133] This is not a critique that applies solely to UPP and related measures. Other forms of analysis may equally have similar weaknesses.

such as product repositioning or new entry, will tend to dampen any incentive to raise price'.[134]

4.79 Some advocates of initial screens might argue that such dynamics are taken into account only when an initial screen has been failed, arguing that the screen is to identify cases worth exploring further – not to identify likely harm. Others might argue that screens could be extended to incorporate supply side responses. For example, in theory, the use of conjectural variation parameters could provide a means to incorporate supply side factors into the various unilateral effect measures that have been discussed.[135] For example, firms could hold conjectures about how the output levels of potential entrants, which pre-merger will be zero, will change as they alter their prices. However, in practice many of these supply side issues are complex and multifaceted, and it is not clear the extent to which responses in these non-price dimensions can usefully be compressed into a simple conjectural parameter. So while price is (usually) a simple concept that can be modelled in a tractable fashion, it is less clear how easy it would be to model the positioning of rival's products, and to use conjectural variation parameters to capture the fact that a post-merger increase in prices may encourage rivals to reposition their products closer to those of the merging parties.

4.80 Furthermore, it is also important to realise that non-price reactions encompass a wide range of possible rival responses, and their relative importance may differ depending on the nature of the market under investigation. So as well as entry and product repositioning as mentioned above, there is also the range of products offered and various dimensions of product quality. If one attempted to adopt a formal conjectural variation modelling approach to these factors a problem that

[134] Formal models of supply side reactions include Cabral (2003), who shows that a merger to monopoly in a spatially differentiated industry where firms are price-setters is likely to invite entry, which may result in prices being lower post-merger, and Gandhi et al (2008) who demonstrate that supply side repositioning may serve to offset any harmful effects arising from a merger.

[135] For example in a study of collusion Gasmi, Laffont and Vuong (1992) consider a model where firms have conjectures over each others' prices and levels of advertising.

would rapidly arise would be one of dimensionality. Even if, in a duopoly, only one non-price reaction was considered alongside price, for example quality, each firm would need to hold four conjectures regarding each of its rivals rather than the usual one. That is, firms would have to consider how each rival's price and quality level would respond to changes in both its own price and quality. If additional non-price reactions were considered the number of conjectures that would need to be considered would become even larger, in particular the number of conjectures each firm would need to hold with respect to each of its rivals is the square of the total number of parameters of competition.

4.81 Perhaps for these reasons, we are not aware of any published papers which model non-price reactions to mergers in a conjectural variations framework.[136] One potential compromise approach that may attract some practitioners may be to try and use a model featuring only price conjectures, and then attempting to make some adjustments to the value of these conjectures to reflect non-price responses. However, this would risk being seen as an ad hoc approach which has no formal justification, and therefore unreliable in delivering meaningful predictions of the competitive implication of mergers. On the other hand, it would at least make clear any ad hoc assumptions made.

4.82 While we stress that a consideration of non-price reactions may be crucial to the assessment of any merger, it is not clear that the most appropriate way to do so is to capture them using a simplistic conjectural variations model. Instead, a better approach may be to recognise these as significant limitations of all short cut unilateral effects methodologies, particularly in those industries where non-price reactions seem to play a particularly important role. The use of short cut screens might be limited only to those industries where competition appears to be reasonably consistent with the assumptions that underpin the screen. The analysis of the competitive effects of mergers should therefore

[136] More generally, Weyl and White (2010) seek to incorporate aspects of non-price competition into standard oligopoly models, while Gaudin and White (2011) are developing simple ways to estimate the consumer surplus impacts of product repositioning in a similar spirit as Weyl and Jaffe (2011).

consist of a full assessment of the entire range of relevant evidence considered in the round.

Conclusions

4.83 Recent research by Jaffe and Weyl (2011) outlines an interesting approach to incorporating conjectural variation parameters into a price pressure test. However, although useful, we highlight that the time and data constraints faced by competition authorities in practice may significantly limit the extent to which their approach can be implemented. However, and importantly, it does provide some reassurance that the use of standard UPP does not introduce a large inherent bias into merger control (given a desire to use price pressure tests as screens). We note that rather than presume a conjectural variation parameter, one might try to model (or at least better understand) the dynamic game. Though in many cases this may be a difficult exercise, it may at least be possible to shed some light on the dynamic nature of competition. Trying to condense complex strategic interactions into one or a few measures risks failing to account properly for the richness of real-world competition if too much weight is placed on those measures. We emphasise that the aim of UPP was to establish a simple initial screen that is better than a market share screen for horizontal mergers involving differentiated products. It does not purport to be an accurate predictor of the competitive effects of a merger or trump a detailed investigation of the strength of existing competition, potential competition and buyer power.

5 SURVEY ON COORDINATED EFFECTS WHEN FIRMS ACCOUNT FOR THEIR RIVALS' REACTIONS[137]

5.1 In this chapter we take a **broader perspective** on the issue of dynamic competitive interactions. Rather than stick slavishly to the textbook definition of a CV model, we instead consider a different issue 'in the spirit' of conjectural variations. That is to say, even if CV models themselves are subject to criticism, the underlying issue of 'modelling how firms react to changes in their rivals' actions' remains valid. We find that modelling coordination with other forms of dynamic competitive interaction does not change the fundamental premise that firms are potentially able to sustain prices above competitive levels. Furthermore, in our view the three so-called **Airtours** criteria – alignment, internal stability and external stability – are cumulative. Indeed, rather than rendering some of the **Airtours** criteria redundant, these models actually serve to further emphasise their central role in any assessment of whether coordinated outcomes may arise as a result of a merger.

Brief introduction to tacit collusion

5.2 The theory of tacit collusion is well established in the I.O. literature.[138] In the standard treatment, firms are assumed to compete in either prices or quantities for the products they sell. They do this on a period by period basis, where each period corresponds to a unit of time and is of equal length. Typically, competition is assumed to take place over an infinite number of periods. This stylized description is meant to capture the notion that firms in the real-world typically have repeated interaction with each other with no clear ending in sight.

[137] We are grateful to Greg Shaffer for extensive contributions to this chapter. Errors are our own.

[138] See Tirole (1988, pp. 245-253) and Shapiro (1989, pp. 361-381) for an overview of repeated games

5.3 The focus of the literature tends to be on whether, for a given set of supra-competitive prices,[139] the costs of cheating can be made sufficiently large (for example, by firms choosing their punishment strategies appropriately) to outweigh the (short-term) gains from cheating. Assuming the costs can be made sufficiently large, and that each firm's punishment strategy is credible (that is, assuming it is a best response for each firm to follow through on its announced punishment if cheating occurs), then the supra-competitive prices are said to be supportable in equilibrium.[140]

5.4 Typically, what the literature finds is that firms can often support monopoly pricing - for a wide range of discount factors - by following grim trigger punishment strategies in which the punishments involve reverting to one-shot Nash behaviour (see Friedman, 1971) forever after,[141] or alternatively by adopting optimal punishment strategies (in the sense of Abreu, 1986 and 1988), following a period in which any firm defects from the tacitly collusive understanding.

5.5 To implement tacit collusion, firms must first be able to coordinate on the supra-competitive prices they will charge, and then be able to prevent each other from cheating on those prices.

5.6 Consider the following simple example: suppose n identical firms produce a homogeneous product. Let π^cdenote the aggregate collusive profits of all firms if the firms follow through on their tacitly agreed-upon supra-competitive price, p^c. Let δdenote the common discount factor (**for**

[139] In this literature, supra-competitive prices are deemed to be prices that exceed those that would arise in a one-shot Nash game.

[140] Friedman (1971) is often credited with being the first to demonstrate the existence of subgame perfect equilibria that support cooperation beyond that predicted in equilibria of the associated stage game. The outcomes are enforced by discontinuous strategies which consist of a player cooperating in the face of cooperation by the other players, and reversion to a threat point in all subsequent periods as a response to any deviation from cooperation.

[141] A grim trigger punishment strategy involves sticking to a given action (say pricing at the monopoly price) unless one player deviates from that action, in which case one-shot Nash behaviour is adopted forever after.

example, the weight firms place on future period profits), and assume each firm's punishment strategy entails reversion to static Bertrand profits (which are zero in this case since the products are homogeneous). Then, the stream of profits a firm can obtain if it cheats is Π^c in period one and zero in all subsequent periods (this assumes the punishment starts in period two), while the stream of profits a firm can obtain if it does not cheat is $\Pi^c/_n$ in each period, which has a present value of $\Pi^c/_n + \delta\,\Pi^c/_n + \delta^2\,\Pi^c/_n + \cdots = \Pi^c/_{n(1-\delta)}$. Thus, cheating can in principle be prevented if the foregoing of future profits outweigh the short run gains from cheating:

$$\Pi^c \leq \frac{\Pi^c}{n(1-\delta)}$$

or, in other words, if the discount factor is high enough: $\delta \geq {}^{(n-1)}/_n$. As has been noted elsewhere, 'with reasonable choices for the discount factor and say, monthly price adjustment, collusion should be possible in oligopolies consisting of a hundred firms' (Armstrong and Huck 2010).

5.7 This result is surprising because it seems to imply that tacit collusion is the norm and thus that consumers are doomed to face relatively high prices. Similar results can be shown to hold when the firms are symmetric and the products are differentiated, and thus the literature is often left trying to sort through whether, in comparing one market situation to another, collusion is more or less likely depending on the minimum discount rate needed to support collusion, when in fact the entire range of discount factors typically under consideration are all within real-world sensibilities. Hence, the theory of tacit collusion in repeated games appears to predict too much coordination. It suggests that relatively high prices should be within reach of firms in nearly all industries, whereas in reality this does not appear to be the case, it appears that there must be mitigating factors.

5.8 Given this, a natural inclination is to try to reconcile theory and practice by focusing on the difficulties firms may encounter in **reaching** an understanding of what supra-competitive prices should be charged in the first place, or of what punishment strategies will be followed. This might lead one to conclude, for example, that collusion will be more likely for homogeneous products than for differentiated products and more likely when the number of firms is small. Another avenue of research may be to look at alleged instances of collusion, overt or tacit, and see if trigger punishments of the kind trumpeted by the theorists are in place (for example, are the firms' punishments disproportionate to the crime). If not, or if the punishments appear to be weak or non-existent, then presumably the firms cannot be colluding.

5.9 In this chapter we, among other things, consider whether the conventional wisdom above is correct in light of some recent (or in some cases old but neglected) developments. In particular, we examine whether it is the case that instances of overt or tacit collusion need to be supported with punishments that are not necessarily proportional to the 'crime'? We also investigate whether it is necessarily the case that if the punishments appear to be benign or non-existent (for example, firms announcing that 'we will match our competitor's low prices') then all is well, the firms are not colluding, and the consumers' interests are being served. Finally, we consider whether coordinated outcomes can be sustained when firms move in sequence and condition their responses on only their rivals' actions in the previous period, such that an earlier 'history' of cheating does not matter.

Criticisms of traditional coordinated effects theory

5.10 Several criticisms have been levied against the existing mainstream theory of coordinated effects. Before turning to a consideration of the recent research mentioned above, it is useful to first briefly review some of the major criticisms that have been levelled at existing approaches so we can consider these developments in light of these limitations.

5.11 In particular we consider the following limitations:

- multiplicity of equilibria
- difficulty of coordinating on what punishment strategies to follow, and

- the implausibility of discontinuous punishment strategies.

Multiplicity of equilibria

5.12 One criticism is that the vector of prices that can be supported in equilibrium is not unique. According to the Folk theorem[142], if the discount factor δ is sufficiently high (**for example,** if the value of the future is high enough), then any individually rational, feasible payoff can be supported as the outcome of a subgame perfect equilibrium to the repeated game. Individual rationality in this context implies that each player must earn a present value of profits that is at least as much as she could earn in the worst equilibrium of the stage game from that player's perspective.

5.13 The logic of the folk theorem is simply that any infinite repetition of the one-shot stage game is itself a subgame-perfect equilibrium (because if everyone believes that their rivals will be choosing their one-shot Nash prices (or quantities), then doing so oneself is in fact optimal). Moreover, any other strategy can be turned into a subgame-perfect equilibrium by threatening any rival who deviates with an infinite repetition of the worst stage game equilibrium from that player's perspective. This is credible because an infinite repetition of the stage game equilibrium itself is subgame-perfect. Given the threatened punishment, no player will want to deviate.

5.14 Unfortunately, while the Folk theorem establishes that 'almost any outcome' can arise in a subgame perfect equilibrium, it does not provide guidance as to what outcome will arise. The supra-competitive price p^c, in the example above, could be as little as one penny above the Nash prices, or it could be the unique price that maximizes joint profits, **for example**, the monopoly price.

5.15 Generally, academic research tends to focus on the possibility of firms colluding at the monopoly level, and therefore trying to extract maximum

[142] See, for example, Rubenstein (1979) and Fudenberg and Maskin (1986)

profits from the industry. However, there may be instances where collusion on this level of prices is not sustainable, but a lesser form of collusion, on prices lower than this but still above the competitive level, may be. As a working assumption in theory (although not in practice) it may be reasonable to assume that, if firms are going to collude, they will do so to the maximum level possible, as this will maximise their profits.[143]

5.16 However when we consider such partial collusion, any asymmetries that we may have between firms have important implications for the ability of firms to reach and monitor the terms of coordination. If firms differ in their patience in considering future payoffs (**for example** in terms of the expressions outlined above, they have different δs) it may not be easy for them to identify and arrive at the maximum collusive price they can jointly sustain. This is because each firm would be willing to stick to a coordinated arrangement up to a different point, and the ultimate extent of any joint agreement will in particular be defined by the firm with the greatest incentive to deviate. However, without any ability to observe or communicate each others' patience, it may be very difficult for firms to actually arrive at an agreement in practice.

5.17 One final point on the issue of multiple equilibria is the fact that, even if collusion is possible, it does not mean that it will arise. In practice there may be many industries where firms would be able to sustain tacit collusion above competitive levels, but nevertheless continue to compete vigorously. Theory does not tell us anything about how frequently in markets where collusion is feasible it will actually arise in practice.

Difficulty of coordinating on what punishment strategies to follow

5.18 A second criticism of standard coordinated effects theory is that there is typically more than one way to punish a rival who deviates. For example, a firm may decide to optimally punish rivals (in the sense of Abreu 1986

[143] Technically this Pareto dominates any other outcome.

and 1988), or it may decide to punish them by reverting to one-shot Nash behaviour forever after, or to punish them for a finite number $T > 0$ periods, or it may decide to punish a rival by, for example, matching the rival's lower price. Ultimately, it is not clear how firms decide which strategy to follow and, if the punishment is not indefinite, how do they decide on the value of T **for example** the length of the punishment period. These are not easy questions to answer, and it is not at all obvious how real-world firms are able to coordinate on what strategies to follow.

5.19 One possibility is to apply a Pareto criterion, as discussed above, and argue that firms should coordinate on the 'optimal' punishment strategies. However, this reasoning is problematic in this case for at least three reasons. First, the optimal punishment strategies may be quite complicated to calculate and may not even have closed form solutions in most cases. It follows that even if firms could agree that they should adopt the economists' notion of 'optimal' punishment strategies, figuring out what they are in any given instance may not be possible. Second, monopoly pricing may be supportable for a wide range of discount factors, regardless of whether the punishment strategies are 'optimal' in the sense of Abreu (1986 and 1988). Or, to put it differently, for a wide range of discount factors, the 'optimal' punishment strategies may only be weakly optimal. Reversion to one-shot Nash equilibria in these cases may be just as good. It is then not clear how firms are able to coordinate on which of these strategies to use. Third, and most importantly, the punishment strategies that support collusion may not be renegotiation proof.[144]

5.20 To see this, suppose the products are homogeneous and firms are choosing prices. In this case, it is well known that the monopoly outcome can be supported in equilibrium (if the discount rate is sufficiently high) through strategies that prescribe cooperation unless some firm deviates in which case all firms revert to marginal cost pricing

[144] An equilibrium is renegotiation proof if, at any price p, no other equilibrium Pareto dominates it.

thereafter. But if a firm actually did deviate, they would all earn zero profits thereafter, which leads to the question why would they settle for this when they could renegotiate and move to a better equilibrium with higher payoffs. But, of course, if firms could renegotiate in this manner, then this would destroy the deterrent to cutting prices in the first place. If firms realized that punishments would be renegotiated, in other words that they are not credible, then price cutting might well be profitable, and the firms would be back in a world of one shot Nash behaviour.

5.21 This latter point is still an open question in theory, and until it is resolved, it appears that one cannot say which punishment strategies will be optimal when renegotiation is possible.

5.22 In practice, the assessment of the whether or not firms can come to an agreement on punishment strategies should be covered by the first of the **Airtours** criteria, that of reaching the terms of coordination, as this is in effect one of those terms.

Implausibility of discontinuous punishment strategies

5.23 A third criticism is that the punishments that support many tacit collusive equilibria are discontinuous. This is certainly true when there is reversion to Nash equilibria, or when optimal punishment strategies are used. Discontinuous punishments are unappealing. They imply, for example, that even a small cut in prices would be met indiscriminately with a harsh punishment. For example, a rival may mistakenly undercut by a penny, or knowingly undercut by a lot, and face the same punishment in either case even though the former may have yielded very little gain to the rival (with differentiated products) and/or had negligible effect on the punishing firm. To put it more colourfully, a notable aspect of many punishment strategies is that the punishment does not fit the crime. As Friedman and Samuelson (1994) note, '[i]n many circumstances, strategies associating severe penalties with arbitrarily small deviations are implausible'.[145]

5.24 This criticism seems all the more valid when moving away from the theory and considering the possibility for coordinated effects in real-world industries. In practice the markets in which firms compete are often characterised by uncertainty and volatility, with changes in demand and costs over time naturally leading to variations in pricing. In such circumstances it may be difficult for firms to accurately identify deviations by rivals and, as demonstrated by Green and Porter (1984), if firms were to follow rigid grim trigger punishment strategies then any agreement may be destined to break down quickly.

5.25 We explore this criticism in more depth in the section on continuous reaction functions below.

Tacit collusion with continuous reaction functions

5.26 As discussed above, a criticism of the repeated game literature is that many tacit collusive equilibria are supported by punishment strategies that are discontinuous in the sense that they embody the threat of severe punishment for any deviation, however small (**for example**, the punishment does not fit the crime). Given that in many cases such punishment strategies appear somewhat unrealistic, a natural question to ask, therefore, is to what extent can collusive equilibria be supported when firms are restricted to using punishment strategies that are continuous in the history of play (**for example** strategies that specify only small retaliations for small deviations from prescribed behaviour) which may more accurately match how punishment works in practice.

[145] One of the earliest treatments of oligopolistic behaviour over time was by Fellner (1949). He proposed that firms react to each other's outputs, and suggested that the output level of a firm in period t would be a function of the output levels chosen by rivals in period t–1. Fellner assumed that the reaction functions would be continuous, so that a small change by one’s rivals would bring about a small change in one's own behaviour.

5.27 Indeed, to the extent that firms do use such continuous punishments in reality, the reliance of existing theoretical results on models with discontinuous punishments potentially significantly undermines the relevance of their conclusions for the practical assessments of coordinated effects. Rather, it is important to examine the findings of the literature on collusion which considers such continuous punishments, and re-evaluate existing policy in light of its conclusions. In other words, we seek to examine the extent to which firms can sustain collusive outcomes when they are restricted to using punishment strategies that are continuous in the actions of rivals.

5.28 This question was first considered by Friedman (1968), who found that it was indeed possible to support collusive equilibria with continuous punishment strategies. However, a significant limitation of Friedman's model is that he did not use subgame perfection as his solution concept, the first to do so was Stanford (1986a).

Stanford (1986a), subgame-perfect reaction function equilibria in discounted duopoly supergames are trivial

5.29 In this article, Stanford considers a class of infinitely repeated duopoly games with discounting and asks whether collusive outcomes can be supported in a subgame perfect equilibrium when punishments are continuous.[146] He defines a reaction function for firm **i** as a decision rule which selects an action for firm **i** in period **t** + 1 as a function of firm **j**'s action in period **t**.

5.30 The two firms produce a homogeneous product and choose quantities in each period. Binding agreements are assumed prohibited, and each firm maximizes the sum of its discounted profits:

[146] Stanford (1986b) shows the existence of nontrivial subgame perfect equilibria in continuous reaction functions of the kind considered above for infinite horizon models in the absence of discounting.

$$\sum_{t=1}^{\infty} \delta^{t-1} \pi_i(q_{it}, q_{jt})$$

5.31 The main result is that equilibria will be subgame perfect if and only if they are trivial, in the sense of replicating the competitive Cournot outcome in each period, independent of prior history.[147]

5.32 In various extensions, Stanford finds that his result does not depend on firms having identical discount factors, and it is robust to quantity games in the sense that with slight modifications in notation and some assumptions, the result extends to differentiated products and prices.

5.33 In discussing the implications of his model and next steps, Stanford concludes:

> Reaction function models limit the complexity of strategies. In such models, the assumptions of continuous strategies and memory that extends only a bounded time backwards are combined to study the possibility of finding 'collusive' outcomes in repeated games. This paper shows that if we wish to retain the notion of credible reaction, continuous or otherwise, we must either content ourselves with the trivial reaction of repeated stage game equilibrium strategies, or extend our consideration to strategies which depend on the firm's own prior period action as well as the action of its rival. The first alternative is unattractive. It is difficult to understand why firms should ignore all intertemporal considerations and forego the attempt to enforce cooperation. In the continuous reaction case, the prospects for the second alternative remain open to question.

5.34 Stanford's research therefore suggests that tacit collusion cannot be supported when firms must use continuous strategies, have memory that extends only one period backwards, and condition their response only a rival's prior period action. This finding potentially has significant

[147] Stanford notes that a trivial reaction function prescribes the same action at each time **t**, irrespective of the observed actions of past periods. For example, each player selects the one shot Nash outcome in each period.

implications for the examination of coordinated effects if punishment strategies in practice are generally continuous in nature. However, subsequent papers by Samuelson (1987) and Friedman and Samuelson (1990 and 1994) suggest revisiting this assessment in a richer modelling framework.

Samuelson (1987), non-trivial, subgame-perfect duopoly equilibria can be supported by continuous reaction functions

5.35 Samuelson motivates his paper by noting that Stanford's work raises the question of whether collusion can be supported by subgame perfect equilibria with reaction functions that allow period t actions to depend upon the period **t** – 1 actions of both firms. He notes that:

> strategies similar to the grim trigger strategies of Friedman (1971) can be exploited to answer this question affirmatively. However, the discontinuities that play an apparently essential role in these trigger strategies are often cause for concern. The strategies appear to be too delicately structured to describe the behaviour that appears in the imprecise environment in which firms operate.[148]

5.36 He considers the case of two firms producing a homogeneous product and competing in quantities. In this case, non-trivial subgame perfect equilibria with continuous strategies are found to exist when 'previous period actions of both firms are arguments of reaction functions'.

5.37 Surprisingly, he finds that a restriction to continuous reaction functions imposes essentially no restrictions on the set of prices that can be supported in equilibria. Intuitively, his strategies call for each firm to

[148] The repeated game literature has shown that discontinuous reaction functions in the form of grim trigger strategies can be used to obtain non-trivial subgame perfect equilibria whether or not firms discount the future. The simplest of these are the trigger strategies in which player **i** chooses some strategy s_i* at the start, continues with strategy s_i* as long as s* is observed in all past periods, and changes (discontinuously) to Nash behaviour, s_i^N , thereafter if any deviation from s* is detected. Grim trigger strategy equilibria first appear in Friedman (1971).

produce the collusive output **x'_i** as long as the other does. A deviation involving higher output by firm **i** is then followed by an adjustment in the outputs of both firms upward along the line segment **(x'_1, x'_2)** and **(x^n_1, x^n_2)**. This adjustment causes firm **i**'s new output to equal the minimum of the output to which firm **i** deviated and the single-period Nash output.

5.38 Samuelson concludes that:

> The strategies resemble the trigger strategies given in Friedman (1971). The primary difference is that any deviation from the equilibrium path in Friedman (1971) causes the game to reach the single-period Nash equilibrium actions while a deviation from the equilibrium path here may push the agents only part of the way toward these actions.

5.39 However we note that, while Samuelson's work was an advance on previous research, it was still limited to the case of two firms and homogeneous products, the former limitation was addressed in subsequent work with Friedman.

Friedman and Samuelson (1990), subgame-perfect equilibrium with continuous reaction functions

5.40 Friedman and Samuelson extend Samuelson (1987) to a general n-player repeated game with discounting. In their model, firms may have different discount factors, the products may be homogeneous or differentiated, and competition may be in prices or quantities. They show that it is possible to construct strategies that are continuous, but that mimic trigger strategies in their method of operation. The key difference between these continuous strategies and classic trigger strategies is that under the former, small defections from equilibrium strategy combinations result in small punishments. That is, a defection from the equilibrium path of any size brings a punishment sufficient to deter the defection, however, the punishments are continuously graded in size and go to zero as the magnitude of a defection goes to zero.

5.41 The analysis is not straightforward and the existence of such reaction function equilibria is not obvious. As the authors note:

> It is clear that continuity requires small deviations to be followed by small punishments. The overkill feature of trigger strategy equilibria also suggests that one can easily adjust the punishments associated with small deviations in a quest for continuity while still deterring those deviations. However, these small punishments lead the players into an infinite collection of subgames with their own continuation equilibrium paths. Subgame perfection must be preserved in each of these subgames. The construction of continuous strategies that respect subgame perfection in these subgames is not trivial and require some care.

5.42 Another feature of the research is that the continuous punishment strategies depend only on the previous period actions of all firms, this is a significant breakthrough as it is in contrast to much of the previous literature in which players' actions in one period would depend on the actions of all players in **all** previous periods. Friedman and Samuelson suggest that their results may prove to be valuable in applied work on repeated games because the empirical estimation of equilibria may be much easier if the strategies are continuous.

5.43 However, the authors also sound a note of caution because the solutions that they find involve particularly complex strategy formulations, potentially because of the fact that they tackle a general class of abstract games. They therefore question whether it is possible to obtain solutions with the desired properties that take on much simpler forms.

5.44 This work is quite noteworthy as it shows that punishment strategies need not be contingent on more than the previous period's actions, and moreover, that the punishment strategies can be made continuous. Friedman and Samuelson suggest that continuous strategies make more sense when firms are not able to discuss mutually beneficial behaviour among themselves, whereas they indicate that discontinuous strategies make more sense if firms were somehow able to communicate explicitly with each other prior to making their strategy selections (as this provides greater scope to make clear the explicit discontinuous threat involved).

Friedman and Samuelson (1994), continuous reaction functions in duopoly

5.45 There remain some important questions, which Friedman and Samuelson attempt to address in this paper. They restrict attention to infinitely repeated games with only two players, but otherwise the model is fairly general, **for example**, the firms may have different discount factors, the products may be homogeneous or differentiated, and competition may be in prices or quantities.

5.46 As an overview, they note that it is well known that repeated games typically have subgame perfect equilibria yielding outcomes that are not Nash equilibria of the stage game. Such equilibria involve strategies in which a deviation from equilibrium triggers a punishment phase, the harshness of which is unrelated to the size of the deviation. They note that in many circumstances strategies associating severe penalties with arbitrarily small deviations are unrealistic, and that it may be more plausible for firms to support coordinated outcomes with continuous strategy combinations that are more akin to the reaction functions of the oligopoly literature.

5.47 They also note that the folk theorem has established that any strictly individually rational, feasible payoff can be supported as the outcome of a subgame perfect equilibrium of a game with a sufficiently high discount factor. They query whether the same is true if attention is restricted to continuous strategies, or if in such a case the set of supportable equilibria shrink. Further, they question whether an outcome that can be supported as a subgame perfect equilibrium for some set of discount factors can be supported for the same set of discount factors when only continuous punishment strategies are used, or whether such continuity places more stringent conditions on the discount factors.

5.48 The questions are answered affirmatively. The main results of their paper are, first, establishing a folk theorem showing that any feasible, individually rational outcome in the stage game can be supported as a subgame perfect equilibrium outcome with continuous reaction functions if discount factors are sufficiently high. They then also show that the set of discount factors for which outcomes can be supported by continuous reaction functions is at least as large as the corresponding sets under Nash reversion trigger strategies. The authors suggest that these findings imply that the use of continuous punishment strategies imposes no restrictions on the set of possible equilibrium outcomes.

5.49 This body of work suggests that, on the one hand, a restriction to continuous strategies would not seem to result in much loss of generality in the sense of supporting folk-like theorems that collusion is sustainable. However, they also appear to lead to unusually complicated formulations, which detract from their value in terms of describing real-world behaviour. The next paper represents a recent break-through in this regard which, though it clearly sacrifices generality, demonstrates similar outcomes with significantly reduced complexity.

Lu and Wright (2010), tacit collusion with price-matching punishments

Main results

5.50 Lu and Wright examine whether tacit collusion (prices above one-shot Nash) can be supported when firms adopt price-matching punishments. Specifically, they consider an infinitely repeated game with two symmetric firms where in each period the firms choose prices. In the event one firm deviates from a coordinated arrangement by lowering its price, the other firm's strategy calls for it to match the deviating firm's price in the next period (within certain bounds).[149]

[149] More formally, Lu and Wright consider the pricing strategy where in period 0 firm i sets its price equal to the common collusive price p^c, and from period 1 onward, it sets its price equal to the minimum of the prices set by all firms in the previous period and p^c, provided this is no lower than some threshold p^n; if it is lower than p^n, then firm i is

5.51 Lu and Wright first consider the case of homogeneous products and constant marginal costs and prove their first main result, that no collusion can be supported in such a case. The proof consists of showing that for an arbitrarily small deviation, the deviating firm's gain will be large, but the punishment it faces will be essentially zero, as the price response by the rival will be arbitrarily small.

5.52 Their second main result is that the monopoly price can never be supported by price-matching punishment strategies.[150] The intuition for this result is that, starting from the monopoly price, a small price cut which is matched in subsequent periods has no first-order impact on total collusive profits (as collusive profits are 'flat' in the neighbourhood of the monopoly price, which maximises industry profit) but does generate a first-order increase in profits in the deviation period for the firm that instigated the price cut.

5.53 The third main result that Lu and Wright present is that the range of collusive prices that can be supported are a strict subset of the range of collusive prices that are supportable by Nash reversion (or optimal punishments). Intuitively, tacit collusion requires firms to be more patient to sustain a given collusive outcome under price-matching punishments compared to traditional Nash reversion. This reflects the fact that under price-matching punishments, a defecting firm can always set the same price as it would in the standard analysis, and face a smaller punishment given that rivals simply match its price rather than further undercut it. In

assumed to simply price at p^n. A price p^c is said to be supportable by price-matching punishment strategies if the price-matching punishment strategy profile, as described above for $i = 1, 2$ is a subgame-perfect equilibrium.

[150] In particular, for any given $0 < \delta < 1$, there exists some highest collusive price $\bar{p}^c(\delta)$ supportable by price-matching punishment strategies. This price satisfies $p^n < \bar{p}^c(\delta) < p^m$. Any price p^c such that $p^n < p^c < \bar{p}^c(\delta)$ is also supportable by price-matching punishment strategies. To show this they set $p^c = p^n$, differentiate and evaluate at $p = p^n$. The resulting expression is positive. Doing the same thing, but setting $p^c = p^m$, the resulting expression is negative. Note that the expression above is concave in p. It follows, therefore, that the expression is initially positive at $p^c = p^n$ but decreases monotonically and at some point before $p^c = p^m$ becomes negative. The highest collusive price $\bar{p}^c(\delta)$ occurs at the point where the first-order condition is satisfied with equality.

addition, the defecting firm can do even better by restricting the amount it deviates from the original agreement, thereby further reducing the severity of its punishment.

Policy implications

5.54 Lu and Wright show that the use of price-matching punishments by firms to collude, rather than reversion to Nash or optimal punishment strategies, has both benefits and costs. This gives rise to an interesting question: is it the case that more realistic punishment strategies make tacit coordination easier than previously thought, but less harmful when it occurs?

5.55 Specifically, the downside for firms is that price-matching punishments are not optimal, in theory firms can do better with more severe punishments, and in this sense it could be argued that they are unappealing (at least in theory). In turn, this indicates that price-matching punishment strategies give rise to collusive outcomes (if they occur) that might typically be **less harmful** than those outcomes supported by discontinuous punishment. This might be inferred from Lu and Wright's findings:

- there is no scope for collusion when the products are homogenous and marginal costs are constant (yet collusion can be sustained with discontinuous punishment),
- the monopoly price can never be supported (yet it can be with discontinuous punishment), and
- fewer collusive prices can be supported compared to the standard case of reversion to a competitive Nash equilibrium (for example, firms have to be more patient in Lu and Wright's model in order for collusive outcomes to be sustained, other things being equal).

5.56 On the other hand, firms may benefit from the simplicity of price-matching punishments if that makes them easier to implement and understand. In this sense it could be considered more **realistic** to model coordination using this approach. Specifically, if firms use price-matching punishments in practice, then it may be that the practical difficulty of **reaching** an understanding on punishment strategies, and therefore a coordinated arrangement, is potentially lower than previously thought. In particular, it may reduce the need for explicit communication between firms – allowing greater scope for firms to 'signal' price matching policies. Indeed, in terms of the 'realism' of price-matching policies, Lu and Wright propose several (informal) justifications for their approach.

- Reversion to Nash may seem extreme when the deviation is small. They echo Friedman and Samuelson (1994) in noting that severe punishments for arbitrarily small deviations seems implausible. Lu and Wright note that an important feature of price-matching punishment strategies is that the punishment a firm faces in response to defecting does actually depends on the size of the deviation.

- There is anecdotal evidence that firms, at least in some settings, have used these types of punishments in practice.[151] Further, there is no solid empirical evidence for believing that firms use discontinuous punishments to support collusion.

5.57 Price-matching punishments may also appeal to a coordinating group because cheating does not necessarily lead to a breakdown of coordination. Specifically, following a small deviation firms may still carry on coordinating, simply to a lesser extent. For example in the case of Lu and Wright's price matching punishment, if a firm undercuts the coordinated price but still charges above the level that would emerge from outright competition, then in the following period prices will still remain above the competitive level.

5.58 Turning to evidence, if it has general application, Lu and Wright's paper would imply that just because a market has no apparent scope for 'discontinuous punishments' does not mean that the firms must be

[151] See, for example, the discussion on pg. 299 in Lu and Wright.

competing vigorously. For example, examining historical data and attempting to identify punishment phases in industries suspected of collusion, may fail to pick up the possibility that collusive outcomes were obtained by less severe punishment strategies. In a similar vein, Lu and Wright suggest that evidence consistent with price matching (such as parallel pricing, and statements indicating the adopting of such a policy) may serve as a useful screen for competition authorities. However, it is well known that where prices move together this need not be caused by coordination between firms and instead may be explained by numerous other factors (such as common cost shocks, common demand shocks or the simple fact that the goods are substitutes – **for example** as the price of one good rises, demand increases for the other inducing a price rise). Further, firms may make statements indicating that they will match competitors' prices so as to appear competitive to consumers even in the absence of collusion. In our view, such a screen should be applied with considerable caution.

5.59 Finally, we note that Lu and Wright find that with linear demand collusion is easier the more differentiated the products.[152] In the context of their model, greater substitutability works in two ways. On the one hand, a given gain from cheating can be obtained for a smaller price cut (and hence a smaller punishment). On the other hand, any punishment hurts more when the punisher produces a close substitute. Lu and Wright find that the former effect dominates such the increased differentiation favours internal stability. However, usually the issue with differentiation is not so much internal stability but **alignment** – agreeing the terms of coordination may be harder where products are differentiated. Indeed, Lu and Wright's results hold primarily in the context of a high degree of symmetry among firms (**for example** if they are differentiated, they are presumed to be symmetrically differentiated). It is not clear that simple punishment strategies exist with large

[152] They claim that their model extends to any number of firms, to quantity-matching punishment strategies, and that their assumption that the punishments last forever can be relaxed to punishments lasting for K periods only.

asymmetries (see also Hviid and Shaffer (1999) below on a similar point).

Tacit collusion in one-shot games

5.60 The literature on tacit collusion typically emphasizes the importance of firms' punishment strategies. It is accepted that firms can earn higher profit in the short run by cheating, but the idea is that if subsequent punishments are severe enough (for example, all firms revert to the one-shot Nash equilibrium forever after), then, from any one firm's perspective, the long term costs of cheating will outweigh the short-term gains from cheating and collusive prices can be supported.

5.61 A different approach is taken in the literature on static price-matching games, and in the (much smaller) literature on kinked-demand curves. These literatures operate under the premise that gains to cheating can be eliminated even in the short run. Instead of fixing the length of each period and assuming that retaliation from the others must wait until the period after cheating occurs, as the literature on tacit collusion does, this literature assumes that retaliation occurs immediately, in the same period that the cheating occurs and before any payoffs are realised.

Static price-matching games

5.62 There is renewed interest by competition authorities in assessing whether tacit collusion can be supported with simple punishment strategies that are easy to implement, are focal, and accord with what real-world firms may be doing. A natural candidate to consider is a price-matching strategy. When firms have price-matching strategies, each believes that if it undercuts on price, its rivals' prices will come down to match it. This raises two fundamental questions. How effective are such strategies, and what new insights can be had **vis-à-vis** more traditional punishments?

5.63 Lu and Wright (2010), discussed earlier, embeds price-matching punishments in a repeated game framework in which firms choose prices simultaneously period by period, and in which punishments can take place no earlier than the period after any cheating occurred. They show that no amount of tacit collusion can be supported when firms' products are homogeneous and punishments are restricted to price matching, but some tacit collusion (although not to the level of monopoly pricing) can be supported when the products are symmetrically differentiated.

5.64 An older literature, however, looks at price-matching responses when the retaliation is effective immediately. In this literature, it is shown that monopoly pricing can be supported whether products are homogeneous or differentiated, provided firms' demands are not too asymmetric.

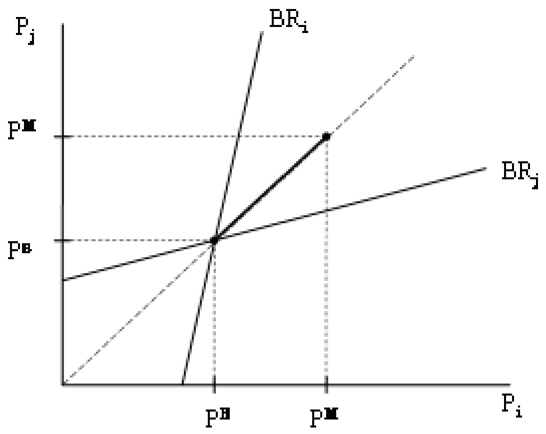
5.65 Essentially, such instant responses mean that the firm which cheats on the agreement never achieves enhanced deviation profits as competitors effectively move straight into the punishment phase, so that even in the period of deviation itself reduced profits are made. As one may expect, in such cases coordination can be found to be highly stable.

Hviid and Shaffer (1999), hassle costs: the Achilles' heel of price-matching guarantees

5.66 To develop some intuition, it is useful to consider a representative model in which two firms compete, and each understands that price decreases will be immediately matched by the other.

5.67 Let firm **i's** demand and cost be given by $q_i(p_i, p_j)$ and c_i, respectively. Then firm **i's** profit can be denoted $\pi_i(p_i, p_j) = (p_i - c_i)q_i(p_i, p_j)$. Assume that prices are strategic complements (**for example**, reaction functions are upward sloping) and make the usual assumptions to ensure that the static Nash equilibrium is unique. Figure 76 below depicts the case of symmetric firms. In this case, P^B denotes the Bertrand-Nash equilibrium price and P^M denotes the monopoly price. In the absence of price-matching, each firm charges P^B and earns its symmetric, Bertrand-Nash equilibrium profit, which, given that the firms' products are differentiated, is strictly positive.

Figure 76: Price-matching with symmetric firms



5.68 Now suppose that in setting its price, firm **i** believes that firm **j** will immediately match any price decrease. Then there is a long-line of literature beginning with Hay (1982) and Salop (1986) which shows that all prices between P^B and P^M inclusive can be supported in equilibrium.[153] To illustrate, suppose each firm is contemplating charging P^M and consider whether one firm can profitably deviate by undercutting this price. If it does not undercut this price, the firm will earn half the monopoly profit. But if it does undercut this price, and the rival's price immediately comes down to match it, then it will earn - not half the monopoly profit, but something less than half. The reason is that the monopoly prices yield the highest aggregate profit along the line $P_i = P_j$, and so any undercutting that is matched by the rival will necessarily result in lower per-firm profits. As a result, price cutting is deterred and the monopoly price (as well as other supra-competitive prices) can be supported in equilibrium.

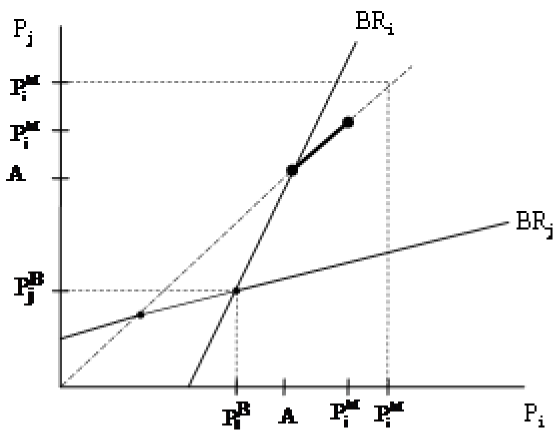
5.69 This theory does not pin down a unique supra-competitive price, and thus potentially does not address the concern that firms may encounter difficulties in reaching an understanding of what supra-competitive prices should be charged. This may not be a major criticism when firms are

[153] See also Logan and Lutter (1989), Edlin (1997), Edlin and Emch (1999), among others.

symmetric because all firms would be better off in this case if they were to settle on the monopoly price (**for example**, the monopoly outcome Pareto dominates the other possible outcomes). On the other hand, the theory does offer up a relatively simple punishment strategy that is (i) tailored to fit the crime, (ii) focal, and (iii) easy to understand and implement.

5.70 A natural extension to consider is the case of asymmetric firms (see Figure 87). In this case, the firms have different Bertrand prices, denoted P_i^B and P_j^B, respectively, and will disagree on the common monopoly price. Let (A, A) denote the intersection of $P_i = P_j$ and $P_i = BR_i(P_j)$, and (P_i^M, P_j^M) denote firm **i**'s most profitable point along the line $P_i = P_j$, and similarly for firm **j**. Suppose $P_i^M \geq P_j^M \geq A.$ Then, Hviid and Shaffer (1999) have shown that when prices are immediately matched, all prices from (A, A) to (P_i^M, P_j^M) can be supported in equilibrium.[154]

Figure 87: Price-matching with asymmetric firms



5.71 Once again the theory does not pin down a unique supra-competitive price, and thus potentially does not address the concern that firms may encounter difficulties in reaching an understanding of what supra-

[154]Note that supra-competitive prices above P_j^M, and in particular, (P_i^M, P_i^M), cannot be supported because firm j can unilaterally impose its will on firm *i* by undercutting to P_j^M, thereby forcing firm *i* to match it.

competitive prices should be charged. On the other hand, as before, the theory offers up a relatively simple punishment strategy that is (i) tailored to fit the crime, (ii) focal, (iii) easy to understand and implement, and (iv) robust to whether the firms are symmetric or not.

5.72 As in the repeated game literature, a limitation of this literature is that the theory appears to predict too much tacit collusion. Nevertheless, there are potentially two important caveats to this conclusion. First, if there is enough asymmetry between the firms, then firm i's best response to a price P_j^M by firm j may be to charge $P_i > P_j^M$ rather than engage in price matching. In this case, supra-competitive pricing cannot be supported, as shown by Hviid and Shaffer, and the only equilibrium is $\left(P_i^B, P_j^B\right)$.[155] Second, the theory is based on the assumption of immediate price matching, which likely only holds in certain institutional settings (for example when firms have contracts with their consumers in which they promise to match any rival's lower price).

Kinked-demand curves

5.73 The theory of kinked-demand curves can be traced back to Sweezy (1939) and Hall and Hitch (1939), who posited that firms will match rivals' price cuts, but not rivals' price increases. It was thought that the resulting discontinuity in the firms' demand curves would lead to price rigidity. However, because of the ad-hoc nature of the assumptions, and the indeterminacy of the kink, this view quickly became discredited (among the vocal dissenters was Stigler, 1978).

5.74 Nevertheless, there is some survey evidence to suggest that firms believe they face such asymmetries in competitor's responses (Bhaskar et al, 1991), and recent work has attempted to place the theory on solid game-theoretic foundations. Perhaps the first to do so was Bhaskar (1988).

[155] Although it should be noted that in a two-stage game in which firms first choose whether to match prices and then choose prices, supra-competitive prices can always be supported. See Logan and Lutter (1989) for details.

Bhaskar (1988), the kinked-demand curve: a game theoretic approach

5.75 Bhaskar suggested the following extensive form game. Firms **i** and **j** simultaneously announce initial prices p_{i1} and p_{j1}. If the prices differ, the firm with the higher price, say firm **i**, announces price p_{j2}. If it undercuts by choosing $p_{i2} < p_{j1}$, firm **j** has the option of announcing p_{j3}, and so on. If undercut, a firm can always respond, and the game ends when no firm undercuts. The moves take place sufficiently quickly that no sales are made until the last prices are announced. Each firm meets the demand forthcoming at these final prices and no consumers are rationed.

5.76 The main result is that, given the standard assumptions on firms' payoff functions, if the firms are not too dissimilar, they will match undercutting in the relevant range and the unique perfect equilibrium will be at the minimum common monopoly price.[156] In particular, using the notation defined above, the equilibrium will occur at $\left(P_j^M, P_j^M\right)$ (see Figure 87). Bhaskar notes that 'kinked demand strategies enforcing prices below the minimum optimal common price may be Nash equilibria but these strategies are dominated for both players and hence will not be adopted'. If the firms are sufficiently dissimilar, then the firm with the higher preferred price will not match its rival's lower price, and the unique equilibrium turns out to be of a Stackelberg type: 'the firm with the lower preferred price acting as a leader, while the follower prices above it'.[157] Bhaskar notes that these roles are not exogenously imposed but emerge naturally.

5.77 A significant aspect of the minimum optimal monopoly price is that it Pareto dominates the Bertrand-Nash equilibrium. The key assumption that drives the result is that a firm can respond to its rival's price change without delay, so that undercutting is unprofitable.

[156] Bhaskar requires that the equilibrium strategies be subgame perfect and undominated.

[157] Since the game ends when one player does not undercut the other, the player with the higher price must have moved last.

5.78 Ultimately, Bhaskar argues that his model results in a simple collusive equilibrium that can easily be obtained even when firms are non-identical, and that it is applicable in industries with a small number of firms producing homogeneous or differentiated products. However, in practice the assumptions he relies on to derive these results seems highly specific. In particular, the rivals' response time is essentially zero, which makes deviating unprofitable even in the short run – a potentially particularly strong restriction. Further, and importantly, the model would seem to rely on implicit pre-play communication.

Bhaskar (1989), quick responses in duopoly ensure monopoly pricing

5.79 Bhaskar follows up his earlier piece by generalizing the game he considers to one in which firms can respond to their rival's price change with negligible delay. He shows that 'quick responses in duopoly ensure monopoly pricing'. Specifically, he considers a game in which two firms produce homogeneous products. Firm 1 moves first, followed by firm 2, then by firm 1, and so on, until some firm **i** chooses not to change its price. Sales then take place at the final prices established, so that the firm's payoffs are determined only by the last two prices announced. Bhaskar requires that the strategies be subgame-perfect, and that the strategies played after any history should not be weakly dominated. His finding is that the equilibrium is unique at the monopoly price.[158]

5.80 The equilibrium strategies that support the monopoly outcome are of some interest even if they are not purely price matching. Bhaskar finds that each firm's optimal strategy involves matching the other firm at the monopoly price if its own price is below some cut-off level, moving to the monopoly price if the rival's price is below the cut-off level, and otherwise punishing the rival with extremely low prices. Further, the ability of firms to adjust prices in response to each other prior to prices being finalised could be thought of as a form of communication. However, it is not clear how firms will be able to come up with and

[158] Similar results are also found in Anderson (1985) and Stahl (1986).

implement these punishment strategies, and as such this approach does not seem to offer much insight when it comes to explaining how firms are able to reach a coordinated outcome without some form of explicit communication.

Currarini and Marini (2009), the kinked demand model and the stability of competition

5.81 Currarini and Marini have made a recent addition to this line of literature. They interpret the original kinked demand theory as postulating that firms would react to changes in rivals' prices asymmetrically: when a firm raises its price it expects the other to raise its price comparatively less; and when a firm lowers its price, it expects the other to reduce its price even more. This expected behaviour generates a demand curve with a kink at the original price level. The main finding is that this has strong stability properties and can result in monopoly pricing.

5.82 As an example, they note if prices are set at the collusive levels (p_1^*, p_2^*) then the kinked demand model assumes the following behaviour (here expressed as a reaction function $k_i(p_j)$ for every **i** = 1, 2, would prevail in the event of a deviation from collusive pricing

$$if\ \tilde{p}_i > p_i^*, then\ k_j(\tilde{p}_i) \leq \tilde{p}_i,$$

$$if\ \tilde{p}_i < p_i^*, then\ k_j(\tilde{p}_i) \geq \tilde{p}_i,$$

5.83 The main result of the paper is that **if firms adopt and expect the above behaviour**, then deviations from collusive prices (p_1^*, p_2^*) are prevented, and collusion is a stable outcome of the static game. However, once again, the model offers little insight as to how firms come to form the necessary expectations to underpin the kinked-demand curve outcome.

Policy implications

5.84 While this research raises some interesting issues, we emphasise that these findings do not suggest any fundamental limitations in the standard approaches used by practitioners towards examining coordinated effects concerns. Rather, we highlight that the issue raised here is effectively already covered by the second **Airtours** criterion, which considers the strength of the punishment mechanism available to rivals of a deviating firm. The case of instant rival responses is simply a particular example of an extremely quick punishment mechanism, and we highlight that punishment is one of the criteria that authorities currently consider.

5.85 However, this literature does have two noteworthy implications for policy that are worth highlighting. First, these results re-emphasise that when considering the possibility for punishment in the context of the potential stability of a coordinated arrangement it is not just the magnitude of the punishment that matters, but also how quickly it can be imposed by rivals. In markets where it may take rivals some time to implement punishment strategies, and where a deviator is therefore able to collect a significant amount of business before punishment commences, collusion is significantly less likely to emerge.

5.86 Second, the lack of discussion as to how firms align on a strategy of instant punishment is striking. However, one possible policy rule is to look further at contracts that give rise to something akin to instant price matching punishments. For example contracts that specify that a firm will meet any price cuts implemented by its rivals may have such an effect, as they could serve to deter any such price cuts from being made, and thereby act to keep prices significantly above competitive levels. However, as a final point note that when firms are asymmetric price matching may be unlikely to actually arise in practice.

Tacit collusion in alternating-move games

5.87 In the previous section, reactions are assumed to take place instantaneously (**for example**, firms have very 'quick-responses'). This assumption seems extreme for most settings. The repeated game literature discussed earlier does not suffer from this criticism because at least one period must go by before reactions can occur, though it has its own particular features, for example, by the time rivals can react, the initial deviating firm is already assumed to be making its next move. This feature is, of course, a consequence of firms making their price and quantity choices simultaneously, a setting that is also arbitrary although convenient for analytical modelling. Perhaps a more natural environment in many real-world contexts is the case in which firms can react to their rivals' actions while these actions are still in effect — though only after some lag (**for example,** not instantaneously). The idea is that firms generally commit to a certain action and rivals may be able to respond while the firm is still committed. This gives rise to a study of tacit collusion in alternating-move games. To the extent that this approach is a more natural and realistic description of how firms respond to one another's actions in practice, it is of interest to practitioners to consider any implications this modelling approach has for coordinated effects analysis.

5.88 The seminal works in this area are the three papers by Maskin and Tirole on 'A Theory of Dynamic Oligopoly'. The first paper in this trilogy. Maskin and Tirole (1988a), introduces the reader to alternating-move games and the notion of commitment, and considers the merits of Markov-Perfect strategies and the associated equilibrium concept, Markov-Perfect equilibrium ('MPE'). It then analyzes a natural monopoly setting. The second paper in this trilogy, Maskin and Tirole (1988b), looks at a pricing game between duopolists with homogeneous products. The third paper, Maskin and Tirole (1987), looks at quantity games. Of these papers, the first two are the most relevant for the purposes of this survey.

Games with homogeneous products

Maskin and Tirole (1988a), a theory of dynamic oligopoly I: overview and quantity competition with large fixed costs

5.89 The core assumption in alternating move games is that a firm commits to a particular action in the short run and cannot change that action for a finite period, during which time other firms may act. Although there may be some lag in their response, short-run commitment ensures that, by the time the other firms react, the first firm will not already have changed its action.

5.90 To formalize the idea of reaction based on commitment, Maskin and Tirole introduce a class of infinite horizon sequential duopoly games. In the simplest version they consider, the two firms move in alternating periods, both seeking to maximize their discounted sum of single period profits. They note that the fact that a firm cannot move again for two periods implies a degree of commitment.

5.91 Maskin and Tirole focus on Markov-perfect strategies, whereby 'each firm uses a strategy that makes its move in a given period a function only of the other firm's most recent move'. As they note, this makes strategies dependent only on the physical state of the system, **for example,** those variables that are directly payoff relevant. Consequently, this allows one to speak legitimately of a firm's reaction to another's action, rather than to an entire history of actions by both firms.[159]

5.92 Alternating-move games are clearly to some extent ad-hoc. To provide some justification for them, Maskin and Tirole consider 'a more elaborate class of models where firms can, in principle, move at any time they choose. Yet, as before, once a firm selects a move, it remains committed to that action for a finite length of time'. They find that 'when attention is restricted to strategies that are functions only of the physical state, in a number of cases of interest the equilibrium behaviour in endogenous timing models closely parallels that in the games where alternation is imposed'.

[159] Attention is restricted to Markov strategies because of their simplicity and because they seem at times to accord better with the customary conception of a reaction in the informal I.O. literature than do, say the reactions emphasized in the repeated game tradition. Contrary to the notion of reactions in the repeated game literature, which are more like threats, the reactions in Markov games are better seen as 'acts of self defence'. For example, cutting one's own price in response to another firm's price cut can be viewed as an attempt to regain lost customers. Or, Maskin and Tirole note, 'the reaction is a response only to the other firm's price cut and not to earlier history or to one's own past prices'.

Maskin and Tirole (1988b), a theory of dynamic oligopoly II: price competition

5.93 In this paper Maskin and Tirole consider a model of duopoly where firms take turns in choosing prices and are assumed to maximize the present value of their profits. Their strategy is assumed to depend only on the physical state of the system, in other words simply the other firm's current price.

5.94 One of the key results to come out of this paper is that if supra-competitive prices are to be supported in equilibrium, a price cut by one firm must be followed by a price cut by the rival firm and so on over some number of periods, but the number of periods over which the price-cutting occurs must strike a balance. On the one hand, it must be long enough to deter firms from wanting to initiate the price cutting in the first place. On the other hand, it must not be so costly that, when one firm cuts its price, the other firm is unwilling also to price cut and instead prefers to relent immediately. Despite these conflicting requirements, Maskin and Tirole show that equilibria with kinked-demand curves always exist, at least for discount factors that are not too low, suggesting that such models can potentially serve to accurately describe coordinated outcomes.

5.95 Maskin and Tirole also examine the case of focal prices: a price is focal for a pair of strategies if, once the focal price is set, firms continue to charge it forever. Thus, a focal price p^f satisfies

$$p^f = R^1(p^f) = R^2(p^f)$$

where $R^i(p)$ is firm i's dynamic reaction function. To the extent that focal prices exist, and are above the 'competitive level', this indicates the ability of firms to achieve stable 'coordinated' outcomes.[160] Their analysis actually suggests that, not only do focal prices exist, but that there is actually a multiplicity of such equilibria, which Maskin and Tirole

[160] We place 'coordinated' and 'competitive level' in inverted commas deliberately – see executive summary to this Chapter.

relate to the literature on kinked-demand curves. In that literature, as it is usually explained, if other firms imitate price cuts but do not imitate price rises, a firm's marginal revenue will necessarily have a discontinuity at the current price. Therefore, as long as the marginal cost curve passes through the interval of discontinuity the current price can be an equilibrium, implying a range of prices that will have this property.

5.96 This result, which has been derived in a framework in which rivals' responses are considered in a significantly different manner to standard modelling approaches, seems to confirm existing folk-theorem results from simultaneous move games.

Renegotiation

5.97 In perhaps their most important theoretical result, Maskin and Tirole turn to the issue of renegotiation, a vexing problem in the literature on tacit collusion in repeated games as discussed above. They first note that it can also be a problem in alternating move games. 'Although the multiplicity of equilibria in our model accords neatly with the traditional kinked-demand curve story, most of these equilibria do not hold up well as self-enforcing agreements. To see why, consider a kinked-demand curve equilibrium in which a price cut precipitates a costly price war. Firms' strategies in the price war form a MPE, but it is difficult to see how such a price war could come about if firms were able to negotiate. Specifically, after the initial price cut, firms might discuss the situation. If there existed an alternative MPE in which both firms did better than in the price war, why would they settle for the war? Why should they not agree to move to the alternative (or some even better) MPE? But if firms renegotiated in this way, they could destroy the deterrent to cut prices in the first place. If a firm realized that lowering its price would not precipitate a price war, it might find such a cut advantageous. Hence, our kinked demand curve equilibrium would collapse'.

5.98 With this in mind, and to study behaviour that is not subject to this attack, Maskin and Tirole define an MPE to be renegotiation proof if, at any price, p, there exists no alternative MPE that Pareto-dominates it. It appears that to gain intuition for practical applications from such models it may be appropriate to focus our attention on such renegotiation proof outcomes. This requirement of renegotiation-proofness turns out to drastically reduce the set of equilibria in the model. Ultimately, they find the unique symmetric renegotiation-proof MPE is the simple monopoly kinked-demand curve equilibrium.

5.99 This result, which pins down a unique equilibrium, is analogous to the Pareto dominance results in the repeated game literature. It ultimately reinforces our intuition that monopoly pricing is indeed a focal outcome, and that such collusion should remain of interest to practitioners.

Comparison with supergames

5.100 Maskin and Tirole conclude their paper by comparing their approach with the standard repeated game literature. They suggest that their approach of modelling rivals' responses offers several advantages. First they note that:

> the strategies in the supergame literature typically have a firm reacting not only to other firms but to what it did itself. By contrast, a Markov strategy has a firm condition its action only on the other firms' behaviour. Thus, in a price war, a firm cuts its price not to punish its competitor (which would involve keeping track of its own past behaviour as well as that of the competitor) but simply to regain market share. It strikes us that these straightforward Markov reactions often resemble the informal concept of reaction stressed in the traditional I.O. discussion of business behaviour (for example the kinked demand story) more closely than do their supergame counterparts.

5.101 In other words, potentially such an approach to thinking about rival responses may better reflect how businesses behave in practice.[161]

[161] Maskin and Tirole (1988b) demonstrate not only how fixed (*for example* 'focal') price equilibria may arise, but also how Edgeworth cycles occur. In both cases firms are

5.102 Second, the supergame approach is plagued by a multiplicity of equilibria. In the repeated Bertrand game, any feasible pair of non-negative profit levels can arise in equilibrium with sufficiently little discounting. They note the following:

> Our model too has a multiplicity of equilibria but a smaller one (profits must be bounded away from zero). Moreover, there is only one equilibrium that sustains monopoly profits (whereas there is a continuum of such equilibria in the supergame framework).

5.103 Overall, Maskin and Tirole's paper is clearly seminal and deserves its prominent place in the literature. However, subsequent research on MPE's has not been able to extend their results very far because of the complexity of solving for Markov-perfect equilibria. In addition, their results are limited because their focus is on homogeneous products. It is therefore not clear how general the implications of their model are, and therefore the extent to which practitioners need to pay particular attention to this approach to thinking about competitor responses.

5.104 To this end, the next paper is important in that it extends the study of MPE to allow for some (limited) differentiation.

assumed to move in sequence, they are also presumed to choose prices from a discrete grid (for example prices can be in pounds and pence but there is no scope to charge in smaller units such as one half or one quarter of a pence). Where discount factors are low enough, an Edgeworth cycle may arise. Intuitively, starting from a high (above monopoly) price, firms undercut each other (winning the whole market) in sequence until the price falls so low that the next firm to move would rather restore the high price than undercut further and win the whole market at an even lower price. Prices then 'jump' up to the high price and the undercutting process starts once again. In contrast, the focal price outcome arises where firms are sufficiently patient, in this case the anticipation of the off-equilibrium undercutting process is sufficient to 'deter' a price cut. In Markov games, it is not really appropriate to think in terms of punishment strategies in the typical 'Airtours criteria' sense (*for example* price cuts are not punishing deviation from a prior agreed strategy). Rather, firms rationally anticipate the future consequences of their actions and see that price cutting today would lead to some amount of price cutting in the future as rivals attempt to win back market share. We note that neither the focal point nor the Edgeworth cycling equilibria are necessarily 'coordinated' outcomes (especially where the firms involved do not communicate with each other).

Games with differentiated products

5.105 Eaton and Engers (1990) consider a model of alternating price competition between two firms selling differentiated products, where each firm's price remains in effect for two periods. They note that since the period length can be made arbitrarily short, their model of alternating price competition does not imply any more inertia than any other discrete time formulation of pricing.

5.106 In the model, a firm's strategy specifies a reaction function mapping the price history to a current price p_i for each time $t$that the firm chooses a price. As in Maskin and Tirole (1988), attention is restricted to reaction functions that are payoff relevant in that only elements of the price history directly affecting current or future payoffs are arguments of the current reaction function.

5.107 They find two kinds of equilibria. The first kind, which they call 'spontaneous equilibria', emerge when the products are highly differentiated. These support a steady state price that each firm will maintain even if it is undercut by its rival. The second kind, which they call 'disciplined equilibria' arise when products are closer substitutes. These also support a steady-state price, but at this price a firm that is undercut by its rival will undercut in turn, setting a price so low that its rival is prepared to forego all sales for at least a period in order to raise prices.

5.108 A difference between the two kinds of equilibria is that, in spontaneous equilibria, more product differentiation allows steady state prices closer to the perfectly collusive level, whereas in disciplined equilibria, less product differentiation allows more collusive steady state prices. In the limit, as products become perfect substitutes, firms will be able to sustain collusive prices.

5.109 More specifically, there are three possible outcomes in any given period. These outcomes correspond to the three types of moves that a firm setting its price can make. Under 'market sacrificing', a firm sets a price so high that it foregoes all current sales, while under 'market sharing', a firm sets a price at which it sells in its own market that period, but not in its rival's market. Matching the rival's price is a particular form of market sharing. Under 'market grabbing', a firm sets a price so low that it sells to all consumers that period. This is either price 'shaving', setting a price exactly δ below the rival's, or 'price slashing', setting a strictly lower price.

5.110 These possible outcomes give rise to the two types of equilibria. For a steady state price $\bar{p}$ to exist there can be no incentive for either firm to undercut $\bar{p}$ to capture its rival's market. Undercutting is deterred because $\bar{p}$ is so low that if a firm were to shave, its discounted profit would decline even though its rival is forgiving in that it does not respond to such undercutting by undercutting further. They call an equilibrium in which undercutting of $\bar{p}$ is unprofitable even though it is not followed by further undercutting 'spontaneous', since a threat (or, rather, a rational anticipation) of punishment is not what deters undercutting. In other cases, however, shaving p would be attractive if one's rival were to remain at $\bar{p}$. In these equilibria, the threat of grabbing (to a disciplinary price of d) in response deters shaving at $\bar{p}$. Eaton and Engers call these 'disciplinary' equilibria.

5.111 The steady state prices that are supported by spontaneous and disciplined equilibria are determined by different conditions. In the first case, in a spontaneous equilibrium, $\bar{p}$ is the price at which firms are indifferent between matching and shaving, given that the rival remains at that price. In the second case, in a disciplined equilibrium, $\bar{p}$ and *d* are determined by the two conditions: (i) at $\bar{p}$ firms are indifferent between matching and slashing to d, and (ii) at d firms are indifferent between sacrificing to P^* and either shaving, matching, or sharing at a lower price f.

5.112 It follows from the two types of equilibria that supra-competitive outcomes can be supported whether or not products are highly differentiated. They admit, however, that the multiplicity of equilibria raises problems, since a stronger criterion is needed to determine the actual outcome. They note that the equilibria they have identified are not necessarily renegotiation proof.

5.113 Eaton and Engers conjecture that dropping the restriction that reaction functions be payoff relevant expands the set of possible subgame perfect Nash equilibria. Nevertheless, they note that any equilibrium in which reactions are payoff relevant is one equilibrium to a specification of competition in which payoff relevance is not imposed a priori. If rivals' responses do not depend upon payoff irrelevant information, there is no gain to conditioning one's own response upon such information. Hence, they point out that the equilibria that are characterized are also equilibria even if responding to payoff irrelevant information is in principle admitted.

5.114 In summary, Eaton and Engers develop a model of alternating price competition between firms selling differentiated products. Subgame perfect equilibria exist that support supra-competitive prices even though each firm's price depends only upon its rival's current price. They find two types of equilibria. One, which they call 'disciplined', arises when products are close substitutes. The other, which they call 'spontaneous', emerges when the products are more differentiated. In disciplined equilibria, the steady state price is enforced by the implicit threat to respond to a price cut with further price cutting. In spontaneous equilibria, no such threat is needed. The price supported by a disciplined equilibrium is greater the less differentiated are the products.

Extensions

Wallner (1999), sequential moves and tacit collusion: finite reaction-functions cycles in a finite pricing duopoly

5.115 Wallner analyzes a finite horizon, sequential move pricing duopoly model, restricting attention to Markov strategies. His solution yields stationary patterns, independent of initial conditions, where the reaction-functions follow cycles of three periods. He shows that the market price never settles down and importantly there are no kinked demand curve equilibria in this case.

5.116 Since matching is never an optimal strategy over a three-cycle, there is no kinked demand curve equilibrium. Unlike in the infinite horizon model, neither is perfect collusion sustainable nor in fact is there any stable market price that can persist over time. In the infinite model there is a large number of kinked demand curve equilibria each based on the reciprocal belief that the rival will also match. In the finite model such outcomes are not Markov perfect, since they unravel from the end. Intuitively, near the end, the gain from continued matching gets smaller (as fewer collusive periods remain) relative to the temptation to undercut and capture the whole market for a period. The finite end date acts as a counter-commitment, **for example**, as a guarantee to undercut high prices, destroying the credibility of a price-matching strategy.

5.117 Wallner notes that he considers only the simplest setting with two firms and homogeneous products. He admits that 'it is not clear how to model sequential moves where more than two firms compete in price' and suggests that a further research path would be to relax the assumption of a fixed sequential order of moves, and endogenise the timing and order of moves in a continuous time framework. Finally, he notes that modelling an 'infinite horizon game with impatient firms remains a challenge for future research', but suggests that the price dynamics that he obtains for the finite horizon might offer a clue to its solution.

Eckert (2004), an alternating-move price setting duopoly model with stochastic costs

5.118 Eckert considers a model in which two firms set prices in an alternating fashion and costs are stochastic. He allows costs to be high or low with some probability in each period. It is shown that:

> if the difference between high and low marginal costs is not too large, when there is no persistence in marginal cost, equilibria do not exist in which firms always match the current monopoly price when that price is set by the firm's rival. By contrast, equilibria exist in which the firms match each other at an equilibrium price level that does not vary with marginal costs.

5.119 Eckert goes on to state that '[f]irms are deterred from deviating from the tacitly collusive price level by the threat of an extended price war of stochastic length involving repeated undercutting'. When costs are low, a firm would prefer to respond to a deviation from the collusive price level with a higher price than the price that would force its rival to restore the collusive price. He notes that '[t]his incentive, to delay forcing a restoration of the collusive price in order to serve the entire market at low cost and high prices, results in an off-equilibrium path behaviour in which firms repeatedly undercut each other'. He demonstrates that by adding the possibility of demand or cost shocks that occur with low probability and that are sufficiently persistent, it is possible to observe such price wars in equilibrium.

Policy implications

The notion of the competitive level, coordination and multiple equilibria

5.120 As noted above, Maskin and Tirole's paper deserves its prominent place in the literature. However, subsequent research has not been able to extend their results very far because of the complexity of solving for Markov-perfect equilibria. It is therefore not clear how general the implications of the alternating-move models are, and therefore the extent to which practitioners need to pay particular attention to this approach to thinking about competitor responses. However, this discussion does highlight a common theme: that of multiple equilibria. In this context, the notions of 'coordination', 'the competitive level', and whether accommodating conjectures are per se harmful are worth discussing briefly. The competitive level can be thought of in several ways and some ideas are only briefly discussed here as they are beyond the remit of this report.

5.121 First, the competitive level could be thought of as the outcome in a one-shot simultaneous move game where firms do not have conjectural variations. This is the typical textbook approach. However, a standard result is that in an infinitely repeated simultaneous move game, any range of prices can be sustained between the one-shot outcome (for example the price obtained if the game is played once) and the monopoly price, provided firms value profits earned in the future sufficiently highly.

Textbook theory says that prices above the one-shot level can be sustained in repeated games. Firms may ignore short term deviatory gains from undercutting the 'collusive' price because they fear that deviating would lead to a punishment (for example a lower price for a certain number of time periods in the future) that is sufficiently great such that the present value of profit from sticking to the 'collusive' price exceeds that from deviating today and then being punished in subsequent periods. Against that benchmark, a coordinated outcome is arguably any outcome (even if just one penny) above the price that would emerge in a game played just once. Of course, from a policy perspective, to claim that to price a tiny amount above the one-shot level is a coordinated outcome might well be undesirable – thus **there is a distinction between what economists might refer in theory as 'collusion' and what competition authorities and courts might consider to be collusion in practice.** This, in itself, is important to emphasise even before we turn to how conjectures enter the fray.

5.122 An alternative approach is to state that the 'competitive level' could be the best outcome for consumers of all the multiple equilibria of a repeated game. That is to say, a theme of this report is that dynamic models often give rise to many possible equilibria – some of which are better for consumers than others. It can be argued that if it is appropriate to model the competitive environment as a repeated game (for example because in practice firms do indeed interact repeatedly), it would be harsh on firms to expect them to behave as if the game were entirely different (**for example** one-shot) – as noted above, why should firms be expected to ignore the likely reactions of their rivals? In other words, **the fact that a firm may have a conjecture as to how its rivals will respond is not in and of itself anti-competitive, even if the conjecture is 'accommodating'.**

5.123 A third approach might be to consider the mechanism by which the ultimate equilibrium is reached. For example, even if the industry equilibrium is worse for consumers than another possible equilibrium, this may simply be a result of shocks to the environment in which firms compete, as opposed to any anti-competitive behaviour. On the other hand, if firms communicate with each other so as to ensure the 'system' in which they compete settles on a high-price equilibrium when a low-price equilibrium was also possible, it might be argued that such communication is anti-competitive. In other words, there is a distinction between outcomes (the ultimate equilibrium attained) and how they are attained (for example as a result of random shocks to the dynamic system or because firms have **communicated** somehow to ensure that a harmful outcome for consumers is reached). Applying this to the Airtours criteria, 'alignment' can be seen as important because it captures the idea that where multiple equilibria exist, firms may well need to communicate to arrive at equilibria that raise their own profitability at the expense of consumers. Thus, in relation to the research topic in hand, it seems important to make a distinction between firms being aware of (and conditioning their behaviour on) their rivals' likely reactions (which is not necessarily coordinated behaviour) and behaviour where **firms seek to shape their rivals' expectations to make them more accommodating,** for example via some form of communication (whether overt or not).

5.124 More generally, this serves to re-emphasise that coordination is not a simplistic binary concept, with perfect coordination on the one hand and perfect competition on the other and nothing in between. Neither is communication between firms a concept that is neatly divided into 'pro-competitive' and 'harmful'. It is beyond our remit to solve these (difficult) issues but we consider it helpful to distinguish between the existence of conjectures (not per se anti-competitive) and actions to make conjectures more accommodating.

Should the Airtours criteria to define 'coordinated effects' be revised?

5.125 Our research question was to consider whether, having reviewed these models, there emerges a good case to revise the three **Airtours** criteria. Our thoughts are as follows.

5.126 First, alignment remains important and under-researched in our view.[162] While **simple** punishment strategies may facilitate reaching the terms of coordination in the event that they are somehow 'easier' on which to agree, there remains the question of **how** firms come to agreement: can they do so without explicit communication?[163] Put another way, even if price matching policies can facilitate coordination, how do rivals align on pursuing such matching policies in the first place? Indeed even if the terms of coordination - such as price matching - are in some cases relatively simple, it still needs to be made clear how firms come to mutually understand what these terms are. In these instances public communication or commitment to such strategies may be an important factor.

5.127 Second, we have argued that the role of monitoring and punishment remain important in the theory of coordinated effects. While soft or instant punishment may facilitate coordination, it can nonetheless be understood in the standard framework of trading off profits from deviation and subsequent punishment against those gained by sticking to the terms of coordination. What the literature does suggest is that 'extreme' punishment strategies may not be required in order to reach some degree of coordination.

5.128 Turning to the final **Airtours** criterion, we note that the models that we have considered do not address external stability – they typically take as given that there is no external competitive force that would disrupt coordination. However, the standard competitive constraints (existing

[162] Academic research often overlooks the practical difficulties involved in alignment and simply examines whether coordinated outcomes are stable, taking it as given that firms can arrive at them in the first place.

[163] This is important because some research suggests that it may be difficult to reach a collusive agreement absent explicit communication. See Cooper, and Kuhn (2010) who find that laboratory studies on the role of communication and collusion suggest that explicit communication increases the likelihood of collusion. This research also shows the importance of explicit threats to sustain a collusive agreement – *for example* communicating on (say) a price is not sufficient, it is important to communicate on what happens if someone does not stick to that price (*for example* the punishment strategy).

competition, potential competition and buyer power) remain important in preventing the exercise of collective market power by a coordinating group, whichever way coordination is underpinned.

5.129 In our view, the preceding three criteria are cumulative. In contrast, one might view the following statement in the Department of Justice / Federal Trade Commission horizontal merger guidelines in the section on coordinated effects as suggesting that **neither** of the first two (alignment and monitoring/punishment) is required:

> 'Parallel accommodating conduct includes situations in which each rival's response to competitive moves made by others is individually rational, and not motivated by retaliation or deterrence nor intended to sustain an agreed-upon market outcome, but nevertheless emboldens price increases and weakens competitive incentives to reduce prices or offer customers better terms'.[164]

5.130 This statement may be interpreted in several different ways. The statement could relate to the idea that harmful outcomes may arise (whether one calls them 'coordination' or not) through focal point equilibria (see Maskin and Tirole, 1988b, quoted above) where firms rationally expect (or **conjecture**) that their rivals will accommodate their pricing behaviour even though there is no agreement as such that accommodation will occur.

5.131 This raises two issues worthy of debate. First, if, as a result of a merger, firms (i) 'arrive at' a worse equilibrium for consumers without any form of communication – say because the equilibrium is so 'obvious', and (ii) the equilibrium is underpinned by accommodating conjectures, it seems awkward to denote that outcome a merger **coordinated** effect. Of course, the fact that it is not labelled as a 'coordinated effect' does not make the merger benign. If for some reason a merger gave rise to a situation where a harmful 'focal point' equilibrium seemed very likely or one in which firm's conjectures became significantly more

[164] See http://www.ftc.gov/os/2010/08/100819hmg.pdf, pp. 24-25.

accommodating, this may be a reason to block the merger (whether under the terminology of 'unilateral' or 'coordinated' effects). That said, it is not immediately apparent how often such focal points would arise in practice as a result of a merger. In contrast, if firms were expected to reach that worse equilibrium through actively shaping their rivals' conjectures, then this case might indeed be best described as a **coordinated** effect.

5.132 Second, it is worth drawing a link between this discussion and that described in Chapter 4. The impact of a merger where firms have accommodating conjectures has been considered by Jaffe and Weyl (2011) and is discussed in Chapter 4. We note there that Jaffe and Weyl have argued that unilateral effects can be thought of as **holding conjectures constant**, while coordinated effects would allow them to **change.** This reminds us of one of the themes in our report: where do the conjectures come from? If we do not know this, it is hard to predict how the merger will change them. Yet this question must be addressed in an analysis of coordinated effects if one is to use conjectures. The specific question of 'what makes conjectures change' is beyond our research brief. The papers that we have reviewed indicate (to us at least) that changing conjectures may require (additional) communication between firms. They also indicate that coordination is harder when firms are asymmetric (although it is beyond our remit to review the literature on the specific types of symmetry that may make coordination more stable).[165]

5.133 In our view, whilst the above may change the relative importance of each of the **Airtours** criteria, none of it renders the **Airtours** criteria as a whole irrelevant – it simply reminds us that there are alternative economic models that give rise to outcomes that are worse (from a customer perspective) than that predicted by a one-shot, simultaneous move game. The question, therefore, is whether the **Airtours** criteria should be expanded to take into account insights from these arguably

[165] See Kuhn (2008) for a recent contribution which assesses the factors that may (or may not) be important in the assessment of coordinated effects.

richer models. In that regard, we note that from the perspective of merger enforcement policy the key questions are: **how does a merger make it more likely that a harmful outcome would arise** (or how an existing harmful outcome would be made worse) and **can this theory of harm be substantiated to the appropriate standard?** In its current form the description of 'parallel accommodating conduct' set out in the quote above, does not clarify the policy approach as regards what types of mergers would be blocked on those grounds. Future US cases may provide further guidance on this although our personal view is that additional theoretical and empirical research is required before robust guidance can be provided. At this stage, therefore, it is not clear (to us at least) that the **Airtours** criteria which are the basis for assessing 'coordinated effects' should be amended. We are not denying the possibility that a merger could harm competition for reasons that are not neatly captured by standard unilateral effects or coordinated effects analysis. Rather we take the view that more work is needed before it is possible to provide **robust guidance** on how to assess the type of merger that would be harmful but yet not captured by the standard approach to merger analysis.

Conclusions

5.134 Our analysis of alternative forms of dynamic competitive interaction indicates that these do not change the fundamental premise that firms are potentially able to sustain prices above competitive levels. We note that, rather than rendering some of the **Airtours** criteria redundant, these models actually serve to further emphasise their central role in any assessment of whether coordinated outcomes may arise as a result of a merger. They also give us cause to reflect on what the concepts of 'coordination' and 'the competitive level' really mean to Authorities in practice, rather than in textbook theory. The fact that a firm may have a conjecture as to how its rivals will respond is not in and of itself anti-competitive, even if the conjecture is 'accommodating'. There may be a distinction between the outcome that emerges and the means by which it is attained, in particular whether firms communicated in any way to achieve (or to strengthen) accommodating reactions.

A AN INTRODUCTION TO NON-NESTED HYPOTHESIS TESTING

A.1 In this Annexe, we introduce the logic behind non-nested hypothesis testing. First, the term non-nested reflects the fact that these models cannot be related by simply changing one or several parameters of the models. If by modifying the parameters of one model, the analyst could recover the other model, then testing between the models would boil down to conduct hypothesis testing on the parameters that enable the analyst to move from one model to the other. The menu approach, however, considers models of firm conduct that are non-nested.

A.2 Second, when testing two economic models with non-nested hypotheses, three outcomes are possible:

- one model is rejected and the other accepted,
- both models are accepted, or
- both models are rejected.

A.3 All non-nested hypotheses tests share the common feature that they are implemented by making pair-wise comparisons between alternative behavioural models. We illustrate the key principles underpinning each test and illustrate their implementation using a hypothetical menu of three non-nested models as in our previous example.

- Model 1: single product firm
- Model 2: product A and B are owned by the same firm, and product C is owned by an independent firm
- Model 3: monopoly.

A.4 The comparative fit of the estimated models can be evaluated using non-nested hypotheses tests. Below we provide a high level overview of the two non-nested testing frameworks used in the conduct estimation literature. These are the Cox's (1961) non-nested likelihood ratio tests (for example Bresnahan (1987)) and the Vuong's (1989) test for non-nested hypotheses (for exmaple Gasmi, Laffont and Vuong (1992) and Salvo (2010)).

Cox's non-nested likelihood ratio test

A.5 Cox's likelihood ratio testing framework for non-nested models is used in Bresnahan (1987). Cox's test checks the adequacy of the model under the null by testing it against an alternative.

A.6 To conduct the Cox's test, a 'supermodel' is formed by taking a (geometrically) weighted average mixture of the models under consideration. The supermodel is constructed so that the model assumed true under the null hypothesis receives a weight, $1 - \lambda$, and the alternative model receives a weight, λ.

A.7 To determine which of the two models best fit the data, the analyst conducts the Cox's test twice. In each case, under the null hypothesis one of the models is assumed to be true, and it is tested against the supermodel. When the null is rejected, the supermodel has (in a statistically significant sense) additional explanatory power compared to the model assumed to be true under the null. This is implemented by testing whether the weighting parameter, λ, is significantly different from zero.

A.8 Consider the Cox test applied to models 1 and 2 in our hypothetical example. The supermodel is a linear combination of models 1 and 2.

- H_0: M1 is true: $\lambda_{12} = 0$
- H_1: the supermodel is better: $\lambda_{12} \neq 0$

A.9 We then reverse the roles of the two models and under the null hypothesis assume that M2 is true, and test it against the supermodel.

- H_0: M2 is true: $\lambda_{21} = 0$
- H_1: the supermodel is better: $\lambda_{21} \neq 0$

A.10 In general, the non-nested Cox testing procedure between models 1 and 2 generate four outcomes:

- Do not reject model 1 and reject model 2: $\lambda_{12} = 0$, $\lambda_{21} \neq 0$
- Do not reject model 2 and reject model 1:$\lambda_{21} = 0$, $\lambda_{12} \neq 0$
- Reject both models: $\lambda_{12} \neq 0$, $\lambda_{21} \neq 0$
- Accept both models: $\lambda_{12} = 0$, $\lambda_{21} = 0$

A.11 In the first two cases the interpretation of the Cox test is clear: one of the two models is clearly preferred to the other. The third case is one in which both models are rejected. In this instance, the test suggests that both models are misspecified. Finally, we have the scenario in which both models are not rejected. In this case, the data are not rich enough to allow the analyst to discriminate between the two models.

A.12 Cox's test can be applied to any menu of models estimated using maximum likelihood or the generalised method of moments (GMM). Both estimators are heavily utilised in the literature.

A.13 In practice, Cox's test can be cumbersome to implement. First, it requires all permutations of the pair-wise tests to be calculated (for example with Nnon-nested models $N(N-1)$ tests are required). Second, the test statistic requires a normalisation which can require non-trivial computation.

A.14 Notwithstanding some practical challenges, Cox's non-nested framework has the highly desirable property that any model that emerges as preferred against other models will have some form of specification check. We return to this issue below when discussing a different family of non-nested tests introduced by Vuong (1989).

Vuong's non-nested hypotheses test

A.15 Next, we consider Vuong's (1989) test as applied in the conduct estimation literature (for example by Gasmi, Laffont and Vuong (1992) and Salvo (2010)). In contrast to Cox's (1961) test, the test proposed by Vuong (1989) is not a specification test because the null hypothesis is not that one of the models is correctly specified. Therefore, although Vuong's (1989) test may suggest that one of the models is preferable to its competitors, it provides no information on whether or not that model is correctly specified.

A.16 As we did for Cox's test, to illustrate how to setup Vuong's non-nested hypotheses test we compare model 1 and model 2 from our hypothetical menu of models. The Vuong test is a version of the likelihood ratio statistic which adjusted for the number of estimated parameters in each of the models 1 and 2, and is normalised so that it is asymptotically distributed standard normal. As in all likelihood ratio tests, the difference in the log likelihood between the two models form the basis of the test. That is, $\ln L2 - \ln L1$, where $\ln L2$ is the log likelihood of model 2 and lnL1 the log likelihood of model 1. When that difference is positive, this implies that according to the data model 2 is more likely to accurately describe the data than model 1, and vice versa when the difference is negative.

A.17 When testing model 1 and 2, the hypotheses are as follows:

- H_0: Both models are 'equivalent'. This is the case when the difference in log likelihood between the two models is insignificant, so that the data cannot tell them apart.

- H_1: One of the models is preferred over the other.

  - if the test statistic is negative and less than the critical value, -c, model 1 is preferable to model 2; and
  - if the test statistic is positive and greater than the critical value, +c, model 2 is preferable to model 1.

A.18 Before providing an example of implementation of the test, it is important to note that the interpretation of the null hypothesis of Vuong's test as applied in the conduct estimation literature differs to the original interpretation of Vuong (1989). Under the null hypothesis in Vuong (1989), the equivalence of non-nested models means that both models are necessarily misspecified. However, as applied in the IO literature, failure to reject the null hypothesis is interpreted to mean that neither model is necessarily misspecified. In other words, they could be acceptable. The different interpretation is non-trivial. Under Vuong's original non-nested hypotheses test, a model is strictly preferred to all other models in the menu if and only if it can reject all other non-nested hypothesis. However, in the version of Vuong's test commonly applied in the IO literature, a model can still be preferred to all other behavioural models, even if it cannot reject all other models. We illustrate this tension in the hypothetical application of Vuong's test in the hypothetical example below.

A.19 We illustrate how to interpret Vuong's test when applied to the full menu of models based on our hypothetical example with models 1, 2 and 3. Consider that the Vuong test statistics on all model pairs are those reproduced in the table below.

A.20 In the row (column) is the model that is preferred if the LR statistic is greater (lower) than the upper (lower) bound. The test statistic follows a standard normal distribution under the null in all cases. The critical values at the 5 per cent level in a two-tailed test are ±1.96. The results of the Vuong test indicate that:

- models 2 and 3 provide a significantly better fit to the data than model 1; and
- the null hypothesis that models 2 and 3 are 'equivalent' cannot be rejected at the 5 per cent level.

Table 7: Vuong test statistics in the hypothetical example

	Model 1	**Model 2**	**Model 3**
Model 1	-	-3.56*	-2.96*
Model 2	3.56*	-	0.34
Model 3	2.96*	-0.34	-

* Indicates significance at the 5per cent level in a two-tailed test.

A.21 Adopting the interpretation of the Vuong's test as applied by the IO literature, these results allow us to conclude that models 2 and 3 are equally valid non-nested models. However, under Vuong's original interpretation of the null hypothesis, none of the models are correctly specified.

Comparing Cox's test and Vuong's test

A.22 Next we discuss and compare some of the key features associated with Cox's and Vuong's non-nested hypotheses tests. Compared to Cox's test, Vuong's test is relatively straightforward to implement for two reasons. First, each pair of models is compared using just one test, whereas with Cox's procedure this requires two tests. As such, for N competing models, we only need to conduct $N(N-1)/2$ tests.

A.23 Second, the test statistic is easier to compute than the test statistic in the Cox's test. Vuong's test only requires that the models be estimated using maximum likelihood and a likelihood ratio is computed, possibly adjusting for the number of degrees of freedom used up in estimation. In contrast, Cox's test statistic requires the evaluation of non-trivial integral containing a mixture of both models.

A.24 As we will highlight in our policy recommendations, evidence that the model is not rejected by model specification tests should be a minimum requirement for it to receive weight in policy analysis. As such, it is also important to note that, unlike Cox's test, Vuong's test is silent on whether the preferred model is correctly specified.

A.25 This is not necessarily an insurmountable problem. One possible solution is to test all model specifications prior to conducting Vuong's non-nested hypotheses tests (for example each model on the menu should be subject to a RESET test, or other comparable specification test). If no evidence of misspecification is found, then that model is added to a menu of models for the Vuong test. If not, the analyst must revisit the model specification or reject it outright. Alternatively, the RESET test might be applied to the 'best' model emerging from Vuong's test.

A.26 Of course, the Cox can be used instead. Under the Cox test, if a model is not rejected when tested against any of the alternatives, then that provides reasonably strong evidence in favour of its correct specification.

B MODELLING MERGERS WITH CONJECTURAL VARIATIONS

B.1 Here we seek to examine how well static conjectural variations models may potentially approximate the impact of mergers in industries where the true form is competition is actually some form of dynamic interaction. In particular, we consider the case where the true form of competition is a simple textbook Stackelberg leader-follower model.

B.2 We proceed by first solving the Stackelberg model both pre- and post-merger, which allows us to calculate the true price increase that would emerge from a merger in this industry. We then solve for a quantity-setting conjectural variations model and calibrate this to accurately reflect the pre-merger outcome of the Stackelberg model. Then, taking these parameter values as given, we proceed as if this conjectural variations model were a true description of the industry and solve algebraically for the post merger outcome. We can then compare the predicted price increase using the CV model to the actual price increase which is given by the Stackelberg model.

B.3 The idea here is that if an analyst sought to model the observed outcome using a CV model, but was unsure of the actual process giving rise to that outcome (here Stackelberg quantity leadership) then it is of interest to assess the error that might arise as a result of failing to appreciate the true underlying model.

Stackelberg competition

Pre-merger

B.4 We consider a classic case of Stackelberg competition, with 1 leader and 2 followers. All firms face the same marginal cost of c, and an inverse demand curve given by $P(Q) = \alpha - Q$, where $Q = q_1 + q_2 + q_3$, those being the quantities produced by each firm.

B.5 This model is solved by backward-induction: we first consider firm 1's quantity fixed and solve for the Cournot competition between the two followers, and then derive firm 1's production by replacing firm 2 and firm 3's quantities in firm 1's profit function.

B.6 So in phase 2 of the Stackelberg game:

$$q_1 = q_1^*$$

$$\pi_2 = q_2(\alpha - q_1^* - q_2 - q_3 - c)$$

$$\pi_3 = q_3(\alpha - q_1^* - q_2 - q_3 - c)$$

Maximising these profit functions gives us the outputs of firms 2 and 3 as a function of firm 1's output:

$$q_2^* = q_3^* = \frac{1}{3}(\alpha - q_1^* - c)$$

We then consider firm 1's profit function:

$$\pi_1 = q_1(\alpha - q_1 - q_2^* - q_3^* - c)$$

Substituting in the expressions for the outputs of firms 1 and 2 and then maximising, we derive:

$$q_1^* = \frac{\alpha - c}{2}$$

This then gives us:

$$q_2^* = \frac{\alpha - c}{6}$$

$$q_3^* = \frac{\alpha - c}{6}$$

So pre-merger firm 1 has a 60per cent share of the market while firms 2 and 3 both have 20 per cent. The pre-merger price is:

$$P_{pre}^S = \frac{\alpha + 5c}{6}$$

Post-merger

B.7 We assume that a merger takes place between two of the firms in this industry. In any case, the ultimate market structure will be one leader and one follower, though note that this can come about either from the leader merging with one of the followers or both followers merging.[166]

B.8 By maximising the follower's profits in stage 2 we obtain:

$$q_2^* = \frac{1}{2}(\alpha - q_1^* - c)$$

Substituting this expression into firm 1's profit function yields:

$$q_1^* = \frac{\alpha - c}{2}$$

This gives us:

$$q_2^* = \frac{\alpha - c}{4}$$

The post-merger price is:

$$P_{post}^S(Q) = \frac{\alpha + 3c}{4} > P_{pre}^S$$

Quantity competition with conjectural variations

Pre-merger

B.9 Now we examine the situation where 3 firms are involved in a static quantity setting game with conjectural variations, and calibrate the relevant parameters so that the outcome of this matches the pre-merger outcome of the Stackelberg model examined above.

B.10 We assume a constant and symmetric CV parameter across all firms:

$$\frac{\partial q_i}{\partial q_j} = \lambda$$

By maximizing each firm's profit, we obtain the following first order conditions:

[166] If the merger is between a leader and follower, this assumes that the merged firm is simply a leader.

$$q_1 = \frac{\alpha - q_2 - q_3 - c_1}{2(1+\lambda)}$$

$$q_2 = \frac{\alpha - q_1 - q_3 - c_2}{2(1+\lambda)}$$

$$q_3 = \frac{\alpha - q_2 - q_1 - c_3}{2(1+\lambda)}$$

Solving these together we obtain the following solutions:

$$q_1 = \frac{\alpha - 3c_1 + c_2 + c_3 + 2\alpha\lambda - 2\lambda c_1}{10\lambda + 4\lambda^2 + 4}$$

$$q_2 = \frac{\alpha - 3c_2 + c_1 + c_3 + 2\alpha\lambda - 2\lambda c_2}{10\lambda + 4\lambda^2 + 4}$$

$$q_3 = \frac{\alpha - 3c_3 + c_1 + c_2 + 2\alpha\lambda - 2\lambda c_3}{10\lambda + 4\lambda^2 + 4}$$

B.11 Note that these outputs depend on 4 parameters (3 marginal costs and the CV) which need to be calibrated so that these match the observed pre-merger Stackelberg outcome. However, we only have 3 equations to calibrate them: equating the outputs of the three firms in both the Stackelberg and CV models. Given that they have identical market shares, the costs of the two followers are calibrated to be the same (jointly denoted c_2 in the expression below). To deal with the additional parameter we assume that it is possible to correctly measure the leader's costs, so we set $c_1 = c$, so that only the followers' costs and the CV parameter are calibrated for.[167]

$$q_1 = \frac{\alpha - 3c + 2c_2 + 2\alpha\lambda - 2\lambda c}{10\lambda + 4\lambda^2 + 4} = \frac{\alpha - c}{2}$$

$$q_2 = q_3 = \frac{\alpha - 2c_2 + c + 2\alpha\lambda - 2\lambda c_2}{10\lambda + 4\lambda^2 + 4} = \frac{\alpha - c}{6}$$

In this case the only meaningful solution yields parameters:

[167] Note that in practice such a calibration exercise would require that the analyst could estimate both the demand parameter α and the marginal cost (which they would attribute just to the leader / firm with greatest market share) of c.

$$c_2 = \frac{8c}{9} + \frac{\alpha}{9}$$

$$\lambda = -\frac{1}{3}$$

B.12 As $\alpha > c$ we have $c_2 > c$; this makes intuitive sense as we would expect the firms with lower market shares to have higher marginal costs.

Post-merger

B.13 Post-merger only firms 1 and 2 remain, with marginal costs (modelled as) c and c_2 respectively.[168]

B.14 By maximizing their profit functions simultaneously we obtain the following first order conditions:

$$q_1 = \frac{\alpha - q_2 - c}{2 + \lambda}$$

$$q_2 = \frac{\alpha - q_1 - c_2}{2 + \lambda}$$

With parameters:

$$c_2 = \frac{8c}{9} + \frac{\alpha}{9}$$

$$\lambda = -\frac{1}{3}$$

Substituting these in and solving gives us the predicted post-merger outcome:[169]

[168] Note that if there is a merger between the two followers (firms with higher marginal costs) then this is unambiguous. However, if the merger is between a leader and follower (the firm with low costs and one with high costs) then this implicitly assumes that we are taking the post-merger costs of the merged firm to be the lower of the two merging parties.

[169] This assumes that the value of conjectures do not change as a result of the merger.

$$q_2^* = \frac{13(\alpha - c)}{48}$$

$$q_1^* = \frac{7(\alpha - c)}{16}$$

This gives us a predicted post-merger price of:

$$P_{post}^{CV} = \frac{7\alpha + 17c}{24}$$

Comparison of price increases

B.15 We now compare the price increase predicted by the quantity setting CV model to the actual price increase that would arise in the true Stackelberg model.

B.16 The actual price increase that would emerge from this merger is:

$$P_{pre}^{S} = \frac{\alpha + 5c}{6}$$

$$P_{post}^{S} = \frac{\alpha + 3c}{4}$$

$$\%\Delta P_{Stack} = \frac{P_{post}^{S} - P_{pre}^{S}}{P_{pre}^{S}} = \frac{\alpha - c}{2\alpha + 10c}$$

While the price increase predicted by the conjectural variation model is:

$$P_{pre}^{CV} = \frac{\alpha + 5c}{6}$$

$$P_{post}^{CV} = \frac{7\alpha + 17c}{24}$$

$$\%\Delta P_{CV} = \frac{P_{post}^{CV} - P_{pre}^{CV}}{P_{pre}^{CV}} = \frac{3(\alpha - c)}{4\alpha + 20c}$$

Comparing the predicted price increase to the actual one:

$$\frac{\%\Delta P_{CV}}{\%\Delta P_{Stack}} = \frac{3}{2}$$

B.17 Therefore the price increase predicted by the CV model is 50 per cent higher than the one that would actually emerge from the merger, meaning that it would significantly overstate the possibility of anticompetitive effects arising.

B.18 This serves to emphasise the point that because CV parameters are 'silent' on the true nature of competition, calibration of pre-merger outcomes using a CV parameter may give rise to highly misleading predictions of post merger outcomes. Of course the same is true of any 'back of the envelope' simulation - adopting the wrong assumptions or model of competition may give rise to uninformative results.

C IMPLEMENTING GEPP WITH OBSERVED COST SHOCKS FOR EACH FIRM

C.1 In an industry with N firms, we can consider N^2equations linking prices and quantities.

$$\frac{dq_i}{dp_j} = \sum_{k=1}^{N} \frac{\partial q_i}{\partial p_k} \frac{dp_k}{dp_j}$$

C.2 For i and j = 1 to N, and where we have $\frac{dp_j}{dp_j} = 1$. If we observe a (separate) firm-specific cost shock for each market participant, and how these in turn affect the prices and sales of each firm in the industry, then we are able to observe these relationships, firm j in each case represents the firm experiencing the cost shock. However, in practice cost shocks will likely not result in tiny marginal changes, but larger discrete shifts in volumes and prices. We can, in effect, multiply each of these equations throughout by Δp_j, the change in price of the firm experiencing the cost shock. In practice we will therefore observe the resultant price changes in product k in response to a cost shock (and therefore price change) of product j, which we denote $\Delta p_{k:j} = \frac{dp_k}{dp_j} \Delta p_j$, and the observed quantity change in product i as a result of the cost shock (and therefore price change) of product j as $\Delta q_{i:j} = \frac{dq_i}{dp_j} \Delta p_j$. We will then have N^2 equations of the form

$$\Delta q_{i:j} = \sum_{k=1}^{N} \frac{\partial q_i}{\partial p_k} \Delta p_{k:j}$$

C.3 These can be written in matrix form as follows

$$y = Ax$$

Where we have

$$y = \begin{pmatrix} \Delta q_{1:1} \\ \Delta q_{1:2} \\ \vdots \\ \Delta q_{2:1} \\ \Delta q_{2:2} \\ \vdots \\ \Delta q_{N:(N-1)} \\ \Delta q_{N:N} \end{pmatrix}, \quad x = \begin{pmatrix} \frac{\partial q_1}{\partial p_1} \\ \frac{\partial q_1}{\partial p_2} \\ \vdots \\ \frac{\partial q_2}{\partial p_1} \\ \frac{\partial q_2}{\partial p_2} \\ \vdots \\ \frac{\partial q_N}{\partial p_{N-1}} \\ \frac{\partial q_N}{\partial p_N} \end{pmatrix}, \quad A = \begin{pmatrix} B & 0 & \cdots & 0 \\ 0 & B & & 0 \\ \vdots & & \ddots & \\ 0 & 0 & & B \end{pmatrix}$$

C.4 Here y is a vector composed of the observed N^2observed quantity changes, while x is the vector of N^2price-quantity partial derivatives that we are trying to estimate – these represent the unknowns in this equation. The matrix A is a partitioned matrix composed of N by N blocks where each 0 in turn represents an N by N matrix of zeros, and for each B we have the N by N matrix

$$B = \begin{pmatrix} \Delta p_{1:1} & \Delta p_{2:1} & \cdots & \Delta p_{N:1} \\ \Delta p_{1:2} & \Delta p_{2:2} & & \Delta p_{N:2} \\ \vdots & & \ddots & \\ \Delta p_{1:N} & \Delta p_{2:N} & & \Delta p_{N:N} \end{pmatrix}$$

C.5 The matrix B (and therefore A) is thus also composed of observed values. The first row of B contains the impact on prices of the cost shock to firm 1, the second the impact of the cost shock to firm 2, and so on. Once the observed price and quantity changes have been put together in this fashion then the vector of unknowns, x, can be simply calculated from A and y through the simple matrix equation

$$x = A^{-1}y$$

C.6 This solution provides all of the required partial derivative terms, which can then be combined with information on margins to calculate GePP.

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