RBB | Economics

Cost pass-through: theory, measurement, and potential policy implications

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Foreword

'Cost pass-through' describes what happens when a business changes the price of the products or services it sells following a change in the cost of producing them. An understanding of cost pass-through is relevant across much of the OFT's work: from prioritizing which interventions to undertake, to assessing the competitive effects of business behaviour in the course of those interventions, and designing and implementing remedies following them.

This report on cost pass-through has been commissioned by the Office of Fair Trading (OFT) from RBB Economics. It provides a comprehensive and up-to-date review of the literature on the causes and consequences of differences in cost pass-through and their measurement. Its principal findings are that cost pass-through by a business differs depending on whether the cost change is idiosyncratic or industry-wide; that the extent of cost pass-through by a business depends on the responsiveness of the demand and supply conditions it faces; and that cost pass-through varies with the degree of competition between businesses up and down the supply chain. Differences in pass-through for these reasons mean price changes can absorb or amplify cost changes. The report draws out some potential implications for competition policy and practice of these findings.

The views in this paper are those of the 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.

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, Chris Walters, at the address below. We welcome suggestions for future research topics on all aspects of UK competition and consumer policy.

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Executive Summary

Cost pass-through arises when a business changes the prices of the products or services it supplies following a change in its costs. RBB Economics has been commissioned by the Office of Fair Trading to undertake a review of the theoretical and empirical literature on cost pass-through, and to consider the potential implications for competition policy and practice.

Insights from the theoretical literature

- Our discussion of relevant theory is framed in terms of absolute pass-through: the degree to which a given absolute change in cost causes an absolute change in price.

- At one extreme, a cost change may only affect an individual firm. At the other, cost changes may affect all firms in an industry or market. A range of intermediate cases may also be relevant. In general, the extent of pass-through to prices may vary significantly between these scenarios.

- The extent of industry-wide cost pass-through in a perfectly competitive market depends on the elasticity of demand relative to supply. The more elastic is demand, and the less elastic is supply, the smaller the extent of pass-through, all else being equal. (Hence, a classic observation in relation to tax incidence, that the less price-sensitive side of the market bears most of the impact of a tax, carries over to cost pass-through in these settings.) There is no scope for pass-through of firm-specific cost changes in a perfectly competitive market environment.

- With other market structures, economic theory indicates that:
  - Pass-through depends on the curvature of demand. It is greater with convex inverse-demand (the inverse demand curve becomes steeper as output decreases) and smaller with concave inverse-demand (the inverse demand curve becomes flatter as output decreases), all else being equal.
  - Pass-through is smaller when marginal cost curves slope upwards (i.e. marginal cost increases as output increases) and greater when marginal cost curves slope downwards (i.e. marginal cost falls as output increases).
  - Pass-through in excess of 100% is possible when inverse-demand is convex enough and/or when there are strong increasing returns to scale such that marginal cost curves slope sufficiently downwards. Industry-wide cost increases can result in increased profits when demand is very convex.

- Many theoretical models indicate that pass-through of industry-wide cost changes increases with the intensity of competition[1], provided that inverse demand is not very convex, in which case pass-through may instead decrease as competition increases. Significantly, however,

[1] The intensity of competitive interaction may be affected by the fundamental character of competition, the level of market concentration, and/or the extent of product substitutability/differentiation.

a wide range of pass-through rates is possible even for the extreme cases of monopoly and perfect competition.

- The extent of firm-specific cost pass-through is typically less than industry-wide cost pass-through. Industry-wide cost-pass-through rates will also normally increase as the market becomes more fragmented. Moreover, for some - but not all - model specifications, the difference between industry-wide and firm-specific cost pass-through rates can be substantial, notably as the intensity of competition increases. However, in general, results for the firm-specific case are sensitive to model specification and a wide range of outcomes is possible.

- The extent of cost pass-through in vertical settings will depend on both the vertical and the horizontal structure of the market. The adverse effects of so-called double marginalisation, when vertically separated upstream and downstream firms transact on the basis of unit prices, will depend on the extent of cost pass-through. Upstream firms will set lower absolute mark-ups relative to downstream firms the greater is the extent of downstream pass-through.

- The extent to which an upstream cost change will be passed through to retail prices will depend on the product of upstream and downstream pass-through rates. If that product exceeds 100%, the effect of the cost change will be amplified (i.e. above 100%). If the upstream pass-through rate multiplied by the downstream pass-through rate is less than 100%, the effect of the upstream cost change will be absorbed (i.e. less than 100%).

- The impact of vertical integration is usually to give rise to an effective upstream pass-through rate of 100%, i.e. the upstream division of the integrated firm passes through inputs at marginal cost and so no upstream mark-up is applied.

- A variety of vertical contractual restraints can be used to overcome the double marginalisation problem, as well as to address other 'externalities' that arise between manufacturer and retailer, and between retailers. The design of those restraints will also affect cost pass-through. In particular:

  – Such restraints may allow the vertically integrated outcomes for price and pass-through to be replicated, i.e. with unit wholesale prices set at marginal cost and 100% upstream cost pass-through.

  – Short-term cost pass-through at the downstream level may be inhibited by fixed contract terms such as resale price maintenance.[2]

- In practice, wholesale prices will frequently be set through negotiation between upstream and downstream firms rather than being imposed by the seller. In this setting, the extent of cost pass-through may both affect and be affected by the nature of the negotiation. For instance, when upstream and downstream monopolists negotiate over the wholesale price only, greater downstream pass-through will effectively reduce the bargaining power of the upstream firm. On the other hand, if those firms negotiate over the wholesale price *and* the

[2] We note that resale price maintenance is regarded as an 'object' restriction under UK and EU competition law.

retail price,[3] the extent of wholesale cost pass-through will depend on the bargaining strength of the parties and the overall pass-through rate which would materialise in the vertically-integrated case.

- Since the structure of vertical relationships will affect pass-through rates, with implications for pricing behaviour and competition, those relationships may be set strategically as part of the competitive interactions between firms.

Empirical evidence

- Empirical work on cost pass-through issues in industrial organisation settings is relatively new, and analysis that attempts to quantify pass-through rates in this context is scarce.[4] Most notably, we have identified few studies that shed light on the relationship between cost pass-through and market structure and competition. Moreover, the pass-through measures reported in the empirical literature, notably pass-through elasticities, are often difficult to interpret and compare.

- Nevertheless, there is a small body of empirical work that has considered pass-through at the firm level, both in response to industry-wide and firm-specific cost changes.

  - The evidence suggests that there may be significant differences between firms in the extent of cost pass-through, even in response to industry-wide cost changes. In other words, firm-level asymmetries appear significant.

  - There is some empirical support for the theoretical proposition that industry-wide pass-through rates will typically be greater than firm-specific pass-through rates, though no clear evidence emerges on the extent of the difference between pass-through rates (and how this might change as the intensity of competition varies).

- There is little empirical work that has estimated the curvature of demand in practice. Nevertheless, some studies using the random coefficient logit model specification suggest positive values of the so-called super-elasticity of demand are associated with smaller pass-through rates.

- Work evaluating the dynamics of pass-through relationships suggests that, while asymmetries between the effects of cost increases and decreases may prevail in the short run, these asymmetries do not persist over the longer-term.

- In the vertical context, the small number of studies that have been undertaken point to higher pass-through rates at the retail level than the wholesale level. (However, caution is required in interpreting these results since higher reported pass-through *elasticities* may not correspond to higher absolute pass-through rates.) Simulation results suggest that vertical restraints may have an important influence on pass-through rates. The available empirical evidence does not establish a clear link between vertical integration and the extent of pass-through.

[3] Note the comment regarding the legal treatment of resale price maintenance in the preceding footnote.

[4] There has been more extensive empirical consideration of pass-through in the context of exchange rate movements.

Policy considerations

- Consideration of cost pass-through is potentially relevant to a variety of different competition policy issues. For example:
  - The price effects of a horizontal merger can be assessed in terms of pass-through of a cost of cannibalisation (which arises because, post-merger, one merging party may be less inclined to lower prices where that would steal sales from the other merging party).
  - The extent of consumer benefits from horizontal and vertical agreements and from mergers is liable to depend on the extent to which cost efficiencies will be passed on.
  - The impact on consumers of a policy intervention which affects upstream market prices will depend on the extent of pass-through down the vertical supply chain (with price on an upstream market translating into a cost on the adjacent downstream market).
  - The effects of (and incentives for) input foreclosure following a vertical merger will depend on the extent to which cost increases for non-integrated firms are passed through to downstream prices, and the way the benefits of eliminating double marginalisation affect the integrated firm's prices.
  - In settings where damage claims from excessive pricing or cartel overcharges are assessed, pass-through of the inflated price by the plaintiff may be a relevant factor.

- It is important to identify the measure of pass-through that is relevant for the competition issue at hand. Thus:
  - Group-specific pass-through may be relevant for the assessment of the impact of a horizontal agreement among several parties.
  - Industry-wide pass-through may be relevant for the assessment of policy interventions that affect an entire market.
  - Horizontal merger price effects can be viewed as resulting from pass-through of simultaneous firm-specific cannibalisation costs affecting the merging parties.

- Pass-through of cost efficiencies is not limited to competitive markets. Customers may benefit from the efficiency consequences of agreements and mergers even in concentrated market settings, therefore. Indeed, relevant pass-through rates may be greater in those settings than in more competitive environments.

- A cost benefit analysis that assesses the pros and cons of a given intervention by competition authorities that raises the marginal costs for all (or a large set of) firms in a market, might usefully consider the extent to which those costs would be passed on to end customers. Market-wide cost increases may be passed on even in relatively concentrated market settings, although pass-through might be lower in such settings than compared to competitive markets unless demand is very convex.

- Since pass-through rates are sensitive to the curvature of demand, presuming a particular functional form for demand (e.g. in assessing the likely price effects of a merger) risks imposing a presumption on the level of pass-through too. Recent research suggests that 'first order' merger price predictions which draw directly on pre-merger pass-through information may perform better than predictions based on simulations which assume the wrong specification of demand.

Obtaining estimates of pass-through in practice

- The findings from the theoretical and empirical literatures indicate that the extent of cost pass-through may vary substantially from one setting to another, e.g. depending on the curvature of demand. This suggests that case-by-case assessment is required.

- Relevant evidence may range from qualitative information on the price effects of past cost changes to reduced-form econometric estimates to the results of counterfactual simulations based on structural econometric models of a market.

- Where cost pass-through is to be estimated directly, by considering the relationship between observed cost changes and price responses, it is vital to obtain and use an appropriate measure of cost.
  - The distinction must be made between price effects that are due to industry-wide cost changes and effects due to firm-specific cost changes.
  - A failure to identify all relevant cost changes may lead to an over-estimate of pass-through rates, while including cost changes that are not relevant may lead to an under-statement of pass-through rates.
  - Where possible, the relationship between pass-through and different categories of cost should be assessed rather than presumed. For example, in some circumstances pass-through of fixed costs might be expected.
  - Evidence on actual business practice, e.g. from company documentation, may be useful in this respect.

- Appropriate account must be taken of any lags in the price responses to cost changes, and of the potential confounding influence of other factors affecting prices, especially where a qualitative approach to data analysis is adopted.

- Where structural econometric models are developed in order to simulate the effects of cost pass-through, considerable care must be taken to avoid adopting overly-restrictive demand and cost specifications (e.g. by assuming a specific functional form for demand), given the key role that these play in determining pass-through rates.

- There is no perfect approach to estimating pass-through rates, and there can be no guarantee that the practitioner will always be able to obtain robust estimates. Good practice suggests that the practitioner should: assess the empirical results in light of the limits of each approach; check for consistency of results across a range of different estimation strategies; and perform sensitivity analysis to assess the robustness of the results obtained. The weight given to particular pass-through estimates must be adjusted accordingly.

- Ultimately, pass-through can only represent one aspect of the assessment of competitive effects. Moreover, the estimation of pass-through rates cannot take place in a vacuum. The practitioner must take account of the relevant market and competition context, including any key dynamic features, in identifying, analysing, and interpreting pass-through evidence.

1. Detailed overview, potential policy implications, and recommendations for practical assessment

1.1. Introduction

Cost pass-through arises when a business changes the prices of the products or services it supplies following a change in its own costs. RBB Economics has been commissioned by the Office of Fair Trading (OFT) to undertake a review of the theoretical and empirical literature on cost pass-through, and to draw out any insights that may be relevant for competition policy and for how cost pass-through may be assessed in practice.

Cost pass-through is relevant to an extensive range of competition issues. A fundamental and frequently important distinction in this respect arises between firm-specific cost changes – i.e. those which affect an individual firm only – and industry-wide cost changes – i.e. those which affect all firms in a market. Situations that lie between these two extremes will also be relevant in other circumstances, when a sub-set of all firms in a market is affected by a cost change.

For instance, if a horizontal or vertical agreement gives rise to a material risk that market power would be created or enhanced, the possible offsetting consumer benefits of such an agreement may depend on the degree to which resulting efficiencies are passed on. Hence, an evaluation of cost pass-through may inform an assessment of the merits of exempting an agreement from the provisions of competition law.

In vertical settings, moreover, an upstream firm's prices are a downstream firm's costs, so the impact on end customers arising from changes to those upstream prices will depend on the extent of downstream cost pass-through. If the OFT, say, intervenes in an upstream market with the effect of reducing prices, the impact on end consumers will depend on the extent to which this reduction is passed on along the supply chain. Where changes occur to upstream costs, the consumer effects will be influenced by pass-through rates at each stage of the supply chain. Similarly, though not directly relevant to the work of the OFT, the extent of the damages that can be claimed by the immediate customers of an input cartel may depend in part on the degree to which they can pass on any cost increases in their own prices.

Pass-through is also relevant to the assessment of mergers. Horizontal mergers can be thought of as giving rise to a cost of "cannibalisation", since, post-merger, each merging party may be less inclined to lower prices where that would steal sales from the other merging party. Viewed in these terms, the price-raising potential of such mergers depends on (1) the size of the cannibalisation costs, and (2) the extent to which these simultaneous firm-specific cost changes will be passed through to prices. At the same time, the offsetting price-reducing impact of any merger-specific cost efficiencies will also depend on the extent to which such efficiencies will be passed through to prices.

In order to shed light on these issues, we first consider what economic theory has to say about the relationship between cost pass-through and competition, in particular how it is affected by the structure of markets, and by the nature of competition between firms. The distinction between firm-specific and industry-wide cost pass-through effects is highlighted. We also review relevant empirical work, before considering more particularly the implications of pass-through in the context of horizontal mergers, as well as vertically-related markets.

An important objective of the study is to draw out policy-relevant insights from theoretical analysis and empirical methodologies and findings, and to offer guidance on how pass-through issues and evidence might be evaluated in practice.

The study is organised as follows:

In this overview chapter we first identify some basic concepts that we will use throughout the study. Next, we provide a simple illustration of pass-through economics and explain the key influence of the 'shape' of demand on cost pass-through, in order to motivate and illuminate the subsequent discussion. Detailed summaries of the main insights that emerge from the theoretical literature and from empirical research follow. We then draw out potentially relevant implications for policy. The chapter concludes with some recommendations for the assessment of cost pass-through in practice.

Relevant economic theory is reviewed in Chapters 2 to 5.

- Chapter 2 draws on the classic presentation of the problem of tax incidence to provide a grounding in the economics of cost pass-through.
- Chapter 3 considers pass-through for the polar cases of perfect competition and monopoly.
- Chapter 4 extends the theoretical analysis to oligopoly situations, covering homogeneous goods markets and differentiated products markets.
- Chapter 5 examines the economics of cost pass-through in vertical settings.

Chapter 6 reports the results of a numerical simulation that explores further some of the implications for pass-through identified in the theory chapters.

Chapters 7 and 8 report on the results of relevant empirical research.

- Chapter 7 reviews the quantitative evidence on pass-through rates and, in particular examines the evidence on differences between the effects of industry-wide and firm-specific cost pass-through.
- Chapter 8 considers empirical results in respect of vertical pass-through issues.

Chapter 9 addresses the application of pass-through measures in the assessment of horizontal mergers.

1.2. Basic concepts

The focus for this study is the pass-through of cost changes to prices; in other words, the extent to which a change in costs results in a change in prices. (Given our remit, most of this report follows the literature in considering the impact on price of a change in the costs of producing an extra unit of output; cf. the textbook concept of marginal cost.) In order to set the scene, this section defines measures of cost pass-through and identifies some basic concepts that inform the consideration of pass-through set out in this study.

1.2.1. Measures of cost pass-through

A number of different measures of pass-through are adopted in the literature. Naturally, it will be important to be clear on the definitions used, and their implications, in drawing on the findings of those papers. We shall refer, in particular, to two definitions:

- **Absolute pass-through** is the degree to which a given absolute change in cost causes a given absolute change in price. For example, suppose that a £1 cost increase causes a £1 price increase. In this case, the absolute pass-through equals 1 (or 100%). By the same logic, if a £1 cost increase causes a £0.50 price increase, the absolute pass-through is one half (or 50%). If a £1 cost shock causes a £2 price increase, the absolute pass-through equals 2 (or 200%).

- The **pass-through elasticity** gives the percentage increase in price arising from a 1% increase in cost. For example, if the pass-through elasticity is 1, then a 1% increase in cost leads to a 1% increase in price, and a 10% increase in cost leads to a 10% increase in price. A pass-through elasticity of 0.5 means a 1% increase in cost leads to a 0.5% increase in price, and so on.[5]

In general, the theoretical section of our report focuses on absolute pass-through, while the empirical section refers to both measures. It is therefore important to bear in mind the following links between them.

First, *absolute pass-through equals the pass-through elasticity multiplied by the ratio of price to marginal cost*. Usually price will exceed marginal cost and hence the pass-through elasticity will be below absolute pass-through. For example, suppose that an increment of £1 to a marginal cost of £100 causes price to increase from £200 to £202. In this case, marginal cost increases by 1% and the price also increases by 1%, so the pass-through elasticity is 1. However, the absolute pass-through will be 2 (or 200%). Since the price is twice as large as marginal cost, absolute pass-through is twice as large as the pass-through elasticity.

Second, *where a firm maintains a constant percentage margin over its marginal cost, this means that it has a pass-through elasticity of 1*. In the example above, the original percentage margin was 50%, i.e. (200 – 100) / 200 = 50%. After the cost shock, the percentage margin is unchanged at 50%, i.e. (202 – 101) / 202 = 50%.

[5] Stennek and Verboven (2001) uses the term "pass-through elasticity".

Third, *the greater is the underlying price, the smaller the percentage price change implied by a given absolute price change*. Thus a £2 absolute price increase will represent a 10% price increase if the initial price is £20 but only a 5% price increase if the initial price is £40. This is a relevant consideration in interpreting reported differences in wholesale and retail pass-through, for example, because often the literature refers only to an estimated pass-through elasticity or a percentage price effect. Suppose that a £1 increase in production costs results in a £1 increase in a wholesale price (from £4 to £5) and a £1 increase in a retail price (from £5 to £6). In this case, cost pass-through leads to a 25% increase in the wholesale price and a 20% increase in the retail price. However, the absolute pass-through between production costs and the wholesale price and between the wholesale price and the retail price is 100% in each case.

1.2.2. Cost absorbing versus amplifying scenarios

Cost-absorbing scenarios refer to situations where the absolute pass-through rate will be less than 1. In absolute terms this would apply to a case where a producer that experiences a £1 increase in relevant unit costs increase its prices by less than £1 as a result.

If the relevant absolute pass-through rate is greater than 1, then this is a **cost-amplifying** scenario. If a retailer responds to a £1 increase in the wholesale price of a product by increasing its own price by £1.20, say, then this will amount to an example of cost amplification, in absolute terms.[6]

In general, as we shall see, it is the curvature of demand and the intensity of competition which principally determines the rate of pass-through in monopoly and oligopoly market settings and, in particular, whether cost changes are absorbed or amplified. The slope of the marginal cost schedule is also important.

1.2.3. Industry-wide versus firm-specific pass-through

A fundamental distinction, and one that is frequently important in practice, arises between two different cost pass-through situations.

Industry-wide cost pass-through relates to situations where all the firms in an industry or market are affected by a common cost change. That might be the case, for example, where the cost of an essential input increases, or where all suppliers are subject to a common unit tax change. (In general, the extent to which a common cost change is passed through to prices may differ between firms.)

In other situations, the relevant focus is on **firm-specific cost pass-through**. In this situation, the cost change affects one firm only. This might be the case, for example, where only one of the firms supplying a market in country X relies on imports from country Y and is, therefore, uniquely affected by movements in the exchange rate between the two countries.

[6] The terms “cost amplifying” and “cost absorbing” are taken from Weyl and Fabinger (2012), which in turn cites work by Rochet and Tirole.

Other cases will lie between these extremes, with some, but not all, of the firms in a market suffering a cost change. That could be the case, for example, where a sub-set of firms in the market is affected by an input cartel, or by the effect of a change in exchange rates.

As we shall see below, in many situations of competition interest, the extent to which different firms in a market are affected by a cost change will have profound implications for the degree to which that cost change will be passed through to prices.

1.2.4. 'Own' price versus 'cross' price firm-specific cost pass-through

In general, even a cost change affecting a single firm is liable to impact on the equilibrium prices and outputs of *all* competing firms in an oligopolistic market. At the same time, the effect on the firm that is directly affected by the cost change will typically be different to the effect on its competitors, even where all firms would otherwise be identical. (The effects on individual competitors may vary substantially too where there are differences in the closeness of the competition between them and the directly affected firm.)

We will find it useful in places in this study to distinguish between the **'own' price cost pass-through effect**, i.e. the effect on the price of the firm that is subject to the cost change, and the **'cross' price cost pass-through effect**, i.e. the impact of a firm-specific cost change affecting one firm on the prices of its competitor(s).

1.3. A motivating example

Much of the theoretical literature relevant to cost pass-through is formally cast in terms of pass-through of unit changes in tax. A standard question in the taxation literature is: who bears a tax? A key result is that a tax levied on suppliers, say, is not necessarily borne by suppliers, at least not in full: "levied on" is not the same as "bears".[7] The question, and the response, translates naturally into an industrial organisation setting where one or more suppliers face an increase in (unit) costs.

To elaborate, suppose that the initial retail price of a product is £10. The issue of interest is whether a £1 increase in the unit costs of supply would result in the product's retail price rising to £11, say, (in which case consumers would bear the entire impact of the cost change) or whether the retail price would remain at £10 (so consumers would still pay an unchanged price and firms would thus bear the entire impact of the cost change, in reduced margins).[8]

The retail price may end up between £10 and £11, such that the cost change is shared between producers and consumers. In the latter case, how is the burden shared? A helpful starting point – that will provide a useful benchmark for later analysis – is to consider a perfectly competitive market. Whether consumers or producers bear most of the cost increase depends on who "needs" the market the most (i.e. who is the *least* sensitive to price).

[7] See, for example, Weyl and Fabinger (2013), which provides a general treatment on tax incidence. Anderson et al (2001) is also informative.

[8] In principle, the price increase could exceed the size of the tax too.

To provide some intuition for this claim, consider the demand side. If consumers are not price sensitive at all, such that a higher retail price has no impact on consumption, then consumers will bear the entire burden of the cost change. On the other hand, if consumers would leave the market in the event of any further price rise, i.e. demand is perfectly "elastic", then producers will bear the full impact of the change. Intuitively, in that case, *any* increase in the price consumers have to pay for the product would destroy the entire market and so producers must absorb the entire cost change in the form of reduced margins (leaving the retail price unchanged).

Now consider an intermediate case where consumers are somewhat price sensitive, so that demand declines as the price goes up, but the market would not be entirely destroyed by some increase in price. Suppose that the effect of the cost increase is that consumers face a higher price, i.e. that they have to spend more than before to acquire the same number of units. This will reduce demand for the product. If a reduction in output leads to lower marginal costs of supply for all firms (e.g. because capacity constraints are eased), then firms will mitigate some of the impact of the cost increase. If marginal costs fall very sharply as output declines, then firms will mitigate relatively more of the price-raising effect of the cost increase and bear a larger share of the overall burden of it. In short, cost pass-through is lower when the supply curve slopes *upwards* and the steeper the slope, the greater the cost mitigation.[9]

It is worth noting that if the supply curve slopes *downwards* (i.e. there are increasing returns to scale), an increase in consumer prices would reduce consumption which, in turn, would increase production costs (since production scale would be lower, reducing scale economies). In that case, rather than mitigate the impact of the cost increase, the shape of the supply curve would accentuate it. This means that cost amplification or 'over-shifting' of the cost change may occur. Put another way, the price paid by consumers may actually increase by more than cost increase (e.g. the selling price may increase from £10 (before) to £11.50 after, such that consumers pay an additional £1.50 as a result of the £1 cost increase. This would mean that consumers would not only bear the entire £1 cost change but also an additional increase of £0.50 (hence the term "*over*-shifting").

In summary, it can be shown that the burden of a change in the unit cost of supply is determined in a perfectly competitive market by the relative elasticities (price sensitivities) of supply and demand; the more keenly consumers decrease purchases in response to a price rise (i.e. the flatter or more 'elastic' the demand curve) and the less responsive are firms' output decisions to changes in price (i.e. the steeper or more "inelastic" and upward sloping is the supply curve), the lower the degree of pass-through.

1.4. Price sensitivity, demand "curvature" and pass-through

Before providing a detailed overview of insights from relevant economic theory, we offer some intuition for the key role played by the shape of demand – and demand curvature in particular – in determining pass-through rates.

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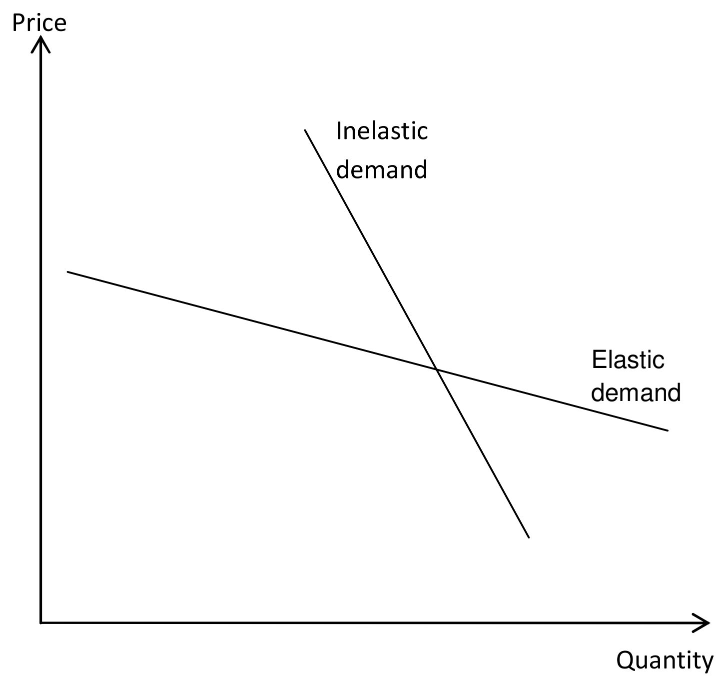
9 An upwards *sloping* supply curve means that marginal costs increase as output goes up; conversely, marginal costs fall as output goes down. The slope of the supply curve should not be confused with how the supply curve shifts following a cost shock. We discuss here a unit cost increase across the board, i.e. one that shifts upwards the *entire* marginal cost schedule without impacting on the slope of the marginal cost schedule.

As highlighted in the previous example, the price sensitivity of demand and supply has an important bearing on pass-through. Outside of perfect competition, pass-through depends not only on the slopes of the demand and supply curves, but on other features as well, notably the nature of the competitive interaction between firms and the curvature of demand. Before examining the role of these other features, however, we briefly explain what the slope of the demand curve implies about consumer behaviour. This will prove helpful in providing intuition for the main results from the theoretical literature on pass-through.

In general, demand (or "inverse demand") is downward sloping, in the sense that as price increases, so quantity demanded decreases. (Frequently, economists will refer to the *inverse* demand relationship, and this is the standard way a demand curve is presented in diagrammatic form, as set out below.[10]) The slope of the "inverse" demand curve, however, may take different values, depending on how sensitive consumers are to price changes. A steep, falling slope implies that a price increase would lead to a small drop in sales. This corresponds to the case where consumers' demands are relatively insensitive to price changes; such demand is relatively inelastic. A flat slope implies a large reduction in quantity demanded in response to a given price increase. This represents situation where consumers' demands are relatively price sensitive, or elastic.[11] The chart below shows these relationships. Price is measured on the vertical axis and quantity is measured on the horizontal axis.

Figure 1: Elastic and inelastic demand



[10] The "demand" curve identifies the amount that is demanded at a given price. The "inverse demand" curve, on the other hand, identifies the price at which a given quantity is demanded.

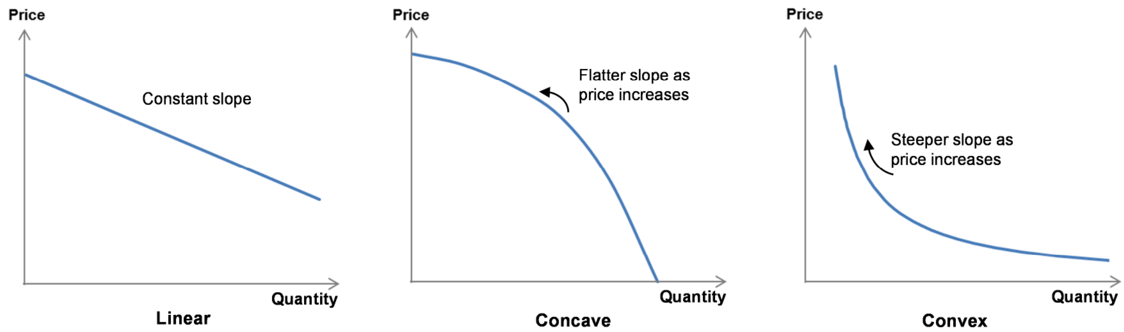
[11] In technical terms, inelastic demand means that total revenues increase as the price goes up. Elastic demand means that total revenues fall as the price goes up. The elasticity of demand may change depending on which part of the demand curve it is evaluated at, including for linear demand.

In the introductory example presented above, we saw how the slope of the demand curve, together with the slope of the supply curve, influenced the extent of pass-through in a perfectly competitive setting. However, it turns out that in monopoly and oligopoly settings it is another feature of the demand curve – its "curvature" – which plays the key role in determining pass-through. (In monopoly and oligopoly settings, where firms realise that they are able to influence market price, they will take account of how sensitive consumer demand is to price changes caused by their price or quantity setting decisions. The curvature of demand influences those decisions, as we explain below.)

The demand functions displayed above are linear in form – they are represented by straight lines; that is, the slope is constant. However, there is no reason to think that consumer behaviour can only be represented by a linear demand curve. As a result, economists also employ demand curves with different shapes, in which the slope of the demand curve may vary with quantity demanded. "Curvature" refers to this feature of demand, as we now explain.

If a demand curve is linear, it has no "curvature" at all – the *slope* of the demand curve is always the same (see the far left panel in the diagram below). The rate at which demand falls away as price increases never changes. On the other hand, if demand falls away at an increasing rate as price goes up, then that demand is dubbed "concave to the origin" (the second panel). Here, demand becomes "flatter" and hence more price sensitive (i.e. more elastic) as price increases. Finally, if the rate at which demand is reduced by successive price rises slows as price increases, the demand curve is dubbed "convex to the origin". In this case, as price goes up, remaining demand becomes less price sensitive (see the third panel).

Figure 2: Curvature illustrations



We consider now the implications of the curvature of demand curve for cost pass-through.

Suppose that a monopolist faces an increase in its unit costs. The monopolist will consider its scope to adjust its price upwards. The monopolist will think: "how much output do I have to sacrifice to pass on a certain amount of this change in my costs?" If the answer is "very little", passing on the cost shock will be more attractive; if the answer is "a lot", passing on the cost shock will be less attractive. The answer to the monopolist's question is related to the curvature of demand. Other things being equal, pass-through will be lower if inverse demand is concave (because passing on the cost increase will cause a relatively large fall in output). On the other hand, pass-through will be higher with convex demand (since passing on the cost increase has a smaller impact on volumes).

More generally, there is a link between the shape of the demand curve and the degree to which an industry-wide shock is passed on to consumers in oligopoly (and monopoly) settings. Pass-through is greater, the more that the *slope* of the demand curve steepens when prices rise (i.e. the more that demand becomes *less* sensitive to price, when the price of a product rises). In more technical terms, pass-through is greater with convex demand and smaller with concave demand.[12] Indeed, with constant marginal costs, pass-through rates will be below 1 whenever demand is concave.

1.5. Summary of insights from relevant economic theory

In this section, we set out a detailed overview of the principal insights from the review of relevant economic theory developed in Chapters 2 to 5 and so the discussion necessarily becomes more technical. However, we have sought to retain the key intuition such that this section may serve as a self-contained presentation of results for those readers seeking a summary view only.

1.5.1. Industry-wide cost pass-through

As explained above, and as the name suggests, industry-wide cost pass-through relates to the way prices respond to a cost change which affects all the firms in an industry/market. This section summarises some important theoretical results in relation to industry-wide pass-through. It draws principally on the analysis of industry-wide cost pass-through effects set out in sections 3.2 (in relation to monopoly), section 4.1.1 (in relation to oligopolistic quantity-setting 'Cournot' competition) and 4.2.1 (in relation to price-setting 'Bertrand' competition). The role of entry and exit on the pass-through of industry-wide pass-through is considered in more detail in section 4.4 of the report.

1.5.1.1. Relationship between competition and the pass-through of industry-wide cost shocks in homogeneous goods markets (with constant marginal cost)

It is helpful at this stage to summarise the results for homogeneous goods industries in the context of firms that face constant marginal costs. In order to link specifically to the literature, we employ a formula that allows us to capture differences in the intensity of competition associated with different models of competition, with perfect competition and monopoly (referred to above) as polar cases. Specifically, let a conduct parameter, θ, be equal to 0 if there is perfect competition and 1 under monopoly.[13] Specific intermediate values of the parameter correspond to particular models of oligopolistic competition, such as homogeneous product Cournot competition.[14] (While there is much debate as regards the interpretation – if any – that one can place on the conduct parameter outside these specific values some argue that the full range of parameter values between 0 and 1 can capture differences in the intensity of competition more generally.)

[12] Many commonly used demand forms are convex in shape. Linear demand is neither strictly concave nor strictly convex.

[13] The conduct parameter, θ, equals the market elasticity of demand multiplied by the percentage margin over marginal cost.

[14] For a symmetric Cournot model, θ is equal to the inverse of the number of firms active in the market.

Absolute pass-through of an industry-wide marginal cost change t can then be expressed as:

$$\frac{dp}{dt} = \frac{1}{1 + \theta(1 + \varepsilon_{SID})}$$

where ε_{SID} is a measure of "curvature" that determines whether the demand curve is linear, convex or concave. (In technical terms, it is the Elasticity of Slope of Inverse Demand.[15])

This framework allows us to address the often cited claim that there is greater pass-through in more competitive markets. Note that we address this point here in relation to industry-wide cost pass-through. (The results differ for firm-specific cost pass-through.)

First consider a perfectly competitive market, with identical firms and constant marginal costs (i.e. a flat supply curve). In this industry, if marginal cost increases by £1 for all firms, then the supply curve shifts upwards by the same amount and (because the supply curve is flat), so must the price. There is full pass-through.[16]

In contrast, if the industry were monopolised, the monopolist would ask itself the same question as described above (i.e. how much output would fall for a given amount of pass on). There we noted that pass-through would be lower with concave demand and higher with convex demand, other things being equal. In fact, it can be shown that the monopolist would increase its price by *less* than the £1 cost increase unless demand is very convex. Put differently, when comparing the extremes of perfect competition and monopoly (with constant marginal costs), the claim that competition leads to a greater degree of pass-through is correct provided that demand is not too convex.[17] This result (with constant but not necessarily symmetric marginal costs) applies more generally.[18]

1.5.1.2. Relationship between competition and the pass-through of industry-wide cost shocks in differentiated product markets (with constant marginal cost)

Weyl and Fabinger (2013) explains that the formula provided above nests a large number of cases of competition in prices (at least) with symmetric, single product firms. Symmetry in this context means that all firms have the same production technology and are equally differentiated (so no single product is particularly close to any one other in terms of substitutability). This means that in equilibrium all firms charge the same price even though products are differentiated.

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[15] In relation to the diagrams above, we discussed the slope of the inverse demand curve. Its elasticity captures the percentage change in the slope of demand arising from a 1% increase in quantity. It equals 0 for linear demand; it is positive for concave demand; and negative for convex demand).

[16] This can be seen by setting $\theta = 0$ in the above formula.

[17] This can be seen by setting $\theta = 1$ in the above formula and noting that pass-through exceeds 1 only if there is very convex demand, i.e. $\varepsilon_{SID} < -1$.

[18] It can be seen that the pass-through rate increases as θ increases provided that $\varepsilon_{SID} > -1$. (Firms need not have the same level of (constant) marginal cost in this scenario.) As noted above, there is much debate as regards how one might interpret values of θ outside of perfect competition, Cournot and monopoly settings (see the RBB report on conjectural variations prepared for the OFT). To the extent that one is willing to adopt a framework in which other values of θ are considered, it can be shown that pass-through becomes greater as the degree of competition increases (i.e. the conduct parameter decreases), provided that demand does not become too insensitive to price as the price goes up (i.e. provided that demand is not too convex). However, significantly, this result is reversed after that point (i.e. when demand is very convex, increases in competition *reduce* the rate of absolute pass-through).

Weyl and Fabinger (2013) notes that Anderson et al. (2001)'s model of differentiated price competition is nested in the above formula by setting $\theta = (1 - D)$, where D is the aggregate diversion ratio. That is to say, if the price of one firm's product goes up and it loses a certain number of units, D is the percentage of lost units that are placed with all other firms in the market.[19]

The arguments from the discussion of industry-wide shocks with homogeneous products can then be applied to conclude that with symmetric single product firms that compete in price, pass-through of industry-wide cost changes increases as the intensity of competition increases (again, measured by a fall in the conduct parameter), provided that demand is not too convex.[20] In this context, a reduction in the degree of differentiation between firms can be thought of as leading to a greater intensity of competition.

We note that the implications from some specific "work-horse" models are consistent with the view that industry-wide pass-through increases as the degree of competition/substitutability increases. Zimmerman and Carlson (2010) provides an example with linear demand.[21] In relation to the logit model, Stennek and Verboven (2001) considers the volume-weighted average pass-through (allowing for asymmetry in cost).[22] Verboven and Stennek demonstrates that this measure is the change in consumer surplus and state that, for constant marginal cost, absolute pass-through is below 100% following an industry-wide shock but that as the number of competing products increases, absolute pass-through tends to 100%. This is consistent with the observation above that increases in the intensity of competition lead to a higher degree of pass-through of industry-wide shocks provided that demand is not very convex.

1.5.1.3. Industry-wide pass-through where marginal cost is not constant

Much of the theoretical literature treats marginal cost as being constant.[23] However, drawing on the intuition set out above for the case of perfect competition, we would expect that where firms have upward sloping marginal cost, pass-through will be reduced compared to the constant marginal cost case. The intuition is as follows: If all firms face a shift upwards in their marginal cost schedules, and such schedules slope upwards (i.e. marginal cost increases as output increases), then the first order impact of the cost shock is to increase price. However, so doing reduces output and thereby moves all firms to a position of lower marginal cost (since marginal cost falls as output falls). This mitigates (part of) the cost-raising effect of the cost shock.

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[19] A practical implication (provided symmetry is a reasonable assumption) is that if one had a reliable estimate of pass-through (e.g. obtained from econometric estimation) as well as evidence on the aggregate diversion ratio (e.g. from survey evidence), then one could recover an estimate of the elasticity of the slope of inverse demand.

[20] This assumes constant marginal costs and that the conduct parameter is independent of the level of output and this result is not necessarily robust to relaxing those assumptions.

[21] On the other hand, in the Hotelling model of differentiated competition between two firms located at either end of a line (considered in Annex B), industry-wide pass-through is independent of the degree to which firms are differentiated, as represented by a transport cost parameter.

[22] If there are two products, 1 and 2, volume-weighted pass-through is given by the output of the first product multiplied by the change in price of the first product plus the output of the second product multiplied by the price of the second product. Where effects vary between firms, such an average measure of the pass-through effect is often useful.

[23] An exception is Weyl and Fabinger (2012).

By a similar argument, if there are increasing returns to scale (such that the marginal cost schedule slopes downwards), this is likely to amplify cost shocks. A cost shock not only has a first order effect of reducing output, the lower output has an additional impact of raising marginal cost further in this case.

1.5.1.4. Industry-wide pass-through in the long term

We note that the possibility of entry or exit may affect levels of pass-through in the long run. Where the literature assesses industry-wide costs shocks, it is found that increased marginal costs lead to higher prices but the curvature of demand impacts on industry structure.[24] Concave demand is associated with market exit and higher output levels for those remaining in the industry. Intuitively, the fact that pass-through is below 1 (a feature of concave demand with constant marginal costs) means that margins decline such that fewer firms can survive in the long term. In contrast, convex demand may in some circumstances induce entry such that incumbents face lower levels of output (because absolute pass-through may exceed 100% with convex demand thereby raising margins and attracting entry).[25]

1.5.2. Firm-specific pass-through

As described above, firm-specific cost pass-through arises as a result of cost changes that affect one firm only. (Group specific cost pass-through can also occur, where a sub-set of firms is affected.) The observations in this section summarise the exploration of this issue that is set out principally in sections 4.1.2 (in regard to 'Cournot' settings) and 4.2.2 (in respect of differentiated 'Bertrand' settings).

As shown for the Cournot case, demand curvature and the intensity of competition are relevant to firm-specific cost pass-through as they are for industry-wide cost pass-through.

Many economic models indicate that firm-specific pass-through is less than industry specific pass-through. The intuition is straightforward. Where a single firm faces competition from other firms, it will be constrained from increasing price (and passing on the cost shock) by not only the degree to which higher prices cause consumers to leave the market entirely but also the extent to which its own higher prices cause consumers to divert to other firms *within* the market. Such "within market" rivals will pose a stronger constraint when they are not also subject to an increase in their costs.[26]

For example, in textbook perfect competition, firms are atomistic (i.e. so small that a change in their output cannot affect the market price). In this theoretical model, a firm-specific cost shock cannot impact on the price because even if the firm changed its output, the change would be

[24] See Besley (1989) and Anderson et al. (2001).

[25] Compared to short run models where entry is not possible, less convexity is required to cause over-shifting due to the possibility that exit may occur as costs increase.

[26] As is discussed further below, if Firm B (a rival of Firm A) faces a cost increase, Firm B may increase price and thereby cause demand to increase for Firm A's product (all else equal). This will mean that Firm A has greater scope to pass on its own cost increase.

too small to impact on the overall output produced in the market. There is therefore no firm-specific pass-through.[27] Further examples are discussed in the following sections.

1.5.2.1. Relationship between competition and the pass-through of firm-specific cost shocks in homogeneous goods markets (with constant marginal cost)

In industries that can be characterised by identical products, quantity setting (Cournot) and constant marginal cost, it can be shown that the market price is directly related to the simple industry average marginal cost (i.e. the sum of marginal costs in the industry divided by the number of firms in the industry). So if only one firm's cost increases by £1, the impact on industry marginal costs will be less than if all firms' costs increase by £1.

Also, firm-specific cost pass-through will be lower as the number of the firms in the market is greater. Intuitively, as the number of firms increases, the industry becomes more like a perfectly competitive one where, as discussed above, firm-specific pass-through is 0. In fact, in Cournot markets, firm-specific pass-through will be equal to industry-wide pass-through divided by the number of firms in the market (and is not dependent on the relative size of the affected firm, as such).

1.5.2.2. Relationship between competition and the pass-through of firm-specific cost shocks in differentiated product markets (with constant marginal cost)

With price-focused (Bertrand) competition in differentiated products markets with constant marginal costs, it is typically (but not always) the case that following a firm-specific cost shock a firm will increase its price. Its rivals may also increase their price, but typically by a lesser amount than if their own costs had also been increased. To give a simple example, consider a symmetric duopoly. Suppose that if Firm 1's marginal cost increases by £1, it increases price by £0.70. Firm 2 may also increase its price; it can do so because now Firm 1 is a weaker constraint due to the cost shock. (Another way to think about this is that Firm 1's higher price diverts demand to Firm 2 and, in response to that higher demand, Firm 2 increases its price.[28]) This will tend to re-enforce the pass-through effect for Firm 1. Firm 2, however, would typically not increase its price by as much as Firm 1 (so its price rise would be less than £0.70). On the other hand, if *both* Firm 1 and Firm 2 faced a £1 increase in their marginal costs (and industry-wide shock), both firms would increase prices by more than £0.70.

With quantity-based competition between differentiated products, different effects may result.[29] A firm will typically respond to an increase in its own costs by reducing output, thereby raising its

[27] While perfect competition is a textbook ideal, auctions may result in qualitatively similar outcomes. Indeed, as the number of bidders increases, auction outcomes often converge to those in perfect competition. For example, in second- and first-price auctions where suppliers have marginal costs that are common knowledge and not subject to random shocks, the winning price is determined by the marginal cost of the second most efficient firm. Pass-through occurs only if a firm-specific cost shock impacts the marginal cost of the second most efficient firm.

[28] In technical terms, prices are normally modelled as so-called strategic complements - Firm 1's best response to a higher price set by Firm 2 is also to increase its price (and vice versa).

[29] Whereas prices are (usually) so-called strategic complements – a firm will have an incentive to increase its own price as rivals' prices increase, quantities are (usually) so-called strategic substitutes - a firm will have an incentive to increase its output if a rival *reduces* its output.

price. However, the response of rivals to this may be to expand their own output. (They would have an incentive to do so if their own prices increase as a result of the original firm's output reduction.) This will have an opposite effect on prices and will tend to reduce the extent of the pass-through effect, all else being equal. The specific linear model considered by Zimmerman and Carlson (2010) predicts that the relationship between firm-specific cost pass-through and the number of firms will be non-monotonic, first decreasing as the number of firms increases, then increasing as the number of firms increases above a certain threshold (when firms are differentiated, at least).[30] However, this result disappears in their model as products become undifferentiated.

We emphasise, however, that with product differentiation, there is no general relationship between a firm's market share and the degree of pass-through. Firm-specific cost pass-through with logit demand, for example, is a non-linear function of market shares.[31] Further, we show in a relatively simple model of Hotelling duopolists (see Annex B) that compete on both price and quality that a wide range of pass-through effects is possible. Specifically, own- and cross pass-through may be positive or negative and may exceed 100%.

1.5.2.3. Industry-wide pass-through where marginal cost is not constant

As above, other things equal, we expect that pass-through is diminished with upward sloping marginal cost and enhanced with downward sloping marginal cost.

1.5.3. Pass-through between upstream and downstream markets

We now turn to a vertical setting and consider pass-through between upstream and downstream markets. (This section summarises analysis set out in more detail in Chapter 5 of the study.) By definition, pass-through addresses the degree to which an upstream cost shock impacts on the price paid by downstream customers. It is therefore a valuable tool in vertical settings.

1.5.3.1. Double marginalisation

Consider, for instance, a manufacturer selling at a unit wholesale price to a retailer that in turn sells on the product to final consumers. The manufacturer will understand that demand for its product is derived from consumer demand. Translating the impact of the manufacturer's

[30] The intuition for this is that the larger the number of firms in the market, the smaller the impact of a single firm's output response to a firm-specific cost change on average output, and hence the smaller the reaction of rivals given the set-up of Zimmerman and Carlson's model. Beyond a certain point, this diluting impact of an increased number of firms outweighs the pass-through reducing effect of increased competition.

[31] For example, Stennek and Verboven (2001) considers absolute firm-specific pass-through in the logit model in terms of the impact of a firm-specific cost shock on not only the own price of that firm but on all prices within the market (i.e. all inside goods) weighted by their respective outputs. It finds that there is not a simple relationship between a firm's market share and the degree of pass on. In our own simulation work using the formula for firm-specific pass-through set out in Verboven and van Dijk (2008), we find that for a given outside good, 'own' price firm-specific pass-through tends to decline as a firm's market share increases, although this is not always the case. In other words, a firm-specific cost change for a firm with a small market share would tend to give rise to a higher degree of pass-through than for a firm with a larger market share.

wholesale price rise into demand for the manufacturer's product requires consideration of pass-through.

For example, if the manufacturer of widgets increases the wholesale price by £1 and the retailer then increases the retail price of widgets by £2, this will have a greater demand-reducing impact for widgets than if the retailer had increased the price by only £0.50. In the former case, the retail stage involves cost amplification; in the latter case, the retail element involves cost absorption. This suggests that other things being equal, the manufacturer will be less willing to set a high mark-up on its wholesale price, the higher is pass-through at the downstream level. For example, other things being equal, the degree of double marginalisation may be less when retailers face cost amplifying conditions (since retailers will not then absorb a wholesale price rise but accentuate it). This will depend, among other things on the structure of the downstream market, and the strength of the competitive interaction between firms.

1.5.3.2. Vertical restraints

The effects of double marginalisation described above may be mitigated through the use of vertical contractual restraints. In the simple setting described above, for example, a unit wholesale price might be replaced with a two-part tariff, whereby the wholesale price would be set equal to the manufacturer's unit cost and the manufacturer would extract profit from the retailer via a fixed fee.

Such changes in the pricing relationship between the manufacturer and retailer are liable to affect the pass-through relationship too. In this case, the wholesale pass-through rate would be 100%, whilst the retailer would assume the same pass-through incentives as a vertically integrated firm.

As a matter of economic theory, resale price maintenance (or, more specifically, a price cap) may be used to similar overall pricing effect in this setting.[32] However, the impact on pass-through of upstream cost changes to wholesale prices may be different, since the wholesale price need not be set equal to upstream marginal cost, for instance.

Moreover, fixing contract terms in this way may restrict the scope to adjust prices in response to on-going cost changes, giving rise to short-term price rigidities which will inhibit pass-through.

1.5.3.3. Bargaining over wholesale terms

The theoretical results described above also presume that the wholesale price is set unilaterally by the manufacturer. In practice, the terms of many wholesale level relationships are characterised by negotiation. How does this affect the way changes in the manufacturer's marginal costs are passed through to wholesale prices?

In an efficient bargaining environment (e.g. assuming no uncertainties), negotiation between the manufacturer and retailer over the terms of a two-part tariff would result in a wholesale price set

[32] See comment on the legal treatment of resale price maintenance at footnote 2.

at marginal cost, and negotiation focused on the fixed fee to be paid by the retailer. In that case, the wholesale pass-through rate would be 100% (as with the two part tariff, described above).

With bilateral monopoly and negotiation over *both* the wholesale *and* retail prices, the latter is set as would an integrated firm (to maximise the total surplus available), while the former results in upstream and downstream mark-ups that are in line with the respective bargaining strengths of the upstream and downstream firms.

Interestingly, when the manufacturer and retailer bargain over the wholesale price only, the retailer's share of the surplus created by the agreement will be enhanced by the degree of pass-through at the retail level. Intuitively, as the retail pass-through rate increases, the manufacturer is less inclined to set a higher wholesale price (since this will have an increasing 'knock on' impact on the retail price, which will further, adversely, affect the manufacturer's sales). This is in line with the intuition of the preceding section that double marginalisation is lower when the *retail* pass-through rate is higher, other things being equal.

1.5.3.4. Vertical effects, pass-through and competition

It should be clear from the previous discussions, that vertical pass-through effects are liable to depend on and affect competition at various levels in the supply chain. For example, if the retail market is competitive, then double marginalisation, and the consequent effects on pass-through will not arise. On the other hand, vertical restraints (or the vertical integration/separation decision) may be used strategically to influence competition between retailers, or manufacturers, affecting pass-through rates in the process.

1.5.4. The interaction between price and quality competition on pass-through

Our focus in this study is on scenarios where firms compete on price or quantity. However, pass-through results may be sensitive to the interactions that arise between the choice of price or quantity, on the one hand, and additional dimensions on which firms might compete, such as product or service quality, on the other.

To illustrate this sensitivity, we have developed a relatively simple, illustrative model (based on the Hotelling line characterisation of differentiation) in which firms compete in quality <u>and</u> price.[33] We find, within the confines of our stylised model, that firm-specific cost pass-through rates may be positive or negative and may switch sign suddenly.[34] This applies both for 'own' and 'cross' price cost pass-through. Moreover, there is not a uniform relation between the two; nor is there a constant or stable relation between 'own' or 'cross' price cost pass-through, on the one hand, and the industry-wide cost pass-through rate, on the other.

[33] See Annex B for details.

[34] Note that the latter effects arise in circumstances where the equilibrium is unstable.

This demonstrates that it is important to consider how cost pass-through may interact with other dimensions of competition.[35] If both price and quality are relevant to competition in practice, an analysis that erroneously ignored the quality dimension to competition may be informative only when the cost of competing on quality is relatively high (i.e. such that quality can be taken as a given).

1.5.5. Dynamic considerations

In practice, pass-through may be dampened where changing prices or output is costly for the firm(s) involved.[36] For example, a small cost shock might not have a material impact on profits. If so, and there are menu costs associated with changing price, then that cost (e.g. the hassle of negotiating a different price or the effort of updating price lists) might exceed the benefit of changing price immediately, leading to relatively sticky prices. Similarly, if demand is expected to be high next year, and if it is costly to vary production quickly, it may be that a cost shock this year would not be passed on as that would reduce output substantially making it very costly to ramp up volumes to meet demand when the expected boom arises next year.

1.6. Summary of findings in respect of empirical evidence

Our review of relevant empirical evidence is contained in Chapters 7 and 8 of the study.

Whilst there has been extensive empirical investigation of pass-through in specific settings, notably considering the effects of exchange-rate changes, this literature sheds rather limited light on the pass-through issues that are of interest in the competition sphere. In the past, there has been very little empirical industrial organisation work that has quantified the extent to which firms pass on changes in cost to prices.[37] However, recently a number of studies in this area have investigated cost pass-through using product-level and firm-level data drawn from specific industries. These include, in particular: coffee, gasoline, processed cheese, the automotive industry, electricity and stationery supplies. Most of these studies focus on industry-wide cost changes.

While the comparison across studies is made difficult by the fact that some report the absolute pass-through rate while others present pass-through elasticities (without the means to convert one to the other), they offer two main insights:

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[35] For example, a reduction in marginal cost of production may increase the margin per unit and thereby encourage a firm to invest in quality which would expand the number of units sold at the higher margin. In that case, the higher quality may allow the firm to maintain or even raise its price; it would thus be a factor that diminishes the rate of production cost pass-through.

[36] A Bank of England survey of price-setting behaviour by UK firms, as reported by Greenslade and Parker (2010), offers useful insight on the factors affecting the frequency of firms' price changes.

[37] Most of the empirical findings in relation to pass-through come from the international economics literature, in which there is a long tradition of estimating exchange rate pass-through, that is, the price response of internationally traded goods to changes in exchange rates. This literature has grown, spurred in particular by the interest of macro-economists in uncovering micro-level explanations for nominal price stickiness. Most of the findings of this literature, however, are not directly relevant to this study, as the focus is to explain the exchange rate pass-through, and not a change in marginal cost. For example, we note that the international economics literature often uses industry-level data (preventing the testing of firm-specific impacts). We also note that when marginal costs are not observed directly, such that a proxy for them must be used, it is important to understand the extent to which a change in the proxy variable (here, the exchange rate) impacts on marginal cost. Typically studies are unable to discern how the exchange rate impacts on marginal cost.

- First, the available empirical evidence reveals a wide range of pass-through rates or elasticities. For instance, absolute industry-wide pass-through can be as low as 20% but can also reach well over 100%. This wide range could be explained by a number of factors, notably market structure, however there is relatively little consideration in the literature of what causes pass-through rates to vary. Similarly, estimated pass-through elasticities range from values close to 0 in some cases to close to 1 in others. Note that because, in most markets, firms earn a mark-up over cost, any pass-through elasticity close to 1 surely implies an absolute pass-through rate above 100%. In fact, even for lower elasticity values, the absolute pass-through rate may be above 100% if the ratio of price to marginal cost is sufficiently high.

- Second, even where firms are subject to similar industry-wide cost shocks, pass-through rates may vary considerably across firms. This suggests that the price response for one product (or for one firm) may not be used as a reliable proxy for the price response of another product (or for another firm). This finding is consistent with economic theory. When it comes to industry-wide cost shocks, even though firms face the same cost change, in differentiated product markets they may adjust prices at a different rate. In other words, the pass-through rate of Firm A need not be the same as for Firm B, even though they face the same cost increase. This is because they may each face a quite different residual demand curve, whose slope and curvature need not be equivalent.

Unfortunately, there are relatively few papers in the empirical literature that have tested the theoretical predictions described in the preceding section. Below we summarise the principal findings of this literature.

First, economic theory suggests that the price response to firm-specific cost shocks is smaller than industry-wide cost shocks. Several papers, employing different types of estimation technique, corroborate the theoretical prediction that industry-wide cost pass-through will be larger than firm-specific cost pass-through. That is, firms adjust price to a larger extent when facing an industry-wide cost shock than a firm-specific cost shock.[38] (Failure to account for industry-wide shocks when attempting to estimate firm-specific cost pass-through can therefore lead to substantially over-stated firm-specific pass-through estimates.) There is, however, no clear evidence about the difference in magnitude between industry-wide and firm-specific cost pass-through. (Having observed an industry-wide pass-through rate of X, we cannot say, for example, that the firm-specific cost pass-through rate is likely to be any particular number – only that it is likely to be less than X.)

Second, theory highlights the importance of demand curvature to pass-through in imperfectly competitive settings. However, very few studies have sought to estimate this curvature in practice. Nevertheless, the limited evidence that is available, obtained in studies using the random coefficient logit model, suggests that smaller pass-through rates are associated with positive values of the super elasticity (i.e. the elasticity of the elasticity) of demand, which gives

[38] The finding that industry-wide is higher than firm-specific cost pass-through is an ancillary result in these papers. No study tests directly this hypothesis.

the percentage change in the price elasticity for a given percentage change in price. When the elasticity of demand increases, firms adjust their mark-ups downwards.

Third, standard oligopoly models predict that as the intensity of competition increases, the *industry* pass-through rate also increases (for demand curves that are not too convex), whilst for many (but by no means all) models, the *firm*-specific cost pass-through rate is predicted to diminish. Very few published articles appear to have tested these propositions empirically. For example, we have identified only a few papers whose findings shed light on the relationship between competition and *industry-wide* cost pass-through.[39] Typically, the studies we have identified use a variety of measures that are not comparable and, because the results are mixed and often statistically insignificant, it is difficult to draw any meaningful insights. A small number of industrial organization studies have used structural model approaches to simulate the price effects of marginal cost shocks under various assumptions about firm conduct. These studies suggest that increased market power is associated with a reduction in industry-wide pass-through. However, importantly, no clear evidence emerges as to how cost pass-through is linked to market concentration measures such as a firm's market share or the market HHI level.

We have not identified any study that has sought to test directly the impact of competition on firm-specific cost pass-through. We cannot, therefore, draw any conclusion from the empirical literature about this important issue. In our view, this is a key area for further research.

A large number of empirical studies have identified differences between short-run and long-run pass-through rates. Typically these studies have also investigated the existence of asymmetric pass-through; that is, whether prices increase by more in response to cost increases than they fall in response to cost decreases of the same magnitude. In principle, asymmetric pass-through can only arise in the short run. (In the long run, the asymmetry should vanish; otherwise firms' mark-ups would follow an ever upward trend.)

Many of these studies have shown that prices adjust more quickly to cost increases than to cost decreases and, as expected, the asymmetry eventually disappears. However, no consistent pattern emerges as to how long this process may take.

Studies that document asymmetric patterns in pass-through often fail to identify which factors cause these asymmetries. A recent study of pass-through in the French coffee market by Bonnet and Villas Boas (2013) is a notable exception. In that case, the authors find that an asymmetric pass-through elasticity (and hence asymmetric absolute pass-through) is explained by demand that is less sensitive to increases in price than to decreases in price.

With regard to the relationship between cost pass-through and vertical features of the market, again, very few studies shed light on these issues. Below we set out the main insights from our review.

[39] Nonetheless, one paper of interest that we review in detail - Kim and Cotterill (2008) - uses a structural oligopoly model, without imposing restrictions on the curvature of demand, in which firms supply differentiated products. The authors simulate a number of counterfactual scenarios to quantify the cost pass-through under different assumptions about firm conduct. Specifically, they compare the cost pass-through for brands of processed cheese when (i) firms are assumed to behave as Nash-Bertrand price competitors with (ii) a market when firms are assumed to collude perfectly (i.e. they maximise joint profit as would a single supplier controlling the supply of processed cheese). Kim and Cotterill (2008) finds that industry-wide cost pass-through falls in the monopoly case.

First, a consistent finding, albeit from a small number of studies, is that industry-wide cost pass-through elasticities (and absolute pass-through rates) between the wholesale price and retail stages are typically high, often above 80%. On the other hand, the studies suggest that a given percentage change in upstream costs appears to cause a relatively small percentage change in wholesale prices. However, because the cost changes assessed may only account for a small percentage of wholesale marginal costs, it cannot be inferred from this observation that the *absolute* pass-through of upstream costs into wholesale prices is low (indeed, one study finds it to be high). This is an important point to keep in mind when assessing the empirical findings that percentage changes in upstream costs do not cause large percentage changes in wholesale prices (which in turn explains their limited impact on retail prices).

Second, the relationship between two firms in the supply chain, or generally a business-to-business transaction, is often more complex than is considered by standard models. While the assumption of linear pricing might be reasonable with respect to retail markets, it is clear that non-linear tariffs are frequently applied in upstream markets between manufacturers/ wholesalers and retailers. In addition, agreements between manufacturers/wholesalers and retailers may seek to impose restrictions on retailers' conduct, for example by requiring retail price maintenance.[40] The nature of the vertical contracts between upstream suppliers/wholesalers and retailers may affect the extent of pass-through, as explained in Chapter 5 above. The one notable study we have identified in this area suggests, albeit based on simulating the effects of different contracts as opposed to comparing actual data under different vertical structures, that non-linear tariffs on their own have little effect on the pass-through elasticity at the wholesale (upstream) level. However, resale price maintenance in combination with two-part tariffs can increase the pass-through elasticity significantly.

Finally, we review the evidence on vertical integration and pass-through. The discussion in Chapter 5 of this study explains why eliminating double marginalisation through integration may boost pass-through in some cases, but have the reverse effect in other cases. As a result, there is no clear link between vertical integration and cost pass-through. The available empirical studies confirm that vertical integration has an ambiguous relationship with pass-through.

1.7. The potential relevance of pass-through to competition policy

This section sets out a number of areas where understanding the degree of pass-through is important for assessing issues that arise regularly in relation to the assessment of the competitive effects of mergers, anti-competitive agreements and market investigations. We identify potential policy implications in relation to pass-through where they arise, in our discussion of the following topics:

- Pass-through and fixed versus variable cost changes.
- Pass-through and the assessment of horizontal mergers.

[40] See comment on the legal treatment of resale price maintenance at footnote 2.

- Pass-through and horizontal agreements.
- Pass-through and input foreclosure.
- Pass-through of the costs of regulatory intervention.

1.7.1. Pass-through and fixed versus variable cost changes

One fundamental question for the assessment of pass-through in practice is which cost categories affect prices. In textbook economic models of competition, the decisive cost measure affecting pricing behaviour is marginal cost, i.e. the additional cost incurred in supplying an extra unit of a product or service.[41] Unsurprisingly, therefore, the analysis of cost pass-through in the theoretical literature has focused on the relationship between changes in (short-run) marginal costs and prices.

Generally, there are several factors which may affect which categories of cost are liable to affect prices and, hence, may be relevant to an evaluation of relevant cost pass-through.

First, the time frame over which pricing is considered will affect the categories of costs which should be included in the pass-through analysis. Economic theory predicts that the longer the relevant timeframe, the greater the proportion of costs which should be regarded as variable. If the timeframe perspective that is adopted for the analysis of pass-through is out of line with that adopted by the business in practice, the conclusions of such an assessment are liable to be biased.

An obvious example arises where transactions are framed in terms of long-term contracts. In that context, all costs that are associated with fulfilment of the contract will be variable costs, and can be expected to affect contract pricing decisions, even if those costs will not subsequently vary with the units of output actually delivered under the contract. Suppose, for example, that the fulfilment of a contract would require a long-lasting fixed investment in machinery. A change in the cost of such machinery is liable to affect the pricing of the contract, in ways which depend on the extent of competition, as with marginal costs in the theoretical literature. Put another way, in this case the relevant unit (or "incremental") cost can be considered to be the ex-ante expected costs of fulfilling the contract (irrespective of whether the expected costs are dubbed fixed or variable in accounting terms).

Second, and often a related issue, the level of costs that are relevant to pass-through analysis will depend on the increment of activity that is relevant to the pricing decision. For example, before committing to a fixed cost investment to expand capacity, a firm may contract to achieve a target return to cover the fixed and variable costs of the output expansion (as with the contract example above). In other words, the firm pricing will ensure that incremental revenue covers incremental cost.

[41] In theory, fixed costs play a role, but only by affecting the structure of an industry; e.g. whether a firm decides to enter a market; whether it invests in a new product line. At the same time, the demarcation between what is a variable or marginal cost and what is a fixed cost will typically change as the relevant timeframe changes.

More generally, the level of fixed costs may have an important influence on the level and rate of expansion (or contraction) of a business – in terms of the opening of new outlets, and the introduction of new products, which in turn affects the price level. Reductions in upfront investments costs make expansion more attractive, while reduced overheads at a given site, for example, may permit a firm to keep the site open in the face of a decline in demand. In short, where lower fixed costs may lead to higher output or the greater roll out of new products, prices will be affected and (fixed) cost pass-through will arise.

Third, where prices are determined through a process of negotiation, there is no reason to suppose that the terms of those negotiations will depend only on the levels of variable costs, even if the outcome of the negotiation is a per unit price. Suppose, for example, that a buyer may self-supply an input, provided that it incurs a fixed cost. If, rather than self-supply, the buyer uses the *threat* to do so to secure a lower input price from another producer, then a reduction in the fixed cost of integrating backwards would enhance the buyer's bargaining strength. In turn, that would allow the buyer to negotiate a lower wholesale price and hence a lower marginal cost.

Substantive appraisal of cost pass-through in practice requires an understanding of the relationship between (the different categories of) cost and pricing as it relates to the business in question. If a business sets its prices on the basis of mark-ups over variable costs designed to earn a target return on fixed costs, for example, then changes in fixed costs will affect those prices, and are relevant to the analysis.[42]

1.7.2. Pass-through and the assessment of horizontal mergers

1.7.2.1. Pass-through as a tool for translating GUPPI into an illustrative price rise

In recent years there has been growing use by the UK competition authorities of "price pressure tests" in the assessment of horizontal mergers, in particular in retail markets.[43] One such approach uses the "Gross Upward Price Pressure Index" or GUPPI, in conjunction with a firm-specific pass-through rate, to arrive at a so-called "illustrative price rise" (IPR).[44] The intuition underpinning this approach is that the merger creates a cost of cannibalisation (as captured by the GUPPI) that can be thought of as equivalent to an increase in marginal cost. The impact on

[42] Internal documents may reveal information on this point. For example, if a business had historically based its price changes on how its entire cost base (i.e. both fixed and variable) had changed, then this might provide evidence that fixed cost saving would lead to lower prices.

[43] See, for example, Chapter 12 of Parker and Majumdar (2011). See also the RBB Economics report on conjectural variations for the OFT (RBB Economics (2011)). In this report we do not debate the merits or otherwise of using price pressure tests, rather, in line with our remit, we discuss the role of pass-through in those tests. We note, however, that the quality of price predictions obtained using pass-through estimates will be sensitive to the GUPPI estimates used too. As such, the approach depends on the view that the industry in question can suitably be approximated by Bertrand competition. It is also vital that the other inputs required for the test (diversion ratios, prices, and margins) are measured correctly. More generally, these tests do not account for dynamic effects such as product repositioning, new entry and strategic responses by buyers. This suggests that they should be viewed as only one part of a holistic merger assessment.

[44] This was developed by Steven Salop and Serge Moresi as an extension of Farrell and Shapiro (2010). The measures are closely related to Werden (1996).

prices then depends on how, post-merger, this cost change is passed through to prices.[45] Proponents of this approach would argue that it allows an IPR to be derived without having to assume a form of demand, whereas other IPRs require the analyst to presume demand is of a certain type (e.g. linear or isoelastic).[46]

Information on relevant diversion ratios, prices and margins allows a GUPPI to be calculated. Combining this with relevant pass-through information then allows the illustrative price rise to be quantified.[47] An estimate of the *firm-specific* cost pass-through rate is required. In this regard, it is worth noting several points.

First, to the extent that this IPR measure is used as an initial screen (e.g. to assess which products or local markets are worth investigating further), there may not be time to engage in a sophisticated econometric exercise. This suggests that the screen may have to rely on estimates of firm-specific cost pass-through obtained from relatively simple reduced form estimation or from ad hoc examples of price responses to changes in cost in the recent past. The pros and cons of such measures are discussed in the following section on the practicalities of assessing pass-through.[48]

Second, the use of a measure of market-wide cost pass-through as a proxy for firm-specific cost pass-through is likely to overstate the firm-specific rate, though by how much may not be clear. As such, it gives rise to an upper bound for this particular IPR (assuming the market-wide cost pass-through rate and other inputs of the IPR formula to be measured correctly) which may be substantially above the true value.

Third, a merger will typically give rise to simultaneous cost effects for both merging parties. Relevant pass-through rates will generally be affected by both cost changes and by the pricing responses of competitors. In theory, a pass-through measure that does not take account of these influences may understate the magnitude of the overall price effect.

Fourth, where measurement of pass-through is difficult, to assume that pass-through is equal to 100% in the absence of other evidence may be misleading, in particular if there is no reason to suspect that demand is convex. Specifically, pass-through of 100% on an *industry-wide* basis requires demand to be very convex (assuming that the marginal cost schedule is not downward

[45] Two firms, A and B, can be thought of as creating a “cannibalisation cost”, associated with price reductions. Specifically, prior to the merger, if the price of firm A’s product fell, it would win some sales from firm B. Pre-merger, firm A would not be concerned about securing sales at firm B’s expense. However, after the merger, volumes secured by firm A from firm B are cannibalised volumes – volumes won from B are not volumes won for the merged firm as a whole. The cost of cannibalisation is the diversion ratio (here defined to be the percentage of A’s gained volumes that are won from B, when A lowers its price), multiplied by the absolute margin on B’s product (i.e. the margin that would be cannibalised). The absolute pass-through of this cost gives an absolute price rise for product A, which, when converted into a percentage price rise, equals the GUPPI on product A multiplied by A’s firm-specific pass-through rate.

[46] Given the link between the pass-through rate and the form of the demand curve discussed in the theory overview above, it would be erroneous to say that the measure would be entirely free of an assumption about the underlying demand curve.

[47] Other possible screening measures can be employed where the pass-through rate is not known. For example, Werden (1996) proposes compensating marginal cost reduction estimates that are not dependent on the form of demand. If a demand form is assumed, then IPRs may be computed assuming Bertrand competition.

[48] Significantly, difficulties with measuring pass-through in practice may often be closely associated with the challenges of identifying the relevant margin properly (a key input into the GUPPI). For example, the relevant cost to use in the margin calculation is the marginal cost of production, yet this may be hard to measure accurately with accounting data. However, if marginal cost is hard to measure, then so is the relevant pass-through rate.

sloping). If industry-wide pass-through is below 100%, then firm-specific pass-through is likely to be even further below 100%.

Fifth, to the extent that the relevant firm-specific pass-through rates (1) decline relative to the industry-wide pass-through rate as the number of firms “in the market” increases, or (2) are a function of market share (as is the case for a number models discussed in our review of relevant theory), then market definition may assist the competitive analysis by shedding light on these structural determinants of pass-through. Moreover, if filtering rules (such as fascia tests) are adopted which assume a link between the number of firms and competition, then this suggests that a consistent approach to the estimation of pass-through rates should be adopted too.

Sixth, if a high pass-through rate is identified as relevant in relation to estimating the price effects of the cannibalisation costs arising from a merger, then any cost decreases arising from merger efficiencies should also be expected to be passed through at a high rate. (See below.)

1.7.2.2. Pass-through of merger specific efficiency gains in concentrated markets

The relevant economics indicates that efficiency gains might offset any anti-competitive price effects of a merger. However, there may be a temptation to discount the prospect of such efficiency benefits when the market is highly concentrated, on the premise that consumers are unlikely to benefit to a large extent from marginal cost savings in these circumstances. That is, it may be assumed that a monopoly firm, say, is unlikely to pass through cost savings to the prices it charges. The European Commission’s horizontal merger guidelines, for example, observe, at paragraph 84, that:

> *The incentive on the part of the merged entity to pass efficiency gains on to consumers is often related to the existence of competitive pressure from the remaining firm in the market and from potential entry. [...] It is highly unlikely that a merger leading to a market position approaching that of a monopoly, or leading to a similar level of market power, can be declared compatible with the common market on the ground that efficiency gains would be sufficient to counteract its potential anti-competitive effects.*[49]

Our review indicates that this perspective is not supported by basic theory. That theory suggests that even monopolists would pass-through marginal cost savings to prices. Moreover, even if industry-wide cost pass-through is greater in a competitive market than in a monopolised market, this need not be true of the firm-specific cost pass-through rates that are relevant to the pass-through of marginal cost savings arising from mergers or agreements.

Indeed, as set out in the theory review, some important models of competition predict that firm-specific pass-through rates will *decrease* as the number of firms increases; i.e. firm-specific cost pass-through may be higher in concentrated markets than in competitive markets. In these circumstances, substantially greater pass-through of firm-specific efficiencies could arise in

[49] See ‘Guidelines *on the assessment of horizontal mergers under the Council Regulation on the control of concentrations between undertakings’* (2004/C 31/03).

respect of ‘2-to-1’ or ‘3-to-2’ mergers than occurs in competitive markets. This suggests that the potential consumer benefits of claimed cost efficiencies should not be dismissed simply because the firms involved appear to have significant market power.

1.7.3. Pass-through and horizontal agreements

1.7.3.1. Pass-through and the efficiency benefits of horizontal agreements

An agreement which is caught by Article 101(1) TFEU may nevertheless escape prohibition if it generates efficiency benefits which can be taken into account under Article 101(3) TFEU. Similar provisions also apply under domestic UK legislation.

One of the criteria to be considered in this context is the extent to which consumers can expect to benefit from efficiencies; i.e. to what extent will such efficiency benefits be passed through to consumers? Where the efficiencies involved cause a reduction in relevant costs, pass-through estimates may therefore assist in weighing up the overall impact of the agreement. The appropriate pass-through measure would be a firm or group specific measure encompassing one of or all the parties to the agreement.[50]

We note that, as with its horizontal merger guidelines, the EC guidelines on the application of Article 101(3) TFEU, for instance, appear to assume that pass-through will be greater in competitive markets. Thus:

> *The greater the degree of residual competition the more likely it is that individual undertakings will try to increase their sales by passing on cost efficiencies.*[51]

However, as noted in our discussion of merger-specific efficiencies, the preceding statement is not supported by the firm-specific pass-through rate predictions of some important theoretical models. (Intuitively many results appear likely to carry over to cost changes affecting small groups of firms too). In a number of important models - although by no means all of them - as the number of firms increases, firm-specific pass-through declines (i.e. as “residual competition” as measured by the number of other firms in the market increases, firms may have a lower degree of firm-specific cost pass-through). Of course, in such cases, the potential for any agreement to have an anti-competitive effect may well also diminish.

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[50] Alternatively, other techniques may exist that do not require estimating the (firm-specific) pass-through rate. For example, the analyst might consider whether the efficiencies obtained would be sufficient to prevent a full merger between the parties from raising prices. In this case, the agreement would seem likely to be benign. Efficiencies might then be compared with compensating marginal cost reductions, i.e. the reduction in marginal cost sufficient to prevent a merged firm increasing price (before considering any dynamic effects such as entry or product repositioning), to assess the competitive effects of the agreement.

[51] See European Commission Guidelines on the Application of Article 101(3) of the TFEU, para. 97.

1.7.3.2. Pass-through and cartel damages

While not usually an area that competition authorities assess themselves, one notable domain in which pass-through is of interest relates to the assessment of damages following a cartel (or damages claimed from a firm found to have set excessive prices) affecting an upstream market, where the customers of the cartel members have customers of their own.

A claimant would argue that it suffered lower profits due to paying an inflated price set by the cartel. A defendant may advance the passing on defence; that is, it may respond that the claimant passed on the higher input price in its own prices and therefore mitigated the impact on profits of the higher input price. (In principle, the effect may be repeated along the supply chain.) The extent of the pass on may depend on whether the claimant's competitors have also been impacted by the cartel. Put differently, we may draw on the discussion above in relation to firm-specific and industry-wide pass-through to assess the extent to which pass-through of a cartel overcharge (or an excessive price) occurs. Verboven and van Dijk (2009), among others, assesses this issue in detail.[52]

1.7.4. Pass-through and input foreclosure

Turning now to the theme of vertical linkages, pass-through is relevant to the assessment of input foreclosure. The impact of input foreclosure arising from a vertical merger, for example, depends on two effects. First, if the input price is elevated on the upstream market, the effect on the downstream market will depend on the extent to which non-integrated firms will *pass on* this marginal cost increase.[53] Second, a vertical merger may eliminate double marginalisation. This implies that the marginal cost of (what has become) the downstream division of the merged entity will be reduced, which in turn will allow it to reduce prices. The extent of this will be affected by cost *pass-through* too. Ultimately, the net effect on the downstream market will depend on the balance of these two opposing effects, and on the impact of pass-through in each case.

1.7.5. Pass-through of the costs of regulatory intervention

Pass-through is a relevant consideration when competition authorities are contemplating interventions which will result in additional costs for businesses. For example, suppose that an authority introduces an obligation on all firms in a market to provide greater pre-sales service when selling a given product. On the one hand, this would enhance consumers' experience

[52] There are a number of issues that affect the damage claim. These include: (i) whether the cartel gave rise to a firm-specific price rise or whether all downstream firms were affected such that the price rise was akin to an industry-wide price rise (in which case pass-through might be higher); and (ii) the impact on profit of reducing output. Even if a claimant passed on some of the cartel overcharge, it may be that this led to reduced output (such that the claimant lost the margin that it otherwise would have earned, absent the cartel, on a number of units).

[53] The upstream division of the integrated firm may have neither the ability nor the incentive to compete less aggressively. Inter alia, it will consider: (i) the extent to which it could influence the price paid by rivals of its downstream division; (ii) the degree to which a higher price charged to those rivals would be *passed on*; (iii) the extent to which the passed-on price would divert volumes to its downstream division; and (iv) by how much the downstream division would then benefit. The lower the degree of pass-through, the less effective is the mechanism by which sales can be diverted to the downstream division and hence the weaker the incentive for input foreclosure other things equal.

when purchasing the product. On the other, this would amount to an industry-wide cost change and so could be expected to give rise to higher prices. When weighing up the pros and cons of the intervention, the extent of pass-through would be a relevant consideration.

Provided that demand is not too convex, greater pass-through might be expected in more competitive market environments. By the same token, the extent of market-wide pass-through might be less in more concentrated markets, such that a greater share of the cost of regulation would be borne by producers.

Further, surprising as it may sound, an industry-wide increase in marginal cost may lead to *higher* firm profits, where demand is sufficiently convex. Specifically, where pass-through exceeds 1, a cost addition would be "over-shifted" to consumers. If demand falls away slowly enough as price increases, overall profits may rise due to the reduction in output being offset by the higher margin.[54] In theory, an industry might be incentivised to lobby for intervention which resulted in an industry-wide increase in marginal costs, therefore.[55]

1.8. Practical suggestions on obtaining and interpreting pass-through evidence

As indicated above, consideration of pass-through is potentially relevant to a wide range of competition issues. It follows that, where appropriate, authorities and practitioners are likely to want to gather and evaluate evidence on the extent of relevant pass-through rates in practice in order to inform their competition assessments. At the same time, pass-through can only represent one aspect of the assessment process. Moreover, the estimation of pass-through rates cannot take place in a vacuum. The practitioner must take account of the relevant market and competition context in identifying, analysing, and interpreting pass-through evidence.

In this section, we consider some of the practical issues that an authority or practitioner is likely to face in this respect. In practice, the process of obtaining and interpreting pass-through evidence requires either that a measure of demand curvature is obtained, from which a pass-through rate may be inferred (assuming a specific model on the supply side, including the intensity of competition) or else pass-through is measured directly. The latter will involve the following steps:

- Identifying relevant measures of cost (and price).
- Estimating the pass-through relationships (e.g. via qualitative or econometric techniques).
- Drawing appropriate inferences from the pass-through evidence obtained.

[54] Mason (2002) highlights this feature and how it may facilitate coordination. He also explains that in a dynamic setting, there is greater scope for coordinated cost raising strategies to dampen competition. He argues that the critical issue is the degree to which suffering higher costs in the first time period gives rise to benefits for participating firms (e.g. dampened competition) in the second period.

[55] Of course, there are many other reasons why such lobbying might occur too.

We address these issues in this section. Before so-doing, however, we would highlight an important aspect of demand curvature – namely that it is of considerable importance as regards the degree of pass-through but at the same time extremely difficult to measure in practice.

Having considered the implications of this (unfortunate but fundamental) issue, we go on to consider the practicalities of identifying relevant measures of cost and price and the several ways in which pass-through rates may be estimated (together with their pros and cons).

Given the potential sensitivity of pass-through rates to the details of the particular context in which they arise, it is important to gather information that is pertinent to the specific situation being investigated and to be aware of potential biases and sensitivities in any pass-through estimates that are derived. Regardless of the approach adopted for estimating pass-through rates, proper account must be taken of the quality of the information used as well as the robustness of the estimates obtained.

1.8.1. A note on the implication of the difficulty in practice of identifying curvature

A key insight from the theory reviewed in this study is that, outside of perfect competition (a theoretical ideal that is rarely, if ever, a feature of industries that are subject to competition policy interest), a critical determinant of pass-through is the "curvature" of demand, i.e. the degree to which demand becomes more (or less) price sensitive as the price increases. Theory also predicts that the shape of the marginal cost schedule also impacts on pass-through (see below).

Unfortunately the curvature of demand is difficult to estimate empirically (although some recent advances have been made - as discussed in Chapter 7 and also below), especially given the time and data that are likely to be available in the context of many competition investigations. An important question is therefore: to what extent can reliable inferences be made about the degree of curvature absent complex econometric estimation?

Some authors have argued that very convex demand is unlikely to arise in practice.[56] However, we have not identified a strong theoretical or empirical reason for a prior belief that convex demand is unlikely. Ultimately, the shape of demand for a given product is related to the aggregation of individual consumer willingness to pay for that product. Because of consumer heterogeneity, an individual consumer's elasticity of demand may vary due to differences in consumer characteristics, such as income level, as well as other factors, such as social and cultural factors. Not only are these features often difficult to observe, it is not clear how they would necessarily impact on the curvature of the demand curve as the following examples illustrate.

On the one hand, if high income consumers are less price sensitive than low income consumers, and if the latter "drop out" (i.e. stop purchasing a product) before the former as prices increase, then it may be that disproportionately more demand at higher prices is

[56] Stennek and Verboven (2001) argues that demand would rarely be convex enough to give rise to overshooting when marginal costs are constant, for example.

accounted for by price insensitive consumers. In that case, market demand may become more insensitive to price as price increases.

On the other hand, the distribution of consumer preferences for a product may be such that increasing numbers of customers will switch away from that product in response to successive price increments, as its price approaches that of a close alternative. A large proportion of customers may switch once price exceeds the price of the alternative. In this case, aggregate demand for the product will become more price sensitive as price increases.

If the practitioner has detailed knowledge of the likely distribution of willingness-to-pay for the marginal consumer of the product in question, it may be possible to make a rough inference about the shape of a demand curve.[57] Unfortunately, as the preceding examples demonstrate, drawing strong inferences about the shape of demand from observable characteristics is not necessarily straightforward.

In principle, if we have evidence on cost pass-through, we could draw inferences about the curvature of demand. If, for example, we observed that a firm had maintained a constant percentage margin in the face of marked changes in its marginal costs, we might infer that inverse demand is convex and that the firm faces an isoelastic demand curve. However, in order to be sure about the curvature of demand in this case, we would also need to be confident that we had measured precisely the firm's marginal cost, how marginal cost changed over time and how this change had been passed through to price.[58]

In practice, pass-through rates may be measured from one set of evidence (say internal documents such as board presentations, feedback from sales force, etc.) whilst estimates of the curvature of demand may be obtained using more complex econometric approaches. To the extent that independent measures of pass-through and curvature are available, it would make sense to check that both measures are consistent, and when they are not, it will be productive to understand the source of the discrepancies, as these may shed further light on which pass-through measure is the most relevant.[59]

The extent to which firms pass through the effects of vertical shifts in inverse demand provides another possible source of information on demand curvature. For example, in a quantity setting context, a downwards shift in the demand curve should have the same effect as an equivalent upward shift in marginal cost.[60] As with empirical estimates of cost pass-through, identifying vertical shifts in demand separately from other influences on price may be difficult in practice.

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[57] Weyl and Fabinger (2012) notes that if consumer willingness-to-pay is proportional to income then their measure of curvature ($\frac{1}{\varepsilon_{ms}}$) corresponds to the curvature properties of income distributions in the segment of the population representing the marginal consumer of the product.

[58] Similarly (in relation to inferring curvature from pass-through), a practitioner may have evidence that pass-through decreased following a regulatory or other market change that increased the intensity of competition. This might indicate that demand was very convex (since an intensification of competition might otherwise be expected to increase the pass-through rate).

[59] For example, if an empirical estimate indicated concave demand yet we identified firms maintaining constant percentage margins (implying a form of convex demand), this should lead us to query either the measure of demand, the measure of the margin or the theoretical assumption on firm behaviour (e.g. perhaps firms maintain a constant margin as a rule of thumb even though it would be profit maximising to employ a non-constant margin) or perhaps the mode of firm behaviour was not constant.

[60] To see this, consider an inverse demand curve $P(Q)$. Assume a firm chooses output, q and has constant marginal cost, c. In this case, in a quantity setting game, the first order condition is: $P(Q) + qP'(Q) - c = 0$. Now consider inverse demand with a vertical shift

1.8.2. Identifying relevant measures of cost (and price)

A first step in estimating pass-through rates will be to identify sources of relevant data.[61] Most obviously this means data in respect of costs and prices, though in some cases cost estimates may also be *derived* as part of an estimation process which utilises other market information (see below). The quality of the pass-through estimates obtained, and the interpretation and evaluation of those results, will ultimately depend on the characteristics of the underlying data. It is essential, therefore, to obtain a clear understanding of what these data measure, and the context in which they have been generated.

Relevant measures of cost

It is important to establish which of a firm's costs are liable to affect prices, and are therefore relevant to the pass-through relationship, and to gather sufficient data to allow the pass-through relationship to be tested.

As noted, textbook economic models emphasise the key influence of short-run marginal costs, i.e. the extra costs associated with supplying an incremental unit of a product or service, on firms' pricing decisions.[62] However, the pricing behaviour of firms in practice may also take into account longer run considerations, such as the recovery of fixed-cost investments. Moreover, even where a measure of marginal costs would be relevant to the analysis, data providing such a measure are unlikely to be available. (In reality, firms do not record data on this basis.) As a result, it may not be possible to observe or construct a measure of such costs, except in very particular situations.

Instead, accounting estimates for average variable cost (AVC) are often used as a proxy for marginal cost. However, there are potential problems with this approach.

First, it is not always clear that accounting cost will reflect relevant economic cost.[63]

Second, in theory, unless the marginal cost schedule is flat, using an AVC proxy for marginal cost may be misleading since it may substantially understate (or overstate):

- the slope of the marginal cost schedule. Where that schedule slopes upwards (downwards), it diminishes (augments) pass-through, other things being equal; and
- the change in level of marginal cost.

Third, and importantly, the level of variable costs will depend on the time frame that is considered. The longer that time frame, the greater the proportion of costs that are likely to be

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equal to t. $F(Q) = t + P(Q)$. The first order condition is now: $P(Q) + qP'(Q) - c + t = 0$. It can be seen that the pass-through of a vertical shift downwards in demand is the same as the pass-through of a vertical shift *upwards* in marginal cost.

[61] An alternative approach is to infer pass-through from a calibrated theoretical model. This would require: (i) an estimated demand function with flexibility to capture curvature; (ii) an estimated or assumed marginal cost schedule; and (iii) an assumed form of competitive interaction (e.g. Bertrand price setting).

[62] The theoretical relevance of marginal costs to pass-through relationships is apparent in the relevant chapters of this study. An upward sloping marginal cost schedule would be expected to diminish pass-through, all else equal.

[63] For example, if the market price of an input changes after it has been purchased, the opportunity cost of that input changes and with it the economic measure of marginal cost but the accounting measure of average variable cost may not.

variable.[64] Hence, careful consideration of the time frame that is relevant to the pricing decision may well be required. Information on the frequency of price changes, and the decision-making processes giving rise to such changes, may be useful in reaching an informed view on this issue. A firm's internal documents may offer a valuable source of information in this respect. For example, a manufacturer may discuss at board level the extent to which a recent cost shock will be translated to retail prices.

More substantively, it may be important to consider (and, where possible, evaluate) whether a wider array of costs may actually affect pricing decisions in the specific context of a particular case. For example, while the literature focuses on the pass-through of marginal costs, as noted above, fixed costs may also be passed on to some degree. While a case-by-case assessment is required, some evidence indicates that firms take fixed costs into account when setting prices.[65] For example, firms may sometimes invest in marketing (or training) on a continuous basis, in order to maintain their brand and reputation, as well as (in the case of marketing) to advertise changes in its offer. In the absence of such expenditure, the firms' sales may diminish significantly and in turn affect their pricing decisions. It is standard practice to consider such marketing costs as fixed, sunk costs which do not affect pricing decisions. However, this approach may fail to capture the realities of pricing in some cases, such as where the prices are set to cover these frequent marketing expenditures. More generally, when setting a pricing target for the coming year, a firm may forecast volumes over the next 12 months and seek to recover expected changes in its entire cost base (i.e. fixed plus variable costs) such that (expected) increases or reductions in fixed cost per unit have some impact on its prices.

In principle, therefore, the practitioner would want to keep an open-mind in respect of the nature of the relationship between particular cost categories and prices. The preceding examples indicate that the relationship between costs and prices may be quite complex in practice. Where possible, rather than making strong assumptions based on a theoretical prior belief (e.g. that fixed costs do not get passed on), it would be informative to test empirically or assess via documentary evidence whether fixed cost variations have impacted the price level.

When giving weight to any measure of pass-through, it is helpful to be aware of any potential margin for error and, if possible, the direction of the potential bias. For example, where the changes in costs used for the pass-through estimation are overstated (respectively, understated), the pass-through rate will be underestimated (respectively, overstated), all else being equal. For example, if a £1 cost change causes a £1 price change, the true pass-through equals 100%. If the cost change was understated (say, £0.50) then pass-through would be overstated (equal to 200%), whereas if the cost change was overstated (say, £2) then pass-through would be understated (i.e. 50%).

Establishing the quantitative significance of relevant cost changes

Even a substantial percentage change in the cost of a given input may imply only a small absolute change in a firm's overall marginal costs of supply and, as a result, may have a limited

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[64] As Katz and Shelanksi (2007) states: "[I]t is important to remember that over a long enough time horizon, everything is variable."

[65] Shim and Sudit (1995) reports survey evidence that 69.5% of 600 US manufacturing firms made pricing decisions based on full costs. In an earlier study, Govindarajan and Anthony (1983) concludes from survey evidence that most Fortune 500 companies base their pricing on average costs, not just marginal costs. Lucas (2003) conducts an econometric study, concluding that it is unresolved whether full cost pricing is the best explanation for how firms set prices.

impact on prices. In order to draw meaningful conclusions from any estimates of pass-through rates derived using such data, it will be important to establish, in absolute terms, the impact of a given proportionate change in the costs of the input in question on the firm's relevant costs of supply.[66]

As an illustration, suppose that in the context of a merger review, a party submits that its prices had increased modestly (say 2%) over the previous year despite a significant increase (say 20%) in the price of a critical raw material. In order to evaluate this evidence, one would want to establish the impact that the change in the raw material price had had on the relevant costs of the firm. For instance, if the raw material in question accounts for 20% of all relevant costs, this implies that the implied percentage change in those relevant costs will be just 4%. Judged on that basis, the observed price increase will indicate a more substantial pass-through than initially suggested.

It may also be relevant to gain an understanding of the absolute pass-through involved. Suppose that before the price increase in question, the raw material input cost was £5 for each unit of the final input supplied, compared with a selling price for the product of £40. In this case, drawing on the example above, the 20% increase in relevant raw material costs would represent a cost change of £1 per unit, whilst the observed 2% price change equals £0.80, implying an absolute pass-through rate of 80%.

Distinguishing firm-specific from industry-wide cost changes

As noted above, and considered in detail in the following chapters of this study, the distinction between pass-through of firm-specific cost changes and pass-through of industry-wide cost changes is potentially critical to the competition assessment. It follows that it will be important to establish whether an estimated pass-through rate relates to firm-specific or industry-wide cost changes (as well as to establish which pass-through measure is relevant to the case in hand). In turn, this implies a need to establish whether cost changes are firm-specific or industry-wide as part of the estimation process.[67]

It may be possible to make some progress on this issue by considering the source of the cost change. For example, the cost changes in question may clearly arise in respect of factors that are likely to have a common effect on many firms, such as movements in the oil price or the price of an essential input employed by all firms in the industry. Even in such cases it will be important to take account of whether firms have different strategies as regards sourcing the common input, e.g. different hedging strategies or approaches to long term contracts with fixed prices which may give rise to firm-specific reactions to industry-wide effects as well as common industry-wide effects. In other cases, it may be possible to identify a cost change as very specific to an individual firm, e.g. where the cost change relates to a technology that is used only by the firm in question.

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[66] This is an essential point when seeking to draw inferences from the empirical literature (which focuses on pass-through elasticities), as discussed in Chapter 7.

[67] See, *Shell/Rontec* for a discussion of industry-wide and firm-specific pass-through in the context of a GUPPI analysis. Pass-through is discussed at paragraphs 89-97: http://www.oft.gov.uk/shared_oft/mergers_ea02/2012/shell.pdf. Industry-wide pass-through was estimated by the parties; the OFT reviewed this analysis and considered industry-wide cost pass-through unlikely to be in excess of 100%. The OFT cautiously adopted 100% as its estimate for *firm-specific* pass-through (see, e.g. paragraph 101).

Consideration of this issue is likely to vary from case to case. On the one hand, whether the cost change that is relevant to the competition assessment is more or less firm-specific will depend on the competition matter – e.g. a merger case (where pass-through of cost changes simultaneously affecting each of the merging parties is relevant), or a cartel damages case involving an input used by a significant sub-set of all producers (where group- or industry-wide pass-through would be more relevant). On the other hand, cost changes that are firm-specific in one setting may not be in another. For example, in one market all the imports from a specific country may relate to one particular brand. In that case, changes in the relevant exchange rate may provide insight into the effects of firm-specific cost changes. In another market, however, the products of several suppliers may be imported from a single country. In this case, the effects of changes in the relevant exchange rate are likely to be relevant to all those products and their suppliers (i.e. a group-specific effect).

If the practitioner has information on the costs of competitors, it may also be possible to use this information to identify and separate out movements in costs that are common to all firms, or to control for such cost variations by including such cost data in any econometric analysis.

Delayed pass-through

In general, it will be important to consider too whether the price effects of cost changes are likely to take a while to materialise and, as a result, whether the full pass-through effect of a cost change are only likely to be observed with a delay. It follows that, in terms of obtaining data for the evaluation of a pass-through relationship between cost and price changes, it would be important to ensure that the pricing data obtained allows the full relationship with costs to be identified.

For example, a cost shock that affects an upstream stage in the supply chain may take time to filter down to retail prices, even if substantial pass-through would ultimately occur. Estimates of pass-through that do not take account of such lags may lead to an understatement of the eventual cost pass-through effect. Moreover, if too short a time frame is adopted for the analysis, it may also fail to distinguish between temporary and permanent differences in the extent of pass-through to wholesale and retail levels.

The desire for a firm to wait to see if a cost shock is likely to be permanent or if it will be counterbalanced by opposite movements provides another reason for possible delay in passing through the impact of the cost change to prices, especially if any price adjustment would be costly.[68] Intuitively, where adjustment costs are large and shocks are small, delayed pass-through may be more likely. In fact, when cost changes are each very small, firms may wait until the cumulative change reaches a certain threshold before they make any price adjustments. In this case, a comparison of contemporaneous changes in costs and prices may yield very different measures of pass-through depending on whether the comparison is made at a point where a price adjustment is implemented (indicating *relatively* high pass-through), or at a point where prices are not adjusted (indicating no pass-through).

[68] As explained above, a firm may incur menu costs if it changes its prices, e.g. because this requires it to undertake some activities to communicate the new price change to customers or must go through the effort of negotiating with its customer a new contract. This will reduce the firm's incentive to adjust prices if the cost change is small.

Similarly, in some industries, firms rely on inputs that experience large price fluctuations. These firms may seek to hedge their positions against such volatility by purchasing future contracts or lock-in a given price with a long term contract. In this case the actual change in the input price is unlikely to have any contemporaneous material impact on prices. Firms may consider adjusting prices only after prices on the future market have changed or after their long-term contracts have expired.

A related issue arises in relation to the direction of the cost change. While the practitioner may be interested in the effect of a marginal cost increase, she may only have information about past reductions in cost with which to predict the price effects of this cost increase. A consideration here would be the extent to which there are sufficient good reasons to expect the speed of pass-through to be greater when passing on cost increases than cost decreases.

Finally, the impact of delayed pass-through can be set in the context of the time period normally used to assess the competitive effects of the type of case in hand. For example, if an efficiency benefit for final consumers would take one year to materialise due to delayed pass-through, there would nonetheless be scope to take this into account if the competitive effects of a merger were assessed over a two year period.

1.8.3. Different approaches to measuring/estimating pass-through

In what follows we consider in more detail alternative approaches to estimating cost pass-through rates, identifying some of the issues that pertain to implementing each of those approaches and interpreting the results that are generated. Specifically, we consider three different approaches, namely:

- Qualitative assessment: this refers to a situation in which the pass-through rate is inferred either from documentary evidence, other testimony and/or examples of cost shocks for which there is limited scope for detailed empirical analysis.

- Non-structural econometric methods: this refers to the case when the practitioner has gathered enough data to estimate a statistical relationship between cost and price variation. This may involve a reduced-form approach which seeks to identify the extent to which price changes can be explained by cost changes, after controlling for other potential confounding influences on price.

- Structural econometrics combined with counterfactual simulations: this refers to the case where the practitioner would estimate a structural model of an (oligopolistic) market and then use the estimates to develop counterfactual scenarios, whereby costs (and potentially other factors) are changed, and the impact on equilibrium prices is computed given certain theoretical assumptions about firm behaviour.

It should be stressed at the outset that the feasibility of each of these alternative approaches is liable to depend on the time, resources and information available.

1.8.4. Conducting a qualitative assessment

In many cases, the practitioner may not have access to sufficient information/data or resources or time to undertake the types of econometric analyses that we review in this study, let alone to perform any counterfactual simulation. As a consequence, she may have to rely on limited information about the effects of past changes in the costs of a firm, focusing on the consequences of particular, significant events (a sharp rise in a given input, for example). Alternatively, she may have to rely on drawing broad inferences regarding pass-through rates from firms' and customers' testimonies, or using information from internal documentation to establish indicative values (or ranges of values) for pass-through rates.

This section discusses a number of considerations that apply when conducting a qualitative assessment of pass-through.

Controlling for other influences on price

One major challenge posed by the qualitative approach is the need to control effectively for other influences affecting prices, as prices are likely to be determined not only by changes in costs but also by other factors affecting market conditions. As a result, any estimator that fails to take adequate account of confounding factors risks bias, as the impact of these other factors may mask the actual relationship between price and costs.

To illustrate, suppose that in the course of an investigation of Firm A's conduct, an estimate of (firm-specific) cost pass-through is obtained for it. In this example, suppose further that the estimate draws on data that relate to a period in which one of Firm A's major competitors (Firm B) had to recall a substitute product, thereby causing demand formerly placed with Firm B to spill over (in part) to Firm A, as well as to other firms with which Firm A competes. If this temporary reduction of capacity by Firm B caused Firm A's price to increase, then this "demand" effect would make it harder to discern the 'true' pass-through of the firm-specific cost shock affecting Firm A. For example, if Firm A experienced a cost reduction, the additional 'demand' effect may offset the incentive to lower price and so pass-through would be understated. If Firm A faced a cost increase, the demand effect would accentuate the shock and pass-through might be overstated. Nevertheless, even if the two effects on prices cannot be separated with precision, the directional influence on price of the "demand" effect may be known, in which case the estimated pass-through rate may at least provide a relevant bound on the true pass-through rate.

Interpreting pass-through rates

In discussing the choice and measurement of relevant cost data, above, we offered an example where a firm submitted that its prices had increased by only 2% over the previous year despite a 20% increase in the price of a critical raw material. We noted there that simplistic use of this cost information could lead to inappropriate inferences regarding the extent of (absolute) pass-through. Specifically, it would be erroneous to conclude, on the basis of that single piece of information, that the absolute pass-through rate is substantially below 1 (i.e. 2%/20%=0.1).

The implications of curvature for drawing inferences from historic measures of pass-through

The practitioner may have information on the effects of past cost changes ("historic estimates"). Suppose for example that the practitioner has information regarding a single event when a change in input prices affected the entire industry. Consider, for example, that the government imposes a new unit tax of £10, which results in prices going up by £5. In this case, the industry-wide pass-through rate is 0.5. However, suppose that for the purpose of an investigation, relevant changes in unit cost are of the order of £1 and the current price level is substantially higher than that which prevailed when the tax was imposed. Can the practitioner simply assume that the pass-through rate will be 0.5 for this cost change too, and that as a result price can be expected to increase by around £0.50?

First, as indicated already above, if the relevant cost change is firm-specific, the industry-wide pass-through rate observed may provide at best a reasonable upper bound estimate of the relevant pass-through rate.[69] Put differently, one might conclude that the pass-through rate should not be more than 50%, but it may be substantially less than this.

Second, estimates of pass-through obtained at one point on the demand curve or for a given size cost shock may not provide good estimates of pass-through rates at different points on the demand curve or for different size cost shocks unless pass-through rates are constant. In such cases, a 'historic' estimate may not be a good estimate for the effect of a different cost change which occurs in a different context.

However, in practice measuring precisely how pass-through differs according to the size of the shock and the level of price is unlikely to be straightforward. This raises an important question. Given the difficulty in measuring how pass-through varies along the demand curve, how much faith can one have using one pass-through estimate as a proxy for pass-through by the same firm, in the same industry, but at a different price level or for a different size shock? If the curvature of demand is unknown then this does not mean that we cannot use the existing estimate. Instead, the practitioner might proceed by: (i) assessing the validity of the original estimate; (ii) noting that even if the original estimate were correct, there remains a risk that the estimate would nonetheless over- or understate pass-through of a different size shock or at a different point on the demand curve (unless the demand curve gives rise to constant pass-through); (iii) assessing whether over- or understated pass-through is likely given the available evidence. In this regard we would note that some recent simulation results, reported by Miller et al. (2013), indicate that pre-change pass-through rates may act as a relatively good approximation for post-shock pass-through rates compared with some restrictive but commonly employed demand forms.[70]

Points (i)-(iii) also apply in relation to the shape of marginal cost. It is not just the curvature of demand that may impact on pass-through; the percentage change in marginal cost as output changes may also impact on the extent to which the pass-through rate differs at different levels of price (and hence output).[71]

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[69] It will be important to assess whether there are other key dimensions of competition that could mean that the industry-wide cost pass-through rate is below the firm-specific cost pass-through rate.

[70] See Chapter 9. The type of shock matters too, i.e. whether one is considering the impact of a vertical shift in marginal cost or a merger (in the latter case, the first order approximation for the impact of the shock may be more complex than in the former case).

[71] Regarding (iii), we note that the simulations considered by Miller et al. (2013) assume constant marginal cost and so the reported simulation findings do not apply to non-constant marginal cost schedules.

Third, the more distant in time the events to which this evidence relates, the less appropriate a historic estimate may be for an assessment of current or forward-looking pass-through rates. For example, consumer preferences may have evolved, and so the shape of the demand curve may no longer be comparable with that which prevailed in the past. Equally, market conditions may not have changed significantly, in which case historic estimates may provide reasonable estimates of pass-through rates in the current period (conditional on the caveats set out immediately above).

1.8.5. Using econometric methods

In some cases, the practitioner may have access to sufficient cost and price data at the industry level and/or the firm level to contemplate estimating the pass-through rate using econometric techniques. This section discusses two approaches – the reduced form approach and the structural approach, where the latter can be used to simulate the impact of cost shocks.

Reduced-form approach

The reduced-form approach consists of setting up a regression model in which price - the dependent variable - is included “on the left hand side”, whilst cost factors and other explanatory factors, such as demand variables, are included “on the right hand side.[72] For example, the price of the product at issue may be regressed on measures of cost, but also on demand factors such as seasonality, or variables that control for changes in the competitive environment. In general, the choice of explanatory variables in the reduced-form model must be motivated by (and hence consistent with) economic theory.

However, the interpretation of the model parameters in this case may not always be straightforward. That is, the parameter estimate of a variable may be a mix of demand side and supply side effects. For example, to explain price variation across products supplied in the same market, the practitioner may include product characteristics as explanatory variables. However, these characteristics are liable to affect both demand for the product and the cost of supply. In the reduced form model, the coefficient estimate for product characteristics will then reflect both the demand and cost effects on price. This need not undermine the value of the exercise. However, the practitioner will need to be careful to set out the model specification clearly, so as to ensure that the pass-through rate is identified correctly from the results. For example, if the practitioner seeks to estimate firm-specific pass-through, she may have to consider including variables that control also for industry-wide change in costs. Otherwise, relevant coefficients may also capture information about industry-wide pass-through.

If cost data are available, the practitioner may seek to estimate the relationship between price and cost. The details of the model will depend on the nature and the availability of data. In general, depending on the dataset, the model may be estimated using a number of different types of econometric techniques. We distinguish data samples as follows.

[72] For an introduction to regression analysis see, for example, Jeffrey Woolridge *Introductory Econometrics: A Modern Approach*, 5th Edition.

- Cross-section: the practitioner has data on price and cost for several products or firms during the same period.

- Time-series: the practitioner has data on price and cost for one product or one firm over several periods.

- Panel-data: the practitioner has data on price and cost for several products over time.

Below we present some of the practical considerations that may be relevant when estimating pass-through using a reduced-form approach. These may apply to structural empirical work that is described further below, but in this area, these issues have hardly been highlighted.

- The practitioner may have access to relatively high frequency (e.g. monthly) time series data. Whether aggregating the data may cause a loss of important information, thereby masking a pass-through relationship (or not), is an important consideration. For example, if costs and prices change frequently, then aggregating the data may either mask these changes or reduce the number of observations so that the practitioner is no longer able to estimate a significant relationship. On the other hand, in some cases, aggregating may also eliminate noise in the data, thereby allowing the practitioner to uncover meaningful correlation.

- When the practitioner has high frequency data, she may consider adopting a dynamic model to account for delay in pass-through. Such a dynamic model would allow the practitioner to estimate the time it takes for price to adjust to cost changes. In particular, the regression could yield an estimate of short run and long run pass-through rates.

- Furthermore, in the presence of menu costs, a firm may not pass-through small cost changes. In fact, the firm may only adjust prices when cumulative changes reach a certain threshold. In this context, the practitioner may set up a regression model that relates price variation to cumulative changes in cost.

In general, the most suitable econometric technique will depend on the types of data available. It is beyond our remit to discuss aspects pertaining to the choice of econometric estimator in this study.

Reduced form estimation: pros and cons

Some advantages and disadvantages of using a reduced-form approach are as follows:

- A reduced form regression may be estimated using a limited data set. That is, the practitioner may regress prices on the relevant cost variables, while accounting for some of the confounding factors using fixed-effects. Unlike a qualitative assessment, this approach may control for other influences on prices that could mask the relationship between price and cost.

- The functional form adopted for the reduced-form regression may play an important role. In general, because it is easier to estimate, reduced form regressions typically use a (log) linear specification. With the linear in levels specification, the absolute pass-through is forced to be constant whereas with the log-linear specification, the pass-through elasticity is restricted to be constant. This may be too restrictive in practice. The practitioner may, therefore, want to consider using non-linear functional forms, e.g. by incorporating a quadratic term.

- A reduced-form model may suffer from endogeneity issues that would bias estimates. For example, the practitioner may need to pay attention to the following issues.

  – There is always the risk that the practitioner does not have enough information to control for all relevant factors that impact prices, but which may also be correlated with cost. If a panel dataset is available, the practitioner can use a fixed-effects estimator, which may alleviate some of this concern.

  – In oligopoly markets, in principle, firms will react to their competitors' price adjustments to cost changes. However, a reduced-form approach will not capture these competitive interactions. As a result, it may generate biased estimates.

- Although the issues presented above may affect some reduced-form analyses, it might be possible to alleviate some of these difficulties in practice. For example, the practitioner may seek to use a 'control group' or 'test market' to assess the impact of cost changes on price. That is, if data are available for other, similar, markets which have not experienced any cost changes, these may be used as benchmarks to assess pass-through rates. Ideally, this approach would eliminate concerns about omitted variables as well as other endogeneity issues related to competitors' adjustments, for example.

Structural model estimation and simulation techniques

In some cases, the practitioner may seek to develop a structural model of a market in order to simulate counterfactual scenarios to evaluate the pass-through of cost changes. Specifically, the simulation consists of altering the marginal cost of one or all firms and computing the new equilibrium price given an assumption about the theoretical model that governs industry behaviour. The difference in equilibrium price gives the pass-through rate.

To develop this analysis, the practitioner builds a structural model that supposes, in particular, a certain level of competition, as well as the dimensions on which firms compete (price, quantity or other non-price dimensions). The practitioner also has to make assumptions about cost structures. Typically, firms are assumed to have constant marginal costs. Finally, the practitioner must account for consumer behaviour, in particular how consumers react to price changes. This requires the specification of a demand function (or a set of functions in differentiated products markets).

Obviously, no structural economic model can replicate perfectly the real world. Nevertheless, the simulation model should be constructed in such a way that it takes into account the most significant features that affect the supply level (cost conditions and competitive interaction) and demand conditions (in particular, the extent to which customers respond to price changes). Structural models can be used to predict the outcome of market interactions, for example, the likely price or production levels. As a result, the practitioner can test them to check whether they are able to replicate observed market outcomes.

However, and importantly, a structural model based on overly restrictive assumptions, in particular about consumer behaviour, may yield misleading estimates of pass-through rates. As explained above, the shape of the demand curve plays a critical role in this respect. As a result, when the practitioner assumes a specific functional form for consumer demand, this assumption, rather than data, also determines to a large extent the pass-through rate.[73] Though the structural model may be calibrated with the current market outcome, any simulation that seeks to assess how changes in cost affect equilibrium prices, may turn out to be misleading.

In applied econometric work, there is a critical trade-off between, on the one hand, the ease of estimating a demand system in differentiated products markets and, on the other hand, the need to adopt simplifying assumptions that restrict the characterisation of consumer behaviour in order to do so. This trade-off is the result of what is termed, the curse of dimensionality, which is to say that the number of parameters to be estimated cannot be too large, given the data available for estimation. For example, in a 10-product market, there are 100 different elasticities to estimate in principle. The dimensionality of the problem can be overcome by making assumptions that reduce the number of different parameters that must be estimated. However, in some cases these assumptions restrict consumer substitution patterns to the point of generating unrealistic predictions.

To illustrate: in the multinomial logit model, substitution between products is assumed to be proportional to market shares, which can be misleading when conducting counterfactual simulations. In addition, the pass-through rate depends entirely on the assumed functional form for demand. In contrast, the random coefficient logit model does not suffer from such a drawback. Instead, in aggregate, consumer substitution hinges on consumer heterogeneity, that is, on consumer characteristics. Consumers of certain products may share many similarities with consumers of other products, and as a result these products may be closer substitutes, all else being equal. Importantly, in the random coefficient logit model, the pass-through is not the result of functional form. Instead, the first and second derivatives of demand, which determine the pass-through rate, are estimated.

The practitioner may use the parameter estimates as well as price observations to calibrate the assumed model of oligopolistic interaction (in differentiated products markets, Nash-Bertrand price competition is usually the preferred model). The first order conditions for profit maximisation can then be used to obtain estimates of firms' marginal costs.[74]

Finally, the last step consists of simulating the effect of a change in marginal cost on equilibrium prices. The difference in equilibrium price before and after the cost change gives the predicted

[73] For example, in the context of implementing IPRs, assuming a linear or an isoelastic demand curve may yield vastly different price increase. The isoelastic curve is cost-amplifying, hence, for the same level of margin and diversion ratio, the IPR is much higher than in the case of a linear demand curve. See RBB Economics: *The Joint OFT/CC Commentary on Retail Mergers: FAQ*, November 2011.

[74] If there is enough data to specify a marginal cost function, the pricing equation derived from the firms' first-order conditions can be also jointly estimated with demand. See for example Berry et al. (1995), which specifies marginal cost as a function of product characteristics.

price adjustment. Note that this approach can be used to simulate the effect of a firm-specific or an industry-wide change in marginal cost.

Structural model estimation and simulation techniques: pros and cons

One apparent advantage of the structural approach is that the practitioner does not need data on marginal cost, which are typically difficult to gather given (as discussed above) that accounting costs may not provide a good measure of economic marginal cost. The marginal cost estimates are determined by: the estimated demand parameters; the assumption about firms' conduct; and the assumed shape of the marginal cost function (which is typically assumed to be constant in quantity produced).[75]

The marginal cost estimate therefore hinges on the model's assumptions. If the demand model fails to capture consumer behaviour accurately or if the assumptions adopted regarding firms' conduct are unrealistic, then the marginal cost estimate will be erroneous. For example, if the model assumes that firms compete but they actually collude in reality, the estimated marginal cost will be overstated. That is, because the firms' mark-ups are lower under the Nash-Bertrand competition than under collusive conduct; as a result, using the Nash-Bertrand first-order conditions predicts a higher marginal cost (for a given observed price level). One way to address the conduct assumption issue is to actually test whether the supposed conduct fits the data.[76]

Moreover, typically the assumed structural model is static in nature. This implies that market developments that have some bearing on firm's pricing behaviour may not be taken into account. For example, existing competitors may reposition their products, or expand capacity; new products may be launched.

In sum, the outcome of such simulation must be weighed appropriately against other evidence, in particular light of other key aspects of the competitive interaction that are not included in the model.

Imposing restrictions on the curvature of demand

As indicated in this study, the shape of the demand curve is a critical factor determining the extent of cost pass-through. Therefore, ideally, the practitioner would not employ a structural model in which the functional form of the demand system effectively determines the pass-through rate. Though these models are relatively easy to estimate or calibrate, the simplifying assumptions may be too restrictive given the task in hand. As a result, the practitioner risks imposing severe, untested restrictions on the very relationships that are being investigated. Where possible, therefore, and where time and data permit, it is advantageous to use a less restrictive model, such as the random coefficient logit model.

[75] This assumption is not innocuous in the present context, given that the slope of the marginal cost curve will affect the magnitude of pass-through

[76] See, for example, Chapter 3 of the RBB study for the OFT on conjectural variations and competition policy (RBB Economics (2011)).

With a rich dataset, is a pass-through estimate needed?

It is helpful to bear in mind the ultimate aim of the competitive assessment. The goal is usually not to obtain a pass-through estimate, per se. On the contrary, pass-through is merely a tool to assess the competition question at hand.

For example, if the practitioner plans to use the structural model to simulate a pass-through rate to assess the competitive effects of a merger, the structural model may just as well be used more directly to simulate the effect of the merger. Instead of developing counterfactual simulations about a marginal cost change, the practitioner can compare the equilibrium price before and after the merger.

The results of the simulation are unlikely to be the end of the story, not least because these models typically fail to capture dynamic effects such as new entry, product repositioning and strategic actions by buyers which may play a critical role in the competitive assessment. The outcome of the simulation analysis would be one factor weighed in the round with other evidence.

1.8.6. Weighing the evidence

There is no perfect approach to estimating pass-through rates, and there can be no guarantee that the practitioner will always be able to obtain robust estimates. Nevertheless, this does not imply that the practitioner should give up seeking to obtain empirical estimates of pass-through relationships where appropriate. The practitioner just needs to be aware of the limitations of each approach, which in turn determines how much weight can reasonably be placed on the estimates that are obtained.[77] In short, when giving weight to any measure of pass-through, it is helpful to be aware of any potential margin for error and, if possible, the direction of the potential bias.

Good practice suggests that the practitioner should:

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

[77] More research into identifying the shape of demand curves would, notably, be welcome.

Insights from Economic Theory

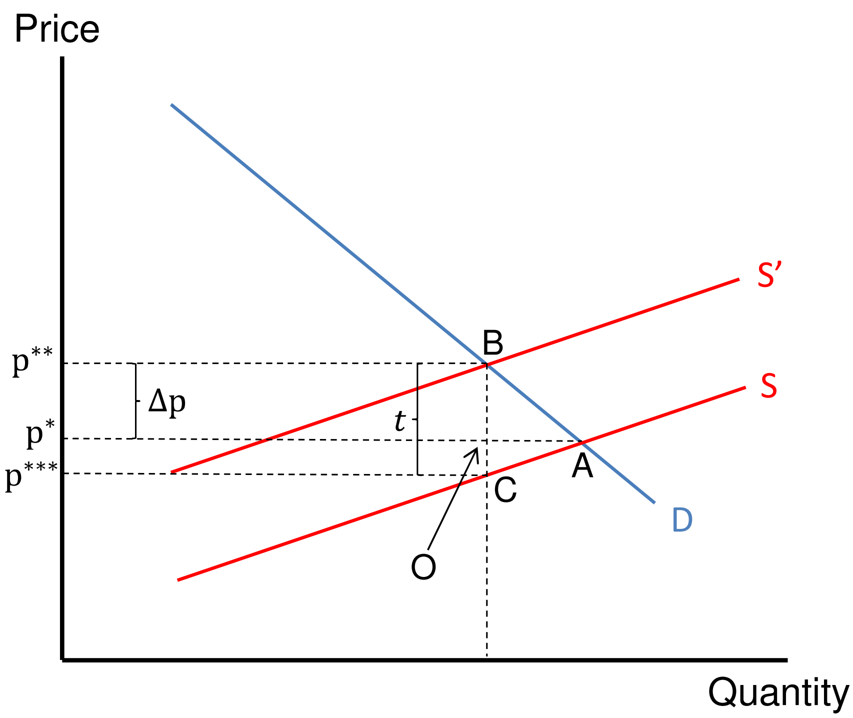
2. Preliminary insights: cost pass-through and the analogy with tax incidence

The classic exploration of pass-through issues has been motivated by tax incidence considerations, and this context provides a good entry point to the economics of cost pass-through.[78] Take the most basic characterisation of the supply of and demand for a product, with the quantity demanded at each price given by a downward-sloping demand-curve and the quantity which would be offered to the market at each price by producers represented by a supply curve. (It is frequently easier to work with the 'inverse' demand curve, which relates price to the quantity demanded, as illustrated in Figure 3 below.) Now suppose that a per unit tax t is imposed on sales. (We could, equivalently, have considered a tax on purchases.) What is the impact of the tax on the prices paid by customers? Specifically, to what extent is the tax passed through to customers and to what extent is it absorbed by suppliers?

This situation is set out graphically below. The imposition of the sales tax causes the supply curve to shift vertically by an amount $t;$ from S to S'. (Suppliers will offer the same amount to the market at price p after the tax is imposed as they would have done at price $p - t$ previously, since an amount t must be paid in tax on each sale made.) As a result, the market equilibrium adjusts from A to B, with the equilibrium market price increasing from p^* to p^{**}, and the quantity bought (and sold) decreasing commensurately. Suppliers will receive a price p^{***} after tax. As can be seen, only a fraction of the total tax change is passed through to customer prices; the change in price, Δp, is less than the amount of the tax, t.

[78] Indeed, many of the analyses considered and insights offered throughout this study are drawn from the tax literature.

Figure 3: Tax incidence and pass-through



The shift in the supply curve means a reduction in the quantity supplied to the market at the original equilibrium price, p^*. A deficit of supply relative to demand results at that price. To restore equilibrium, prices must, therefore, increase. However, to the extent that the level of demand is sensitive to price, this increase in price will cause the quantity that is demanded to contract. Unless supply is perfectly elastic, the consequent price increase will be less than the amount of the tax even though the supply curve is shifted vertically by the full amount of that tax. In other words, some of the incidence of the tax increase will be borne by suppliers.[79]

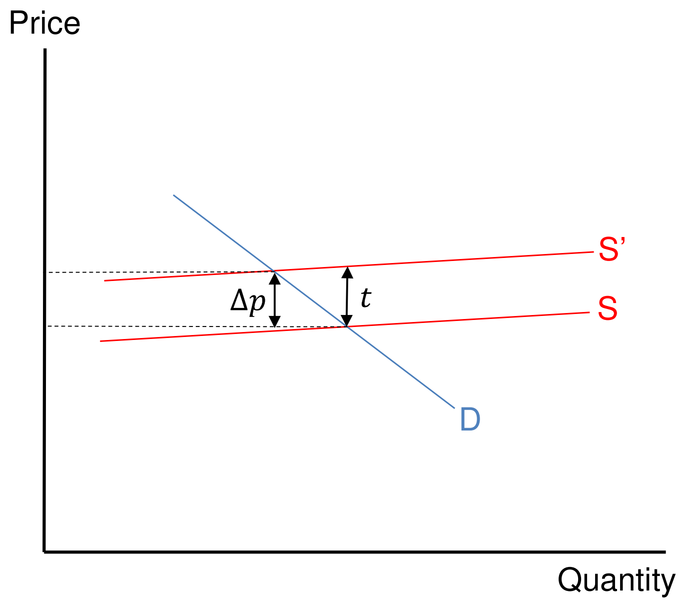
These considerations suggest that the degree to which a sales tax will be passed through to customers is sensitive to the slopes of demand and supply. In fact, it is the *relative* slopes of these curves that matter.

To explore this further, first consider the case where the supply curve has a relatively shallow slope compared to demand; i.e. supply is relatively elastic.[80] This is represented in Figure 4 below. In this case, as is evident, the pass-through rate is high. In other words, a substantial proportion of the tax is passed through in price increases. Moreover, even if supply is less price-sensitive than this, pass-through rates will remain high so long as the price-sensitivity of demand remains *relatively* low.

[79] This assumes that the supply curve does not slope downwards. This issue is discussed further below.

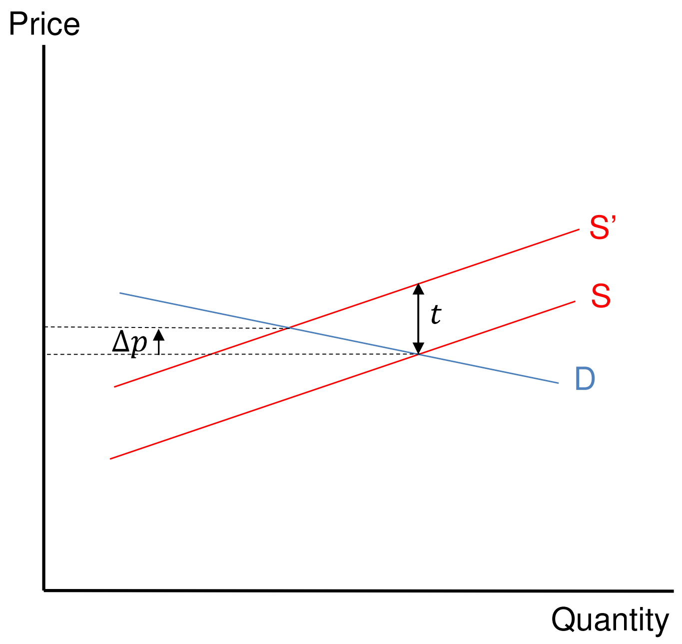
[80] Note that since the elasticity is the *proportionate* effect on quantity of a proportionate change in price, elasticity will vary along a straight-line demand or supply curve, though the slope is constant.

Figure 4: 'High' pass-through scenario



On the other hand, if demand is relatively price sensitive (i.e. shallow sloped) compared to supply, pass-through rates will be low. This scenario is illustrated in Figure 5. As can be seen, the imposition of the tax translates into a relatively modest change in prices, Δp. Moreover, even in circumstances where demand is only moderately price sensitive, pass-through rates will nevertheless remain low if supply is also relatively inelastic (steeply sloped).

Figure 5: 'Low' pass-through scenario



In summary: the more elastic is supply relative to demand, the greater the extent of pass-through; the greater the elasticity of demand relative to supply, the smaller the extent of pass-through. However, provided supply does not decrease as price increases and demand does not increase as price increases, pass-through will never exceed 100%.

Obtaining an expression for tax incidence

We will briefly examine this issue a little more formally. Suppose that suppliers will supply an amount $S(\tilde{p})$ to the market if they receive a price $\tilde{p}$. If the market price is p but suppliers have to pay a tax t on each item sold, they will receive $p-t$ per unit sold after tax. Hence, the amount they will then be prepared to supply at a market price p is $S(p-t)$. If the quantity demanded by customers at that price p is $D(p)$, a matching of supply and demand requires:

$$D(p) = S(p-t)$$

What we want to know is how the equilibrium price will change as the tax rate t is changed.

Suppose that an increase in the tax causes price to increase too. In that case, demand will fall. The amount by which demand falls will depend on the slope of the demand curve. All else equal, we might expect the increase in price to cause supply to increase. However, the tax increase also has an offsetting effect on the supply-side; it increases the wedge between the price paid by customers and the price received by suppliers. All else equal, the increase in the tax wedge will cause supply to be less attractive, and to contract.

To maintain an equilibrium between supply and demand, the change in demand brought about by the tax - via its effect on price – must match the change in supply, otherwise demand and supply would become unbalanced. The demand effect depends on the product of two terms: the effect of the tax on price, and the effect that this price change then has on demand. They are represented on the left-hand side of the following equation. The overall supply-side effect depends on two elements. First, there is the effect of the tax on price multiplied by the effect of that price change on the amount supplied. That is the first term on the right-hand side of the equation below. Second, there is the direct effect of the tax. A £1 increase in unit tax will reduce the amount received by suppliers by £1 on every unit sold, all else equal. This impact of this effective £1 reduction in price will then depend on the responsiveness of supply to such a price change. This is the second term on the right-hand side of the equation that follows. Thus, more formally:

$$\frac{dD}{dp} \cdot \frac{dp}{dt} = \frac{dS}{dp} \cdot \frac{dp}{dt} - \frac{dS}{dp} \cdot 1$$

Some manipulation of this equation establishes that the value of p which ensures supply and demand remain equal will change in response to a change in t according to the following pass-through relationship:

$$pass - through = \frac{price\ sensitivity\ of\ supply}{price\ sensitivity\ of\ supply + price\ sensitivity\ of\ demand}$$

This confirms the graphical intuition above, namely that the extent of (absolute) pass-through depends on the *relative* magnitudes of the slopes of demand and supply. To see this, re-consider Figure 3. Graphically, the extent of pass-through will depend on the ratio between the lengths of the lines BO and BC. The greater the ratio of BO to BC, the greater the pass-through. The more sensitive is supply to changes in price (the shallower the slope of the supply curve in the diagram), the larger the ratio of BO to BC; i.e. the more of the tax change that is passed through to prices.

The expression can be re-stated in terms of elasticities as follows:[81]

$$pass - through = \frac{1}{1 + \frac{elasticity\ of\ demand}{elasticity\ of\ supply}}$$

If the elasticity of demand is large relative to the elasticity of supply, so the pass-through rate will be low. Conversely, if the elasticity of demand is small relative to the elasticity of supply, the pass-through rate will be high.

Note that an identical outcome will result if the tax is imposed instead on customers. (The same pass-through condition can be obtained starting from the revised condition for equilibrium between supply and demand, namely $D(p + t) = S(p)$.) The ultimate incidence of the unit tax does not depend on whether it is levied as a purchase tax on customers or as a sales tax on suppliers – a classic tax result.

Whilst the analysis in this section has been couched in terms of tax, the underlying economics translates straightforwardly to a change in unit costs, as discussed in the next chapter.

[81] Here we refer to the absolute magnitude of the elasticity of demand, assuming its sign is, in fact, negative (demand falls as price rises).

3. Pass-through in the polar cases: perfect competition and monopoly

The polar cases of perfect competition and monopoly provide natural benchmarks for consideration of pass-through issues for the broader spectrum of oligopoly settings that are typically most relevant to competition policy. In this section we introduce these cases, before proceeding to the analysis of pass-through in oligopoly.

3.1. Perfect competition

The formulation and intuition for pass-through set out in the tax incidence example above carries over to the perfect competition paradigm.

Under perfect competition, firms are price takers and will expand supply whilst the market price is above the marginal cost of supplying another unit.[82] If marginal costs increase by a uniform amount Δc, firms will only continue to supply the same quantity if prices also increase by Δc. (If there is no change in price, it will no longer be profitable to supply the marginal units previously supplied, and supply will contract.) Where the supply curve is upward sloping, the result is a reduction in the quantity supplied at every price. This effect can be seen in Figure 3 above. In other words, there will be a vertical shift in the supply curve for each affected firm, and therefore in industry supply too.[83]

The question of interest is how a given increase in firms' costs would be passed through to prices.

As the tax incidence scenario illustrated above shows, the expression for <u>industry-wide</u> pass-through under perfectly competitive conditions is:

$$pass - through = \frac{1}{1 + \frac{elasticity\ of\ demand}{elasticity\ of\ supply}}$$

If supply is relatively elastic (shallow sloped) or demand is relatively inelastic (steeply sloped), the pass-through rate will be relatively high. In the extreme, if supply is perfectly elastic (horizontal) or demand is perfectly *in*elastic (vertical), the pass-through rate will be 100%. More generally, if industry supply is upward sloping and demand is downward sloping (with neither being vertical nor horizontal), equilibrium prices will increase by *less than* 100% even in the perfectly competitive scenario. The pass-through rate will decrease (increase) as demand becomes more (less) elastic and/or supply become less (more) elastic.

Under the assumption of perfect competition, the market equilibrium price will be determined by the marginal cost of the last unit of supply required to satisfy demand. Hence, the market price

[82] A change in fixed costs will not affect that supply unless if affects the number of firms that are active in the industry.

[83] The industry supply curve is simply the aggregation of the marginal cost curves of individual firms.

will change only if the marginal cost of this marginal unit changes. Under textbook conditions of atomistic supply, a firm-specific increase in cost will not change the competitive price, therefore; i.e. the firm-specific pass-through rate will be 0.

3.2. Monopoly

Even in the monopoly case, where there is no competition, by definition, the monopolist's profit-maximising price will respond to changes in marginal cost.

Profit is maximised when marginal revenue equals marginal cost. An increase in marginal cost will, therefore, necessitate a commensurate increase in marginal revenue in order to restore this condition. This will involve a reduction in output/an increase in price. An increase in marginal cost will reduce the margins earned on lost and gained sales. In turn, this will encourage an increase in prices to increase the margins earned on retained sales.

An expression for monopoly pass-through

[In this section, we show how the expression for the cost pass-through relationship is obtained. Doing so involves some technical notation and manipulation. However, the intuition for the results obtained in this section is set out below. Hence, readers that are interested only in that intuition can skip this more technical material.]

Consider a monopolist that faces inverse demand $p(q)$ and marginal cost $t + c'(q)$. (This formulation allows marginal costs to be changed by an amount t for each level of output, whilst also allowing those costs to vary with output.[84]) In order to maximise profit, the monopolist chooses output so as to equate marginal revenue with marginal cost, according to the following first order condition:[85]

$$\overbrace{qp'(q) + p(q)}^{marginal\ revenue} - \left[\overbrace{t + c'(q)}^{marginal\ cost}\right] = 0$$

The question at hand is how does the choice of the quantity, q, which brings about profit maximisation respond to a change in (marginal) costs; specifically, a shift in the value of t?

Making use of the implicit function theorem and differentiating with respect to t yields:

$$2p'(q)\frac{dq}{dt} + qp''(q)\frac{dq}{dt} - 1 - c'(q)\frac{dq}{dt} = 0$$

The first two terms are the effects of a change in t on marginal revenue, whilst the second two terms are the effects on marginal cost.

[84] A change in t corresponds to a vertical shift in the cost curve, where t could, but need not, correspond to a unit tax. In general, a cost change could affect the shape of the cost curve in more complex ways. However, we restrict our analysis here to the more tractable specification here.

[85] The monopolist may, equivalently, set its price to maximise profit, yielding the alternative expression of the first order condition: $(p - c)q'(p) - q(p) = 0$.

Noting that price depends on the quantity supplied, which itself depends on t - $p = p\big(q(t)\big)$, and so $\frac{dp}{dt} = p'(q)\frac{dq}{dt}$, the monopoly cost pass-through expression is given by:

$$\frac{dp}{dt} = \frac{p'(q)}{2p'(q) + qp''(q) - c''(q)}$$

where $p'(q)$ is the slope of inverse demand, $2p'(q) + qp''(q)$ is the slope of marginal revenue, and $c''(q)$ is the *slope* of marginal cost.

Dividing numerator and denominator by $p'(q)$, this expression can also be restated as:

$$\frac{dp}{dt} = \frac{1}{2 + \frac{qp''(q)}{p'(q)} - \frac{c''(q)}{p'(q)}}$$

where $\frac{qp''(q)}{p'(q)}$ is the elasticity of the slope of (inverse) demand, i.e. the proportionate rate at which the slope of inverse demand changes as quantity increases, and $\frac{c''(q)}{p'(q)}$ is the ratio of the change in marginal cost to the change in demand that would be brought about by a marginal output change.

Monopoly pass-through with constant marginal cost: non-technical discussion

If, as in Bulow and Pfleiderer (1983), the level of the monopolist's marginal cost is assumed not to change with the quantity it supplies,[86] the expression for pass-through in the monopoly case is given by:

$$pass - through\ = \frac{slope\ of\ demand}{slope\ of\ marginal\ revenue}$$

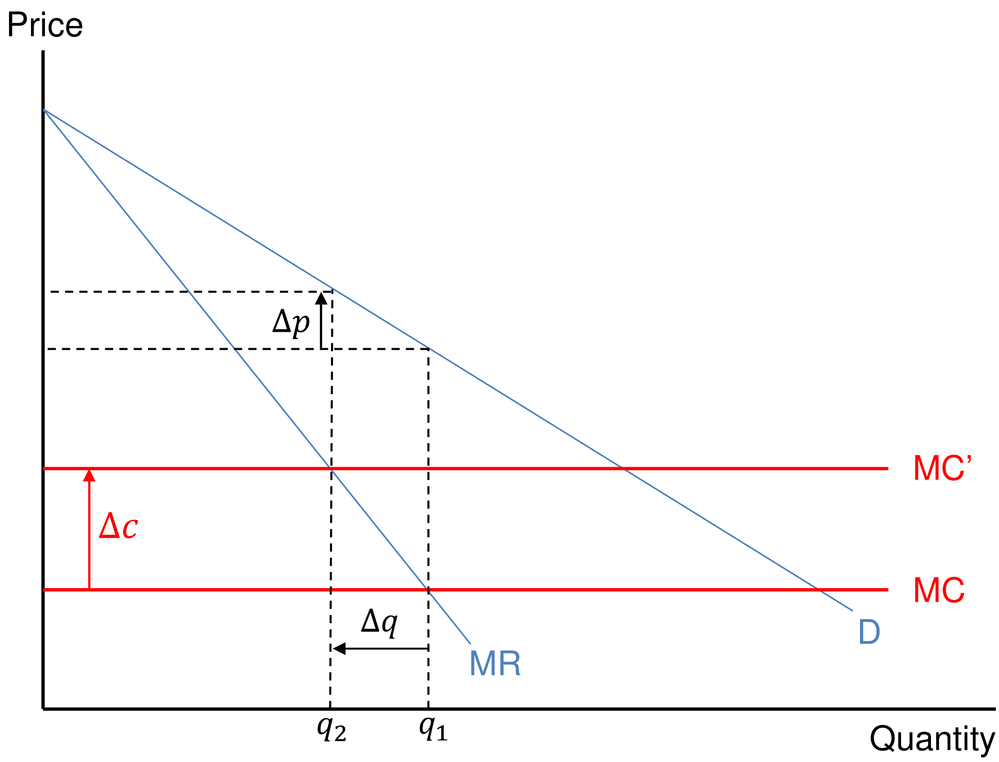
A number of insightful observations follow immediately from this. In particular, there is a simple intuition for the relationship between the slopes of demand and marginal revenue identified in this pass-through expression. An increase in marginal cost means that the profit-maximising equalisation of marginal revenue and marginal cost is disturbed. To restore this, the monopolist must reduce its output in order to increase the level of marginal revenue. The extent of the output contraction necessary to achieve this will depend on the rate at which marginal revenue increases as output is reduced, i.e. on the (negative) slope of the marginal revenue curve.

The change in price induced by this output contraction will, in turn, depend on the slope of the demand curve. The steeper the (negative) slope of demand, the greater the price increase that will result from a given reduction in output. For a given slope of demand, the greater is the output reduction brought about by the cost change, the greater the extent of pass-through.

To see this graphically, consider the illustration for linear demand set out in the diagram below.

[86] So the rate at which marginal cost changes with output, $c''(q) = 0$.

Figure 6: Pass-through with linear demand and constant marginal cost



Faced with an initial marginal cost MC, the monopolist chooses output q_1 at which the marginal revenue (MR) and marginal cost (MC) curves intersect. Now suppose marginal cost were to increase to MC'. The monopolist will adjust its output, to q_2, in order to restore the profit-maximising relationship between marginal revenue and marginal cost. The extent of the required output adjustment, Δq, will depend on the slope of the marginal revenue curve. In turn, the increase in price, Δp, that results from this change in output depends on the rate at which price increases as output contracts – i.e. on the slope of demand.

Taken together, the change in price Δp that results from the change in cost Δc, i.e. the amount of pass-through, therefore depends on (1) the rate at which a contraction in output restores the balance between marginal revenue and marginal cost, and (2) the rate at which the resulting output contraction causes price to increase.

The impact of demand curvature

The slope of marginal revenue, and, therefore, the extent of cost pass-through, is affected by the rate at which the slope of the demand changes as price is changed, i.e. on the curvature of inverse demand.[87] In fact, for the case with constant marginal costs, the pass-through expression can be re-stated as follows:[88]

$$pass - through = \frac{1}{2 + elasticity\ of\ slope\ of\ inverse\ demand}$$

where the elasticity of the slope of inverse demand is the proportionate rate at which the slope of inverse demand changes as output is increased. Thus, the monopoly pass-through rate departs from ½ to the extent that demand curvature (and the elasticity of the slope of demand) is different from 0.

When inverse demand is linear, curvature is 0 and the pass-through rate is fixed at ½ irrespective of the slope or elasticity of demand.[89] Since the slope of the monopolist's marginal revenue curve is always twice the slope of demand in the linear case, it follows that price will increase at half the rate of marginal revenue in response to a reduction in output. Hence, the profit-maximising output response to a given increase in marginal cost will result in half of the marginal cost increase being passed through to prices.

If demand is concave, the rate of pass-through will be smaller than in the linear case; if it is convex, pass-through will be greater than in the linear case.[90,91] Indeed, if demand is sufficiently convex, the pass-through rate will exceed 100%, i.e. so-called "overshifting" will occur.[92]

Example: With constant elasticity of demand, ε_D, the standard condition for profit maximisation results in the monopolist setting price at a constant proportionate mark-up over marginal cost:[93]

$$\frac{mark - up\ over\ marginal\ cost}{price} = \frac{1}{elasticity\ of\ demand}$$

An elasticity of demand above 1 is required for sensible outcomes. It follows that any increase in marginal cost will result in a further mark-up of price. Pass-through will exceed 100%. To see this, suppose that the absolute value of the elasticity of demand equals 2, say. The profit-maximising mark-up over price will therefore be 50%. If marginal cost equals 3, price will be set at 6; if marginal cost equals 4, price will be set at 8. A 1 unit increase in marginal cost brings

[87] This is given by the second derivative of the inverse demand function $p''(q)$.

[88] As shown in Bulow and Pfleiderer (1983), the pass-through expression can also be re-stated in terms of the elasticity of demand, ε, and the so-called super-elasticity – the elasticity of the elasticity of demand – as follows:

$$pass\ through = \frac{\varepsilon}{\varepsilon + 1 + \frac{p}{\varepsilon}\frac{\partial \varepsilon}{\partial p}}$$

[89] $p''(q) = 0$

[90] See Figure 2, above, for a graphical comparison of linear, concave and convex demand.

[91] If demand is concave, the elasticity of slope of inverse demand is positive; if demand is convex, the elasticity of slope of inverse demand is negative.

[92] See also Stennek and Verboven (2001) which derives expressions for the pass-through elasticity.

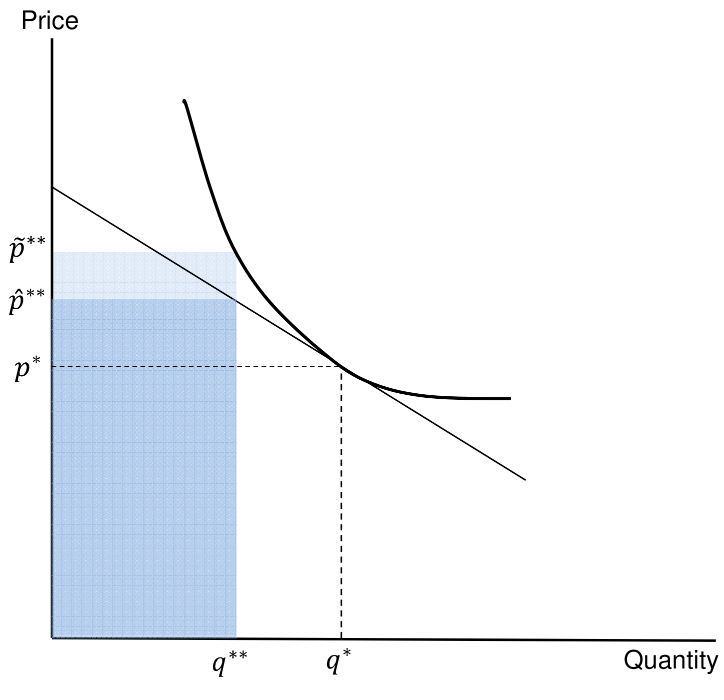
[93] This requires an elasticity of demand above 1 for sensible outcomes.

about an increase in price of 2 units. Thus, price changes at twice the rate at which marginal costs change. The pass-through rate is 200%.[94]

Demand curvature is the extent to which demand becomes more or less sensitive to price as the price increases (and output declines). It is instructive to consider the impact of demand shapes by comparing demands from a common starting point where prices and quantities are the same and consumers are equally price sensitive. With concave demand, as output contracts from that point, demand becomes *more* sensitive to price compared to linear demand. It is harder, therefore, to pass on a cost increase compared to linear demand. On the other hand, with convex demand, as output declines, demand become *less* sensitive to price rises – it is therefore easier to pass on a cost increase.

The latter point can be set out graphically, following Weyl and Fabinger (2009). The authors compare a linear demand function, on the one hand, and a strictly convex one on the other. By construction, the initial profit maximising monopoly outcome is set equal for both demand curves, at price $p^*$and quantity q^*. The slopes of both demand curves are also constructed to be the same at this point. This means that marginal revenue will be identical for both demand forms at this level of output too. The scenario is plotted in the following diagram, which draws on Weyl and Fabinger (2009).

Figure 7: Pass-through and demand curvature



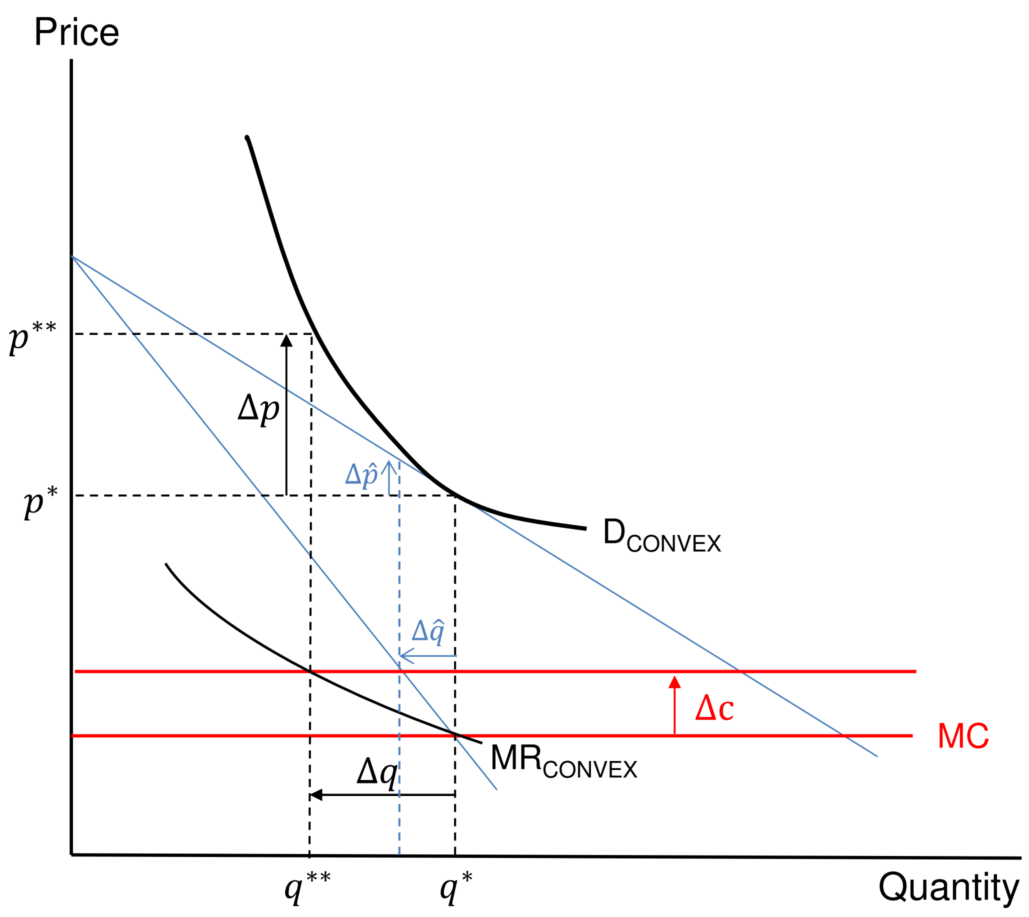
[94] More formally, $\frac{dp}{dc} = \left(\frac{1}{1-\frac{1}{\varepsilon_D}}\right) > 1,$ provided $\varepsilon_D > 1$, which follows from profit maximisation.

Suppose that the true demand is convex and that the cost shock shifts quantity from the pre-shock optimal level q^* to a point q^{**}. In this case, it should be clear that the monopolist will be able to secure a higher price under convex inverse demand ($\tilde{p}^{**}$) than had demand been linear ($\hat{p}^{**}$). Revenues, represented by the shaded areas are greater in the convex demand case, as is evident from the diagram. Profits are also higher.[95]

The greater profitability of a given output reduction under convex demand reflects that fact that revenues attenuate more slowly as output declines. Intuitively, as noted above, more convex demand means that relatively more consumers are willing to pay a higher price for the product in question. This encourages a greater price response by the monopolist following a change in its costs.

With these points in mind, it is informative to add the relevant marginal cost and revenue schedules to the above diagram (again, drawing on Fabinger and Weyl (2009)).

Figure 8: Pass-through and demand curvature



[95] Output, and hence costs, are the same for both demand scenarios.

As with the first diagram, the example is constructed so that marginal revenue is identical for both forms of demand at the initial output level, q^*.

As can be seen from the diagram, the slope of the marginal revenue curve is shallower in the convex demand case. Starting from the initial position, the adjustment in output, Δq, required to restore the profit maximising equalisation of marginal revenue and marginal cost in the case of convex demand will be greater than with linear case ($\Delta \hat{q}$). This quantity adjustment will also give rise to a greater increase in price, $\Delta p,$ in the convex demand case than in the linear demand case, $\Delta \hat{p},$ too. It follows therefore, that pass-through of the initial cost change will be greater with convex demand. Indeed, when marginal costs are constant, cost amplification (absolute pass-through in excess of 1) is possible only with convex demand.[96]

Ultimately, therefore, the curvature of demand is liable to have an important bearing on the extent of pass-through. Whether estimation methodologies are capable of identifying or approximating this factor in practice is therefore a critical empirical issue.

As noted, the focus for this study is cost pass-through. However, it should be apparent from this diagrammatic representation that a vertical shift in inverse demand will also give rise to similar pass-through effects. Thus, an *increase* in observed margins might coincide with a reduction in output following a downward shift in demand that is sufficiently convex.

The impact of upward-sloping marginal costs

When the level of marginal cost also changes with the level of output, an additional element is introduced into the pass-through equation. In this case, the general monopoly pass-through expression can be restated as follows:[97]

$$pass - through = \frac{slope\ of\ demand}{slope\ of\ marginal\ revenue - slope\ of\ marginal\ cost}$$

In this case, the slope of marginal cost enters the denominator of the pass-through expression. Positively sloped marginal cost curve, i.e. marginal cost which increases with output, will reduce the magnitude of pass-through, all else equal.[98] To see why this is, note that if marginal cost slopes upwards, i.e. it is increasing in output, a contraction in output would lead to a reduction in marginal cost as well as an increase in marginal revenue. In this case, a smaller reduction in output will be needed in response to a given increase in cost, Δc , in order to restore the profit-maximising relationship between marginal revenue and marginal cost. The smaller the contraction in output following the cost change, the smaller the pass-through to prices, all else equal.

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[96] The impact of upwards or downwards sloping marginal cost can be seen by imagining that the marginal cost curves shown are both pivoted at quantity q^*, as illustrated in Figure 9 below.

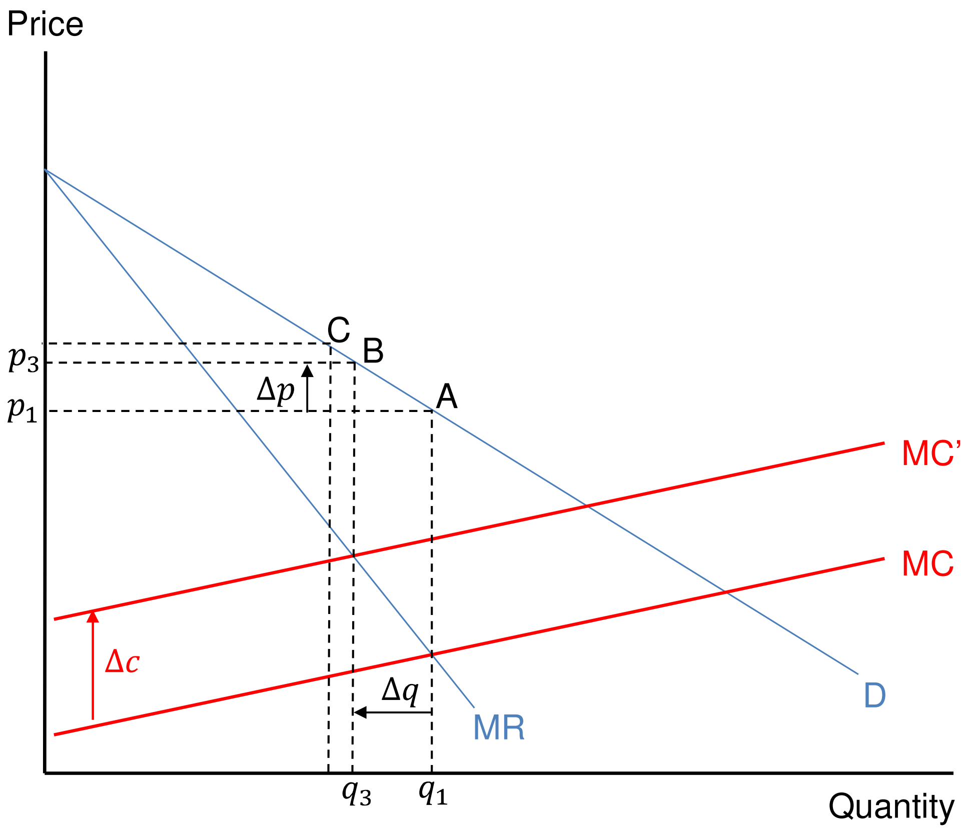
[97] Recall that:

$$\frac{dp}{dt} = \frac{p'(q)}{2p'(q) + qp''(q) - c''(q)}$$

[98] To illustrate, suppose the slope of marginal revenue is -4 and the slope of demand is -2. In this case, if marginal costs are constant – i.e. the marginal cost curve has 0 slope – the pass-through rate will be 50%. On the other hand, if the marginal cost curve is upward-sloping with slope 1, the pass-through rate will be given by $\frac{-2}{-4-1} = 0.4$. In other words, if the marginal cost curve has a positive slope of 1, the pass-through rate is reduced to 40%, all else equal.

This is illustrated in the diagram below, which is identical to Figure 6, except that the marginal cost curve is now upward sloping. Compared to the outcome in that previous case (marked by C in this diagram), it should be evident that a smaller contraction in output – to q_3 – is required to ensure that marginal revenue equals marginal cost following the same upward shift in marginal cost Δc. This is because as output is reduced, the level of marginal cost is also reduced, since the marginal cost curve slopes upwards. As a result, the change in price, Δp, which follows is smaller too; i.e. pass-through is reduced.

Figure 9: Monopoly pass-through and upward-sloping marginal costs



3.3. Summary: Perfect competition and monopoly

In a perfectly competitive setting:

- With perfect competition, the extent of industry-wide pass-through will depend on the relative elasticities of demand and supply. If demand is relatively elastic, pass-through rates will be low; if it is relatively inelastic, pass-through rates will be high.

- If demand decreases with price and supply increases with price, the competitive pass-through rate will be between 0 and 100%.

- In a perfectly competitive setting, there is no scope for individual firms to pass through firm-specific cost changes, so the firm-specific pass-through rate will be zero.

With monopoly:

- Though there is no competition in a monopoly setting, pass-through of cost changes to prices will still typically occur. When marginal costs are constant, the monopoly pass-through rate is determined by the ratio of the slope of demand to the slope of marginal revenue. In the case of linear demand, the slope of demand is half the slope of marginal revenue, so the monopoly pass-through rate is 50%.

- In general, the curvature of demand plays a key role in determining pass-through rates outside the competitive case. Starting from the linear benchmark (no curvature, and a pass-through rate of 50%), the monopoly pass-through rate is adjusted up or down depending on whether demand is, respectively, convex or concave. If demand is sufficiently convex, the pass-through rate may exceed 100%.

- The extent of cost pass-through will be reduced by an upward-sloping marginal cost curve, all else being equal, and increased by a downward sloping marginal cost curve.

4. Oligopoly: the effect of strategic interaction between firms

In oligopoly settings, the pass-through relationship between costs and prices is made more complex by the influence of a number of other factors affecting the nature of the competitive interaction between firms, notably:

- the nature of strategic interactions between firms;
- the extent of product differentiation; and
- the implied relationships between industry structure and prices.

In this section, we consider pass-through for both of the main paradigms of oligopolistic competition, namely Cournot (quantity setting) and Bertrand (price setting) competition. We focus throughout on markets with single-product firms.[99]

Compared to monopoly, the distinction between pass-through of firm-specific cost changes, on the one hand, and industry-wide cost changes, on the other, becomes relevant in oligopolistic settings.

4.1. 'Cournot' competition in quantities

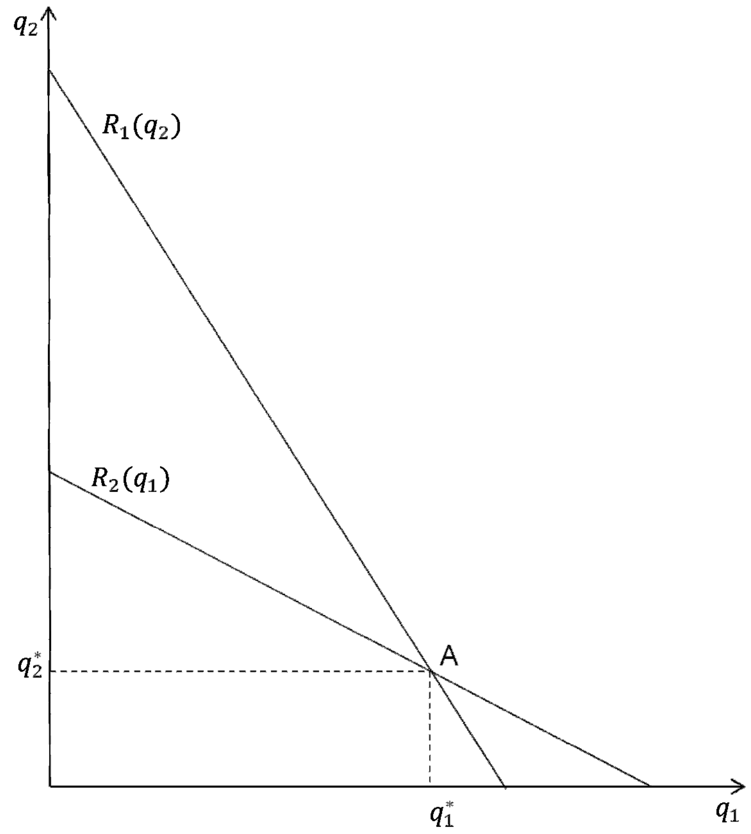
In this setting, each firm chooses its output to maximise profit, taking as given the outputs of all other firms. In general terms, a firm's profit-maximising output choice will depend on the outputs of its rivals, as well as the shape of demand and its own costs. Firm i's so-called best response (or 'reaction') function identifies its profit-maximising choice of output, q_i, for each combination of its rivals' outputs. The Cournot market outcome is a Nash equilibrium in which each firm's output choice is a best response to all other firms' output choices.

This is illustrated graphically In Figure 10 below for the duopoly case with linear demand and constant marginal cost. Firm 1's best response function $R_1(q_2)$ identifies its profit maximising output, q_1 for each value of rival firm 2's output, q_2. Analogously, $R_2(q_1)$ gives firm 2's profit maximising output, q_2, for each value of q_1. Both reaction functions are downward sloping; the greater its rival's output, the smaller will be firm i's profit maximising choice of output, q_i (so called strategic substitutability). Market equilibrium occurs at point A, where these reaction functions intersect, with firm 1 producing equilibrium output q_1^* and firm 2 producing output q_2^*.[100]

[99] Issues in respect of multi-product firms are considered in the numerical case study presented in Chapter 6 and in the context of horizontal mergers below.

[100] For stability, the slope of firm 1's reaction function must be steeper than that of firm 2.

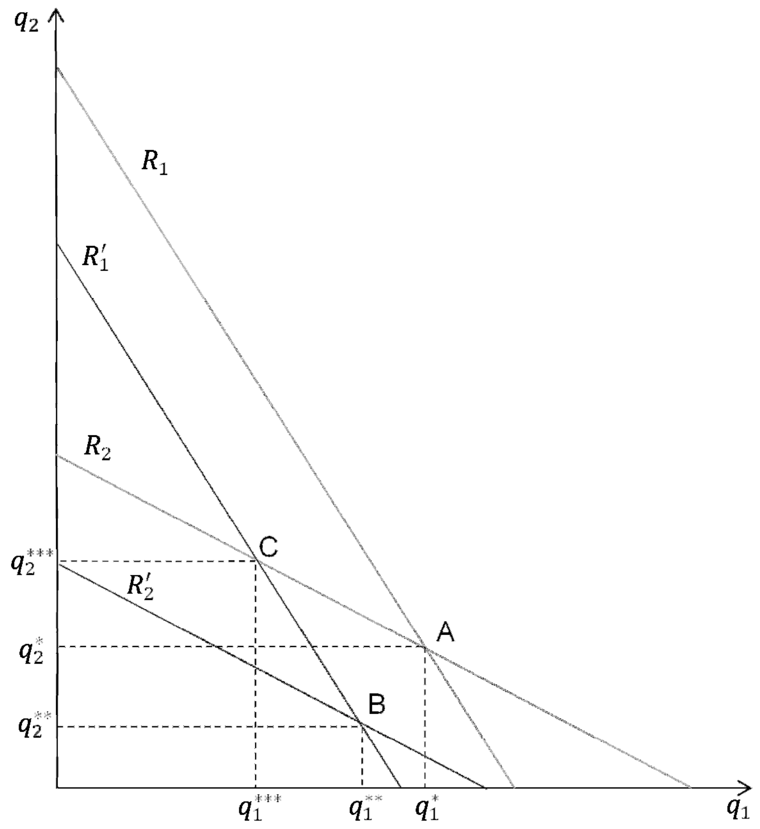
Figure 10: Cournot equilibrium



The issue at hand in the current case is how those equilibrium outputs, and hence the market price, would adjust if the marginal costs of one or both of the firms were to change. Graphically, if firm 1 suffers an adverse cost shock, it will produce less output for every value of firm 2's output. This implies a shift inwards in its reaction function, as shown by the shift from R_1 to R_1' in Figure 11 below. Similarly, if firm 2 suffers an adverse cost shock, its reaction function will shift inwards from R_2 to R_2' too, as shown.

If both firms are subject to the same, industry-wide cost shock, the market outcome will shift to B, with firm 1 producing equilibrium output q_1^{**} and firm 2 producing output q_2^{**}. On the other hand, if only firm 1 is subject to the cost shock, only its reaction function will shift. It is noteworthy, however, that even if it is *only* firm 1's costs that are affected by the shock, and only firm 1's reaction function that shifts as a result, nevertheless the outputs of firm 1 *and* firm 2 will be affected in equilibrium. (Firm 2's best output response will change as firm 1's output changes, which will change in response to the change in firm 2's output, and so on.) The outcome is at C. In the Cournot setting, an increase in firm 1's costs which causes its output to contract will result in firm 2's output expanding, all else being equal.

Figure 11: Cournot competition – the impact of cost increases



In a Cournot setting, price is determined by the sum of individual firm outputs. It follows from the diagram (firm 1 reduces output by more than firm 2 increases output) that price falls and firm-specific pass-through is positive. However, it is less than industry specific pass-through (when both firms reduce output).

4.1.1. Pass-through of industry-wide cost changes in the Cournot setting

In this section, we build on the simple graphical presentation to consider the pass-through relationship for industry-wide cost changes in the Cournot setting.[101]

Obtaining an expression for industry-wide cost pass-through under Cournot competition assumptions (more technical)

[In this section, we show how the expression for industry-wide cost pass-through in the Cournot case is obtained. Doing so involves some technical notation and manipulation. However, the intuition for the results obtained in this section is set out below. Hence, readers that are interested only in that intuition can skip this more technical material.]

[101] Seade (1985) provides important early insight into pass-through in the case of Cournot competition.

Formally, in a Cournot market each firm i chooses q_i to satisfy the following first order condition:

$$q_i p'(q_i + Q_{-i}) + \ p(q_i + Q_{-i}) - \ c_i'(q_i) - t_i = 0$$

where $p(\cdot)$ is inverse demand, Q_{-i} is the aggregate output of all other firms (taken as given), and $t_i + c_i'(q_i)$ is firm i's marginal cost. A set of individual firm outputs will constitute an equilibrium outcome if, taking the relevant outputs of all other firms as given, this first order condition is simultaneously satisfied for each firm's own output.

If firms have identical marginal cost functions then $t_i = t$ and each firm's outputs will be identical too. In this case, aggregating across all n firms gives:

$$Qp'(Q) + np(Q) - nc'(Q/n) - nt \quad = 0$$

Drawing on the implicit function theorem and differentiating with respect to t:

$$(n+1)p'(Q)\frac{dQ}{dt} + Qp''(Q)\frac{dQ}{dt} - nc''(Q/n)\frac{dQ}{dt} - n = 0$$

Re-arranging, we can then obtain an expression for the change in aggregate equilibrium output, Q caused by a marginal change in t:

$$\frac{dQ}{dt} = \frac{n}{(n+1)p'(Q) + Qp''(Q) - nc''(Q/n)}$$

Since the market price, p, is a function of aggregate demand, this aggregate output change will also imply a change in price. Thus, the expression for pass-through of an industry-wide marginal cost change with Cournot competition between n symmetric firms is given by:

$$\frac{dp}{dt} = \ p'(Q) \cdot \frac{dQ}{dt} = \frac{np'(Q)}{(n+1)p'(Q) + Qp''(Q) - nc''(Q/n)}$$

If firms' marginal costs are constant across different levels of output, $c''(\cdot) = 0$ and the pass-through relationship simplifies to:

$$\frac{dp}{dt} = \frac{np'(Q)}{(n+1)p'(Q) + Qp''(Q)} = \frac{n}{(n+1) + elasticity\ of\ slope\ of\ inverse\ demand}$$

Indeed, this expression will hold even if firms have *different* marginal costs if each of those marginal costs is constant across outputs.

Cournot pass-through with constant marginal costs: non-technical discussion

With constant marginal costs, the expression for pass-through of industry-wide cost changes under Cournot competition is:

$$pass - through = \frac{1}{\frac{n+1}{n} + \frac{elasticity\ of\ slope\ of\ inverse\ industry\ demand}{n}}$$

Note that this expression is very similar to the monopoly expression described earlier, except that 1 replaces n in the latter; i.e. the Cournot case collapses to the monopoly expression when $n = 1$. At the other extremity, as n becomes large, pass-through of industry-wide cost changes in the Cournot case converges on the perfect competition result. Specifically, as n increases, the impact of demand curvature declines, $\frac{n+1}{n}$ converges on 1 and the pass-through rate converges on 100% provided that the elasticity of the slope of inverse demand exceeds -1.

In other words, an increase in competition (here, brought about by an increase in the number of firms) causes pass-through to increase provided that demand is not too convex. However, if demand is very convex, an increase in the number of firms would *reduce* the pass-through rate.[102]

A related point is that pass-through in excess of 100% is possible given a sufficiently convex demand curve (i.e. where the elasticity of the slope of demand is less than -1). Further, as Seade (1985) shows, the firms in a Cournot oligopoly may actually profit from an increase in costs if the pass-through rate is sufficiently above 100%, i.e. if demand is sufficiently convex. Intuitively, with convex demand prices are increased by more than the increase in cost and so the absolute value of the margin goes up following a cost shock. Provided that volumes do not fall too much (i.e. if inverse demand is sufficiently steep) then the combination of higher margins and only a small fall in volumes will give rise to higher profits.

With linear demand (and constant marginal cost) the demand curvature term drops out, and the independence of the pass-through rate from the parameters of demand that is observed for the monopoly scenario carries over to the Cournot competition setting.[103] In this case, the pass-through rate then depends only on the number of firms, n, and over-shifting will not occur:

$$pass - through_{Linear} = \frac{n}{n+1}$$

The effect of increasing marginal cost

If marginal costs increase with output, this will reduce the extent of pass-through, all else equal. The slope of marginal cost enters the pass-through expression accordingly, in the same way as for the monopoly case.

4.1.2. Pass-through of firm-specific cost changes in the Cournot setting

Assuming constant (but potentially asymmetric) marginal costs, the expression for firm-specific pass-through in the n-firm Cournot setting is:

$$pass - through = \frac{1}{(n+1) + \ elasticity\ of\ slope\ of\ inverse\ industry\ demand}$$

[102] To see this, observe that with convex demand the elasticity of the slope of inverse demand is negative. As n increases, the contribution of this negative slope elasticity term in the denominator is reduced, resulting in a more positive denominator and implying a smaller pass-through rate.

[103] This can be seen by setting $p''(Q) = 0$ and $c''(q) = 0$ in the general expression above.

Hence, firm-specific cost pass-through is $1/n^{th}$ of industry-wide cost pass-through in the homogeneous Cournot setting.

Obtaining the firm-specific pass-through expression (more technical)

[In this section, we show how the expression for firm-specific cost pass-through in the Cournot case is obtained. Doing so involves some technical notation and manipulation. However, the intuition for the results obtained in this section is set out below. Hence, readers that are interested only in that intuition can skip this more technical material.]

We start from the aggregate first order condition set out for the industry-wide case above, but allow t_i to vary between firms. Allowing for asymmetric marginal costs, that aggregate first order condition is:

$$Qp'(Q) + np(Q) - \sum_j c_j'(q_j) - \sum_j t_j = 0$$

Drawing on the implicit function theorem and differentiating <u>with respect to t_i only</u>:

$$(n+1)p'(Q)\frac{dQ}{dt_i} + Qp''(Q)\frac{dQ}{dt_i} - \sum_j c_j''(q_j)\frac{dq_j}{dt_i} - 1 = 0$$

If symmetry across firms is assumed: $c_j''(q_j) = c''\left(\frac{Q}{n}\right)$. In this case:

$$(n+1)p'(Q)\frac{dQ}{dt_i} + Qp''(Q)\frac{dQ}{dt_i} - nc''(Q/n)\frac{dQ}{dt_i} - 1 = 0$$

The first three terms in this expression are identical to the industry-wide version. The one difference compared to that expression is in the last term, which is now 1 not n, reflecting the fact that the cost change affects one firm only.

Rearranging, and noting that: $\frac{dp}{dt_i} = p'(Q) \cdot \frac{dQ}{dt_i}$

$$\frac{dp}{dt_i} = \frac{p'(Q)}{(n+1)p'(Q) + Qp''(Q) - nc''(Q/n)}$$

If marginal costs are constant across outputs ($c_j''(q_j) = 0$), the cost term disappears from this expression, including in the case where marginal cost is different for each firm. In this case, dividing throughout by $p'(Q)$ gives the expression for firm-specific cost pass-through set out above.

Non-technical discussion

When $n = 1$, this expression for firm-specific cost pass-through reduces to the monopoly version. (The effects of industry-wide and firm-specific cost shocks will also be identical in this case.) For linear demand, it implies a pass-through rate of 50%. The magnitude of firm-specific cost pass-through decreases as the number of firms on the market grows, as illustrated for the linear case below.

Strikingly, the magnitude of firm-specific cost pass-through does not depend on the distribution of individual firm sales, notably the relative size of the firm that is affected by the cost shock. That is, firm-specific cost pass-through is the same regardless of the distribution of market shares. For example, when the market includes four firms, firm-specific cost pass-through is one quarter of the industry-wide cost pass-through, whether each firm has 25% market share, or whether one firm has 70%, and the three remaining firms share equally the rest.

With constant marginal costs, this result can be explained by the fact that prices are determined by the simple *sum* of marginal costs in a Cournot industry. Thus, a firm-specific cost saving will be passed through to price to a much lesser extent than in the monopoly case (and much less than with an industry-wide cost change) if the firm in question faces competition from multiple rivals, even if it accounts for 99% of sales in practice.

Comparing this expression with the corresponding one for industry-wide cost pass-through set out above, it is evident that the ratio between the firm-specific and industry-wide cost pass-through rates depends only the number of firms active in the market:

$$\frac{industry-wide\ cost\ pass-through}{firm-specific\ cost\ pass-through}=\frac{1}{n}$$

For example, in a duopoly market, firm-specific cost pass-through is half the level of industry-wide cost pass-through. The following table sets out the relationship between the number of firms and the ratio between the firm and industry pass-through.

Table 1: relationship between number of firms and the industry-wide to firm-specific cost pass-through ration

Number of firms	Pass-through Ratio
1	1
2	1/2
3	1/3
4	1/4
5	1/5
10	1/10
50	1/50
100	1/100

There are two main points to note:

- First, as the number of firms, *n,* increases, the firm-specific cost pass-through rate increasingly diverges from the industry-wide cost pass-through rate.

- Second, market shares play no role in the relationships between the industry-wide and firm-specific cost pass-through rates.

Differentiated products

Zimmerman and Carlson (2010) extends the analysis of firm-specific pass-through in the linear demand Cournot case to allow for product differentiation, which relaxes the intensity of oligopolistic competition between firms. Unsurprisingly, as the substitutability between products diminishes, the extent of firm-specific pass-through converges on the monopoly level (as each firm becomes essentially a 'local' monopolist), whilst pass-through will converge on the homogeneous Cournot level as the degree of substitutability increases (in which competing quantities are strategic substitutes in the Cournot setting). Interestingly, Zimmerman and Carlson (2010) finds a non-monotonic relationship between firm-specific cost pass-through and the number of firms in the market. Specifically, below a threshold number of firms, the pass-through rate decreases as the number of firms is increased whilst, above this threshold, firm-specific pass-through increases with the number of firms.[104]

Firm i will respond to a firm-specific increase in its own costs by reducing output, thereby raising the price of its product, all else equal. In this Cournot setting (in which competing quantities are strategic substitutes), firm i's rivals will respond to this contraction in the amount it supplies by *expanding* their own outputs. The effect of this competitor output expansion is to reduce the upward pressure on firm i's price caused by its own output contraction, thereby reducing the extent of cost pass-through.

However, as the number of firms increases and the overall market becomes more fragmented, the impact of firm i's output contraction on market prices and, hence, on rival's behaviour will diminish. As a result, the expansion in rivals' outputs which causes the negative 'feedback' effect in respect of firm i's price will diminish too, causing the extent of cost pass-through to increase, all else equal. As the number of firms exceeds a threshold (which depends on the extent of product differentiation), this second effect will outweigh the first effect, and pass-through will increase with the number of firms after that.

4.2. 'Bertrand' differentiated product competition in prices

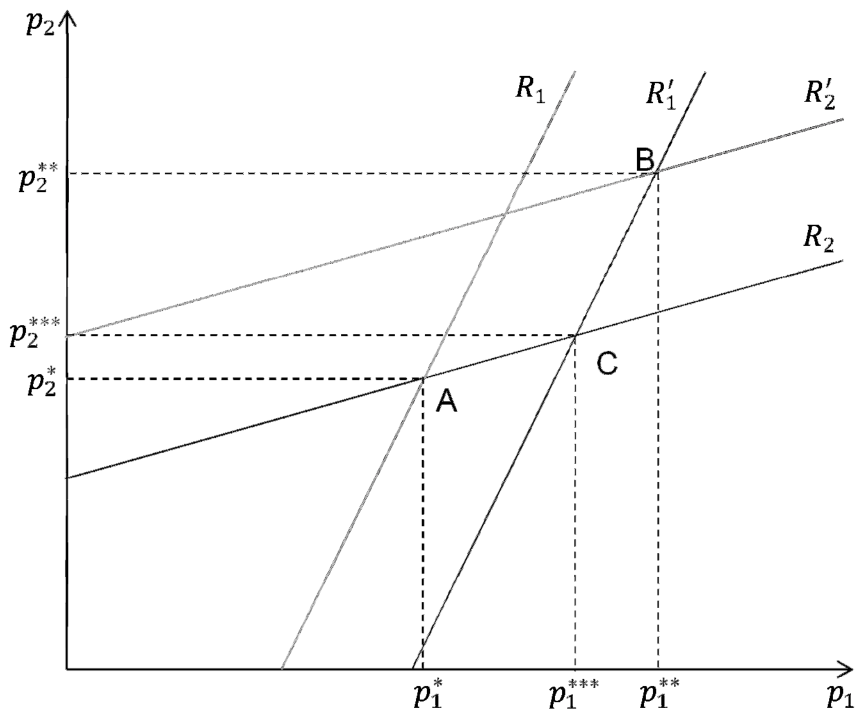
In the Bertrand setting, each firm chooses its price to maximise profit, taking as given the prices of all other firms as given. An equilibrium market outcome exists where each firm's price is a best response to its competitors' prices.

[104] The threshold varies with the extent of differentiation.

A key consideration in this context is the degree of product differentiation. At one extreme, where differentiation is maximal, each individual firm will operate as a monopolist over a segment of the overall market. At the other extreme, as the extent of differentiation is reduced, the setting converges on a homogeneous good market and competition under Bertrand assumptions will be intense.[105]

A graphical representation for the linear duopoly case is set out below. Note that each firm's best response function is upward sloping in rivals' prices. Under Bertrand competition, a firm will respond to an increase in its rivals' prices by raising its own price. (Prices are so-called strategic complements.)[106] This has important implications for pass-through, as it implies that any upward pressure on prices caused by an increase in one firm's costs will be re-enforced by the effect that this has on rival firms' pricing decisions.

Figure 12: Differentiated Bertrand competition



Compared with the monopoly case, the impact of an increase in marginal costs on firm i's pricing behaviour will now depend on the effect that this cost increase has on rivals' prices too. The intuition for the equilibrium price response to cost changes can be illustrated using the graphical representation above.

[105] In the extreme case, only a one firm outcome is sustainable in equilibrium in these circumstances.

[106] Contrast with 'Cournot' settings, where a firm's best response function is decreasing in rivals' outputs; outputs are so-called strategic substitutes.

Suppose that the initial market configuration has firm 1 setting price p_1^* and firm 2 setting price p_2^*. This is point A in the diagram. If an industry-wide cost change affects both firms, each firm's reaction function will shift out; for a given price set by its rival, each firm will now set a higher price itself. The effect would be to shift the industry equilibrium to B, with firm 1 and firm 2 each setting higher prices, p_1^{**} and p_2^{**} respectively.

In the case of a firm-specific shock, affecting firm 1 only, just firm 1's reaction function will shift, from R_1 to R_1'. In this case the market equilibrium will shift to C. Even though only firm 1 is directly affected by the cost shock, firm 2's price will also increase in equilibrium. This is because prices are strategic complements, and as firm 1's price increases it is optimal for firm 2 to increase its price too. However, firm 1's equilibrium price is affected to a much greater extent (from p_1^* and p_1^{***}) than firm 2's equilibrium price, which changes from p_2^* to p_2^{***}. In other words, pass-through of a firm-specific shock affects firms asymmetrically (the own price pass-through exceeds the 'cross' price pass-through effect). In both cases, the effect on price is less than in the case of an industry-wide shock.

4.2.1. Pass-through of industry-wide cost changes in the differentiated Bertrand setting

Anderson et al. (2001) provides an analysis of industry-wide pass-through in the context of differentiated Bertrand competition. We follow its approach below.

Obtaining an expression for pass-through of industry-wide cost changes with differentiated Bertrand competition (more technical section)

[In this section, we show how the expression for industry-wide cost pass-through in the differentiated Bertrand case is obtained. Doing so involves some technical notation and manipulation. However, the intuition for the results obtained in this section is set out below. Hence, readers that are interested only in that intuition can skip this more technical material.]

In the differentiated Bertrand setting, each firm i will set its profit-maximising price p_i to satisfy the following first order condition:

$$\left[p_i - [c'(q_i) + t]\right]\frac{\partial q_i(p_i, p_{-i})}{\partial p_i} + \ q_i(p_i, p_{-i}) = 0$$

where firm i's sales q_i are a function of p_{-i} - the set of all other firms' prices - as well as its own price.[107] Crucially, therefore, firm i's choice of p_i is now sensitive to the pricing decisions of rivals, as well as its own marginal costs and the relevant properties of demand.

Analogously to the Cournot case considered previously, pass-through determines how the set of equilibrium prices that simultaneously solve these first order conditions will change in response to a change in marginal costs. Drawing on the implicit function theorem and differentiating totally with respect to t, the change to the profit maximising first order condition for firm i is as follows:

[107] Note that in this case we are no longer talking about *inverse* demand, $p(q)$.

$$\left[2\frac{\partial q_i}{\partial p_i} + p_i\frac{\partial^2 q_i}{\partial {p_i}^2} - c''(q_i)\left[\frac{\partial q_i}{\partial p_i}\right]^2 - [c'(q_i)+t]\frac{\partial^2 q_i}{\partial {p_i}^2}\right]\frac{dp_i}{dt}$$

$$+\sum_{j\neq i}\left[p_i\frac{\partial^2 q_i}{\partial p_i \partial p_j} + \frac{\partial q_i}{\partial p_j} - c''(q_i)\cdot\frac{\partial q_i}{\partial p_j}\cdot\frac{\partial q_i}{\partial p_i} - [c'(q_i)+t]\frac{\partial^2 q_i}{\partial p_i \partial p_j}\right]\frac{dp_j}{dt} + \frac{\partial q_i}{\partial p_i} = 0$$

Thus, the impact of the change in t on firm i's equilibrium first order condition depends not only on the effect on its own price (the first term) and its own marginal cost (the third term) but also on the effect on the prices of all its rivals (the second term). The system of individual pass-through effects is then determined by the solution to this system of equations.

If symmetry between all n firms is assumed, the pass-through rate in respect of price p_i can be expressed as:

$$\frac{dp_i}{dt} = \frac{\frac{\partial q_i}{\partial p_i}}{2\frac{\partial q_i}{\partial p_i} + \sum_{j\neq i}\frac{\partial q_i}{\partial p_j} + [p_i - c'(q) - t]\cdot\left[\frac{\partial^2 q_i}{\partial {p_i}^2} + \sum_{j\neq i}\frac{\partial^2 q_i}{\partial p_j \partial p_i}\right] + c''(q)\cdot\left[\left[\frac{\partial q_i}{\partial p_i}\right]^2 + \sum_{j\neq i}\frac{\partial q_i}{\partial p_j}\frac{\partial q_i}{\partial p_i}\right]}$$

If firms are assumed to have constant marginal costs, $c''(q) = 0$ and $c'(q) + t = t$. Multiplying numerator and denominator by $p/_q$ and dividing throughout by the numerator, Anderson et al. (2001) shows that absolute pass-through of an industry-wide change in marginal cost t for the differentiated Bertrand case can then be expressed as:

$$\frac{dp}{dt} = \frac{1}{1 + \frac{\varepsilon_{DD}}{\varepsilon_{dd}} - \frac{\varepsilon_m}{\varepsilon_{dd}}}$$

where:

$\varepsilon_{dd} = \frac{p}{q}\frac{\partial q_i(p_i,p_{-i})}{\partial p_i}$ is the elasticity of firm i's demand with respect to its own price, holding all other prices fixed;

$\varepsilon_{DD} = \frac{p}{q}\frac{\partial q_i(p_i,p_{-i})}{\partial p} = \frac{p}{q}[\frac{\partial q_i(p_i,p_{-i})}{\partial p_i} + \frac{\partial q_i(p_i,p_{-i})}{\partial p_{-i}}]$ is the elasticity of firm i's demand with respect to a shift in <u>all</u> prices; and

$\varepsilon_m = \frac{p}{\frac{\partial q_i}{\partial p_i}}\frac{\partial}{\partial p}[\frac{\partial q_i(p_i,p_{-i})}{\partial p_i}]$ is the elasticity of the <u>slope</u> of firm i's perceived demand with respect to the common price, p.

Further note that, since symmetry implies $\frac{\partial q_i}{\partial p_j} = \frac{\partial q_j}{\partial p_i}$:

$$\frac{\varepsilon_{DD}}{\varepsilon_{dd}} = \frac{\frac{p}{q}[\frac{\partial q_i(p_i,p_{-i})}{\partial p_i} + \frac{\partial q_i(p_i,p_{-i})}{\partial p_{-i}}]}{\frac{p}{q}\frac{\partial q_i(p_i,p_{-i})}{\partial p_i}} = \frac{[\frac{\partial q_i(p_i,p_{-i})}{\partial p_i} + \frac{\partial q_{-i}(p_i,p_{-i})}{\partial p_i}]}{\frac{\partial q_i(p_i,p_{-i})}{\partial p_i}} = 1 - D$$

Where D is the aggregate diversion ratio, i.e. the proportion of sales lost by one firm as its price is increased that are captured by its rivals.

Pass-through with constant marginal costs: non-technical discussion

With constant marginal costs, the expression for pass-through of industry-wide cost changes under symmetric differentiated Bertrand competition is:

$$pass - through = \frac{1}{2 - D + \frac{elasticity\ of\ slope\ of\ demand}{own\ price\ elasticity\ of\ demand}}$$

where D is the aggregate diversion ratio.

Thus, the expression for industry-wide cost pass-through for the differentiated case starts from the familiar 50% pass-through rate for monopoly with linear demand and is then adjusted to take account of the interaction between firms, as represented by the aggregate diversion ratio, and the curvature of demand. In the differentiated product setting, this curvature term now takes account of the effect on the slope of firm i's demand of an increase in all product prices.

All else equal, pass-through rates in respect of industry-wide cost shocks will be greater the greater is the aggregate diversion ratio, i.e. the greater the extent to which sales lost by one firm as its price is increased are captured by competitors. It should be noted in this respect that the role of aggregate diversion in these expressions arises not because a firm will take account of the extent to which sales are diverted to rivals as it increases its price, but rather because of the extent to which the sales of the firm in question will benefit from the diversion which results from the knock-on price increases of all its rivals.[108] This increase in rivals' prices, and the uplift in sales for the firm in question that this will bring about, will cause that firm to raise its own prices in the differentiated Bertrand setting, all else being equal.

As the intensity of price competition increases, notably if the extent of differentiation is reduced, the own price elasticity will increase and aggregate diversion will tend towards 100%, so the pass-through rate will converge on 100%. Conversely, as the extent of differentiation is increased, and the intensity of competition reduces, the aggregate diversion ratio will fall to 0 and the curvature term will reduce to the 'own' effect only. In other words, the pass-through expression will collapse to the monopoly version. This result is intuitive; as differentiation on the market is increased, each firm will behave increasingly as a 'local' monopolist over a part of the market.

Anderson et al. (2001) also confirms the result derived by Seade for the Cournot case that there will be overshifting of a tax or cost increase, i.e. pass-through in excess of 100%, if demand is sufficiently convex. (This can be seen from the expression above.) Further, the authors find, again analogously to Seade, that firms may actually profit from such a tax increase if the extent of over-shifting is substantial enough, i.e. demand is convex enough. Indeed, the authors argue that such extreme convexity is more plausible with Bertrand competition than in a Cournot

[108] It is $\frac{\partial q_i(p_i,p_{-i})}{\partial p_{-i}}$ rather than $\frac{\partial q_{-i}(p_i,p_{-i})}{\partial p_i}$ which is in the expression as originally derived, though the two are equal in the case of symmetry, allowing the convenient switch described above.

setting, where it implies marginal revenue that is increasing in output. Therefore, Seade's results are not only confirmed in this regard, but they are also established on a more plausible basis in the Bertrand setting.

In the linear case the curvature term disappears and so the pass-through expression reduces to:

$$pass - through_{Linear} = \frac{1}{2 - D}$$

The effect of increasing marginal costs

If marginal costs increase with output, this will reduce the extent of pass-through, all else equally. The slope of marginal cost enters the pass-through expression accordingly, in the same way as for the monopoly case.

4.2.2. Pass-through of firm-specific cost changes in the differentiated Bertrand setting

The general differentiated products setting provides for a much richer competitive environment than the homogeneous Cournot setting. However, this also creates the potential for considerably more complexity at the general level as a result. The literature has, therefore, typically adopted simplifying assumptions, notably symmetry, in order to generate more tractable modelling environments. However, consideration of firm-specific cost pass-through issues inevitably involves an element of asymmetry (as illustrated above). Hence, further specification has been adopted to make practical headway. At the same time, it is important to recognise that particular features of the results generated by these specific models may be model-specific.

4.2.2.1. Linear demand

Zimmerman and Carlson (2010) considers a particular specification of linear demand, i.e. where firm i's demand q_i is assumed to depend linearly on its own price p_i and the prices p_j of $n-1$ competitors. More specifically, the impact of all competitor prices on that demand depends symmetrically on the extent of differentiation indicated by a single parameter φ, as follows:

$$q_i = \alpha - p_i - \varphi\left(p_i - \frac{1}{n}\sum_{j=1}^{n} p_j\right)$$

Thus, the level of firm i's demand will depend on the differences between its own price, p_i and the average price of all firms in the market. The larger the value of φ, i.e. the less differentiated the products, the greater the sensitivity of demand to this price differential. Firms are assumed to have constant marginal costs.

This set-up provides a relatively straightforward setting in which to explore pass-through of firm-specific cost shocks. We are interested in comparing three pass-through effects, namely:

- the 'own' pass-through of a firm-specific marginal cost shock affecting firm i to firm i's own price ($\frac{\partial p_i}{\partial c_i}$);

- the 'cross' pass-through of a firm-specific marginal cost shock affecting firm i to rival firm's prices p_j ($\frac{\partial p_j}{\partial c_i}$); and

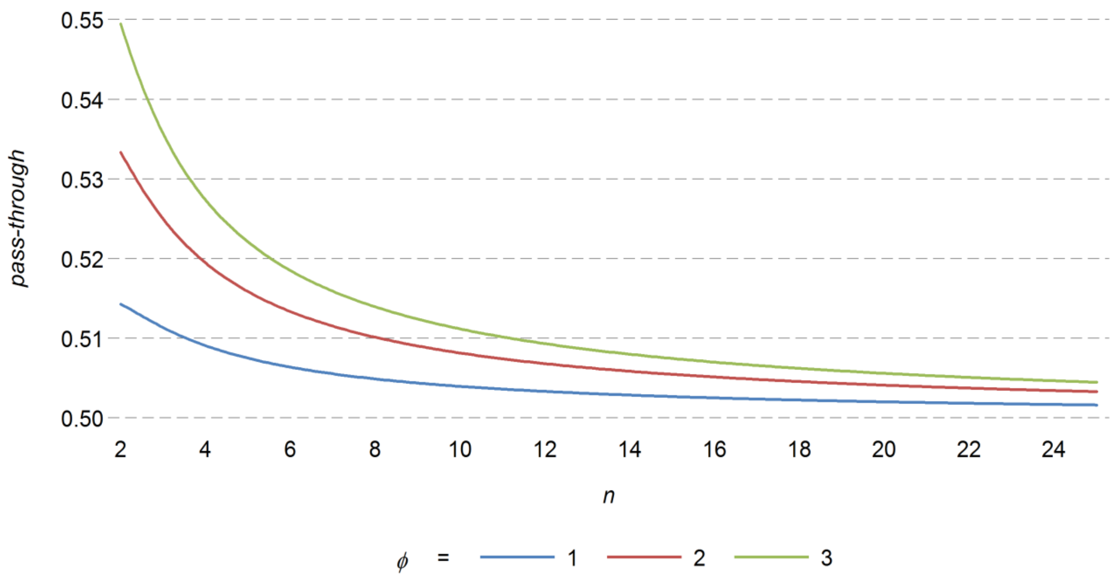
- the impact of an industry-wide marginal cost shock ($\frac{\partial p_i}{\partial c}$).

Relationship between pass-through and market concentration

The diagram below plots the relationship between the level of 'own' price firm-specific cost pass-through and the number of firms, n, in the market. It does this for different values of the product differentiation parameter.

As the number of firms in the market increases, the magnitude of the 'own' price cost pass-through effect decreases, converging on the monopoly level (0.5) as the number of firms becomes large. As the number of firms in the market increases, the impact of any one firm's prices on rivals' pricing behaviour will diminish. As such, the affected firm's price reaction to an increase in its costs will cause less uplift in rivals prices which means that the 'own' price effect will be reduced too. In the limit, the market-wide price effect will be entirely dissipated and 'own' price pass-through will converge on the monopoly level.

Figure 13: Relationship between 'own' price firm-specific cost pass-through and market concentration

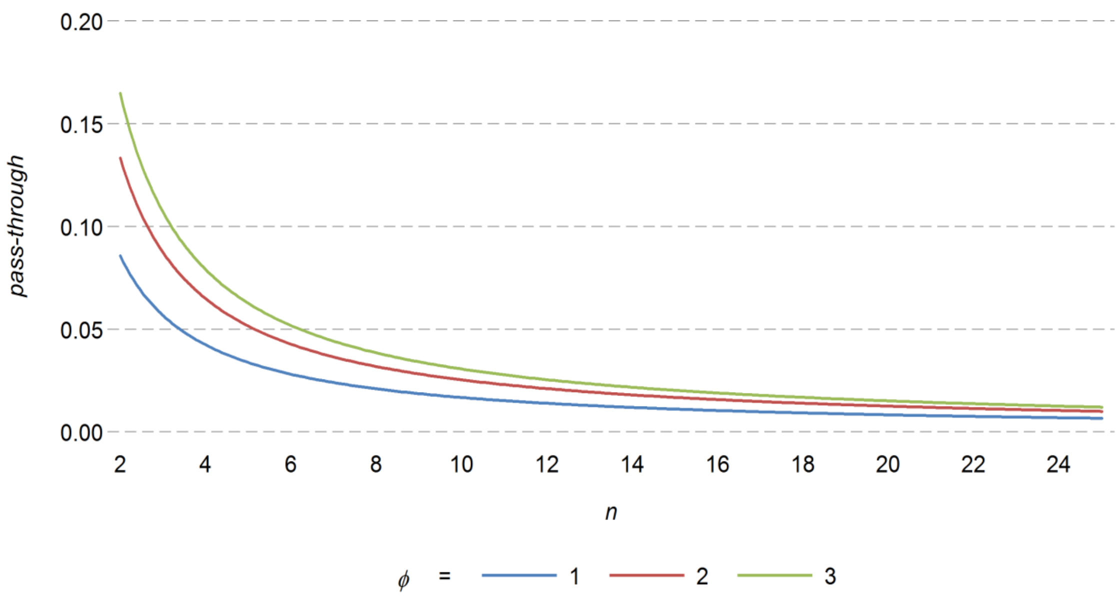


Source: RBB Economics

The greater the degree of substitutability between products (i.e. bigger φ) the stronger the interaction between firm's prices and hence the greater the re-enforcement effect due to the strategic complementarity of prices, leading to a larger 'own' price pass-through effect.

The impact of the number of firms in the market on the magnitude of 'cross' price firm-specific cost pass-through is graphed in the next figure.

Figure 14: Relationship between 'cross' price firm-specific cost pass-through and market concentration



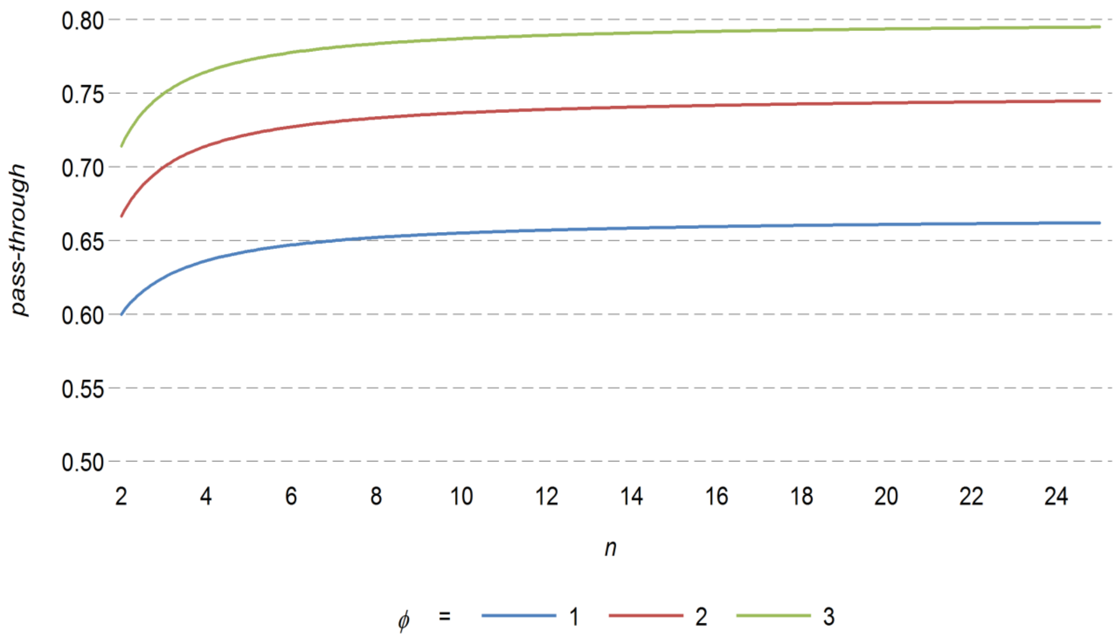
Source: RBB Economics

As with the 'own' price effect, the magnitude of pass-through of a firm-specific cost change to the prices of competitors diminishes as the market becomes more fragmented. In this case, however, the relevant pass-through rate converges on 0 as the number of firms becomes large.

The intuition for this results is as set out in the description of the 'own' price effect. The larger the number of (symmetric) firms on the market, the smaller the impact of one firm's price changes on competitors. The more differentiated the market, the smaller the 'cross' pass-through effect.

Contrast these effects with the impact of an industry-wide cost change, as plotted in the next diagram.

Figure 15: : Relationship between industry-wide cost pass-through and market concentration



Source: RBB Economics

In the case of an industry-wide cost change, pass-through rates are greater when the market is more fragmented, converging on 1 as the number of (symmetric) firms becomes large. Since the cost change affects all firms, there is no dilution of the effect with more firms in the market. Instead, more firms implies more intense competition, and that leads to greater pass-through, in much the same way as increased substitutability of products does.

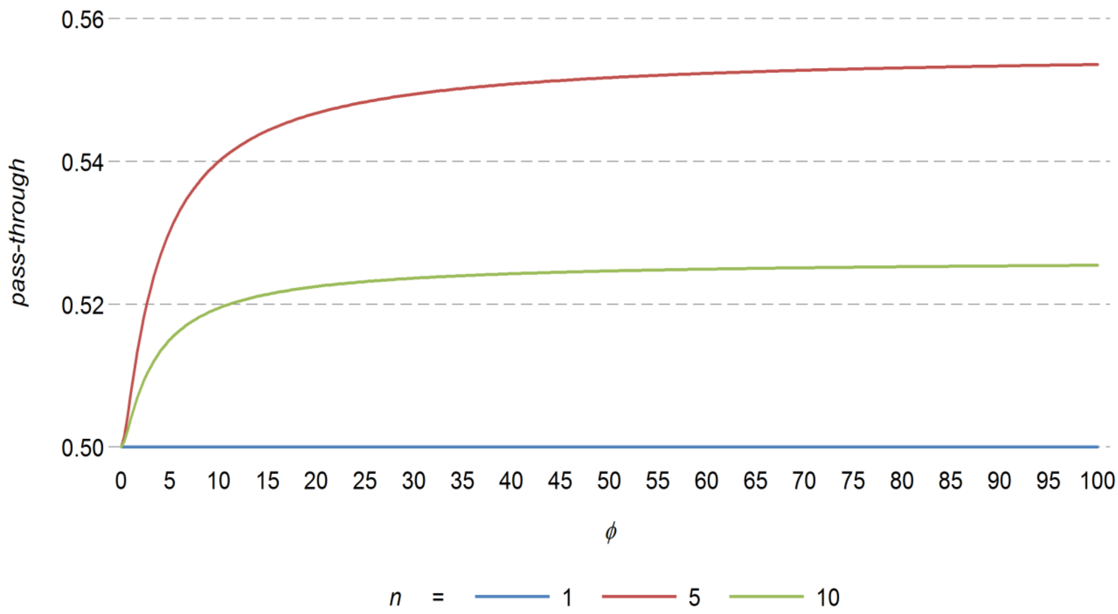
Simple comparison of the graphs for the firm-specific and industry-wide cases above established that the pass-through rates diverge as the number of firms increases, with firm-specific cost pass-through converging on 0 and industry-wide cost pass-through converging on 1.

Relationship between pass-through and product differentiation

For completeness, we also consider the relationship between pass-through rates and the extent of product differentiation more explicitly.

The following diagram graphs the variation in the firm-specific pass-through rate for firm i as φ increases, i.e. as the market becomes more homogeneous (and as the number of firms changes). The pass-through rate increases (albeit relatively modestly) as the degree of product differentiation is reduced and decreases, as described above, as the number of firms is increased.

Figure 16: 'Own' price firm-specific cost pass-through



Source: RBB Economics

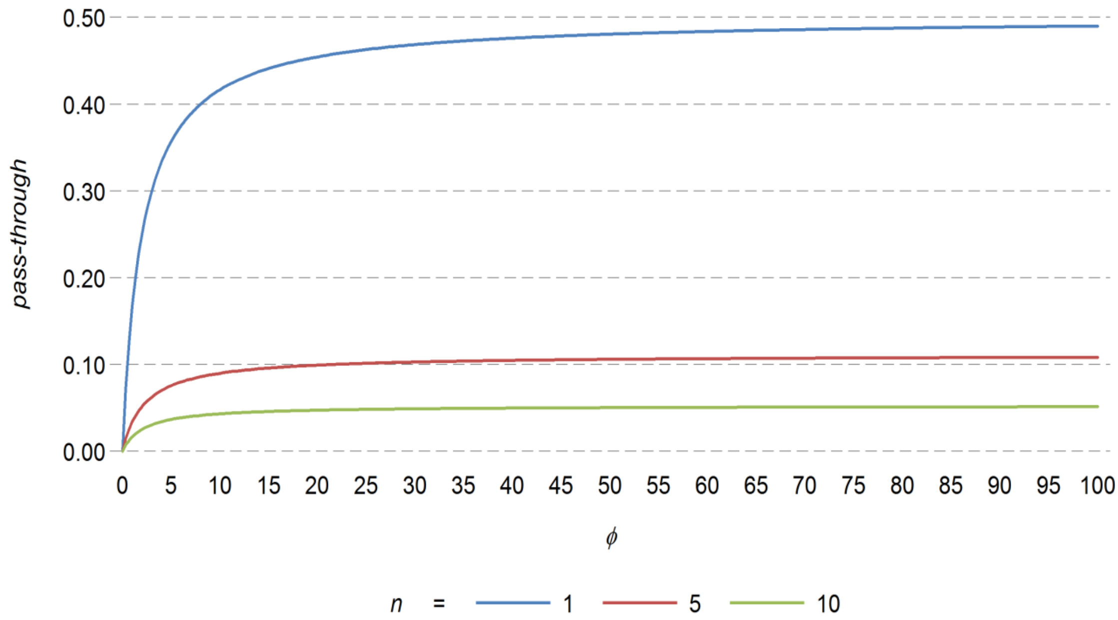
When $\varphi = 0$, differentiation is absolute and there is no competition at all between firms. Consequently, each firm acts like a monopolist. Unsurprisingly, therefore, the firm-specific cost pass-through rate is 50% - the value for monopoly with linear demand and constant marginal costs.

In this Bertrand setting, the pass-through rate increases as the extent of differentiation is reduced (i.e. as φ increases such that products become more substitutable). As that happens, the competitive interaction between firms – and, critically, their prices – increases. Under Bertrand assumptions, if firm i increases its price then rivals will set higher prices in equilibrium too. However, firm i's best response to higher rival prices will be to increase its own price still further. Hence, as the competitive interaction between firms grows, so the own-price firm-specific cost pass-through rate will increase.

In Zimmerman and Carlson's set-up, the firm-specific cost pass-through rate never falls below 50% even as the extent of product differentiation becomes limited and the number of firms increases. The intuition for this is that as the total number of firms grows, the impact of firm i's price changes on the behaviour of other firms becomes negligible; the 'cross' firm-specific pass-through effect becomes negligible (See diagram below.). As a result, the change in firm i's price is increasingly determined only by the direct effect of the cost change, just as in a monopoly (or maximum product differentiation) scenario. Unsurprisingly, therefore the pass-through rate converges on the monopoly rate of 50%.

Now consider the effect of reduced differentiation and an increase in the number of firms on the cross pass-through of the marginal cost change affecting firm i to rival firm j's price, p_j. This is illustrated in the diagram below.

Figure 17: 'Cross' price firm-specific cost pass-through



Source: RBB Economics

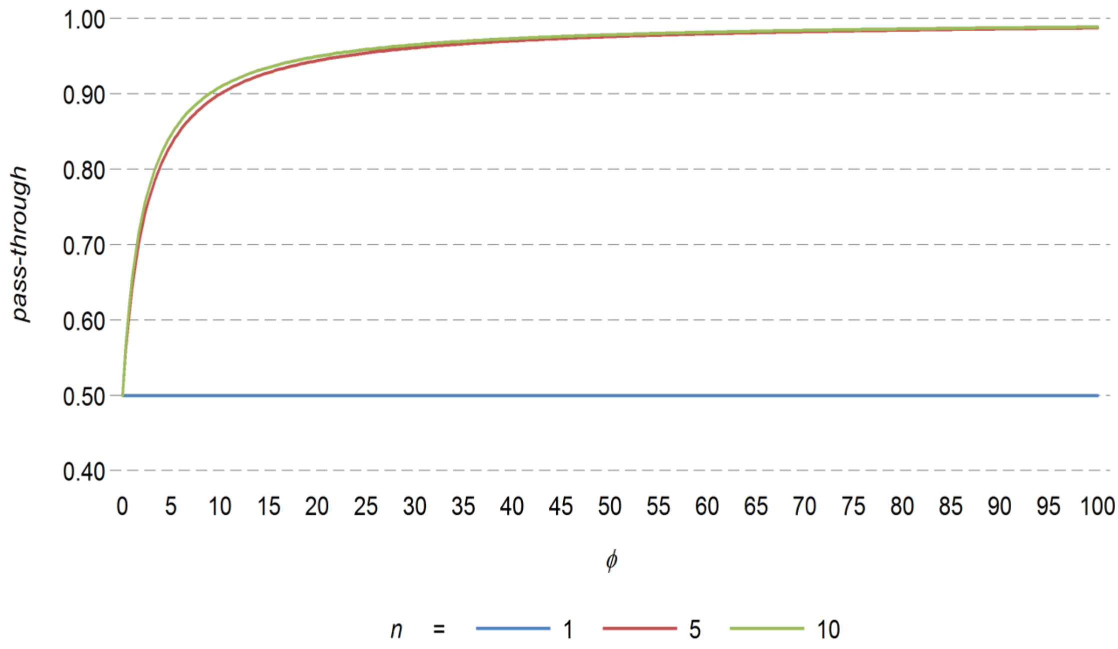
The broad shape of the effects of reduced differentiation and increases in the number of firms is as for the 'own price' effect, albeit the level of pass-through is much lower, as might be expected.

When $\varphi = 0$ and there is no competition at all between the differentiated products, a change in firm i's prices will have no effect on firm j. Hence, firm j's price will not respond to the marginal change in firm i's costs. As substitutability increases and competition intensifies as a result, a pass-through effect emerges. This is because the cost shock causes p_i to increase. In turn this will cause firm j to increase its price p_j too, as the graphical illustration above shows. The stronger the competitive interaction between firm i and firm j, the greater the pass-through effect. This is because of the increasing strategic complementarity between rival firms' prices as the extent of differentiation is reduced.

Finally, consider the pass-through rate for an industry-wide cost shock.[109] This, and its variation with the differentiation parameter φ and the number of firms are illustrated in the figure below.

[109] It can be shown that the industry-wide pass-through rate derived from the Zimmerman-Carlson model is identical to the more general formulation for differentiated Bertrand settings with linear demand set out above.

Figure 18: Industry-wide pass-through

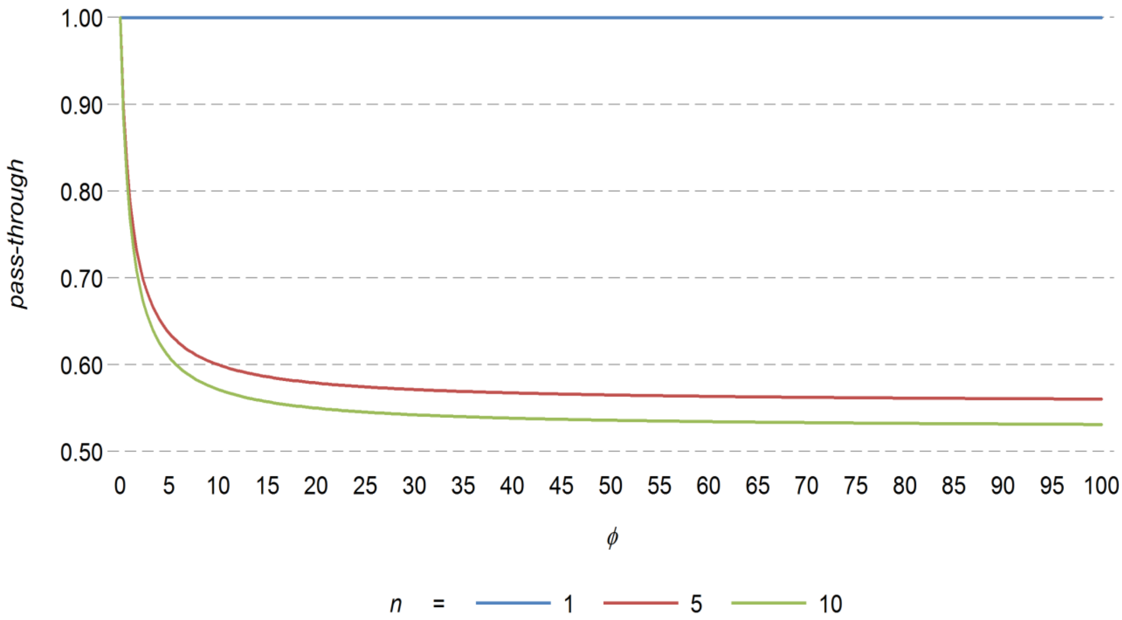


Source: RBB Economics

When there is no competition between firms ($\varphi = 0$), each firm operates as a 'local' monopolist, and the effects of the firm-specific and industry-wide cost-shocks are identical. As the competitive interactions between firms intensify, so the industry-wide cost pass-through rate increases, converging towards 100% as φ tends towards infinity (i.e. product homogeneity). Hence, the industry-wide cost pass-through effect converges on the perfect competition value in the limit, as one would expect.

In the diagram below, we plot the ratio of the industry-wide and firm-specific pass-through effects for firm i. The chart shows that when firms are highly differentiated, the industry-wide and firm-specific pass-through rates are similar, for the reasons explained above. However, as the industry becomes less differentiated, the industry and firm-specific pass-through rates increasingly diverge. As the intensity of the competitive interaction between firms grows, the difference between a scenario where only one firm is affected by a cost change and the scenario where all firms are affected becomes increasingly pronounced. The 'multiplier' effect due to the strategic complementarity of prices in the Bertrand case (one firm's price increase causes rivals to raise their price too) is far stronger in response to an industry-wide cost change.

Figure 19: Firm-specific pass-through relative to industry-wide pass-through



Source: RBB Economics

Significantly, from a practical perspective, the 'gap' between the industry-wide and firm-specific pass-through rates grows as the extent of product differentiation increases. Hence, the industry-wide cost pass-through measure will provide an increasingly misleading over-estimate of the magnitude of the firm-specific pass-through effect.

4.2.2.2. Logit demand

Firm-specific cost pass-through rates with logit demand are non-linear functions of market shares. Verboven and van Dijk (2009) provides the formulation of the 'own' firm-specific cost pass-through rate for firm i, namely:

$$\frac{\partial p_i}{\partial c_i} = \frac{1}{s_i(1-s_i)}(s_i T_i + (1-s_i)^2)$$

where:

s_i is firm i's share, for $i = 1\ to\ N$, and is given by $s_i = \frac{e^{a_i - bp_i}}{1+\sum_{k=1}^{N} e^{a_k - bp_k}}$;

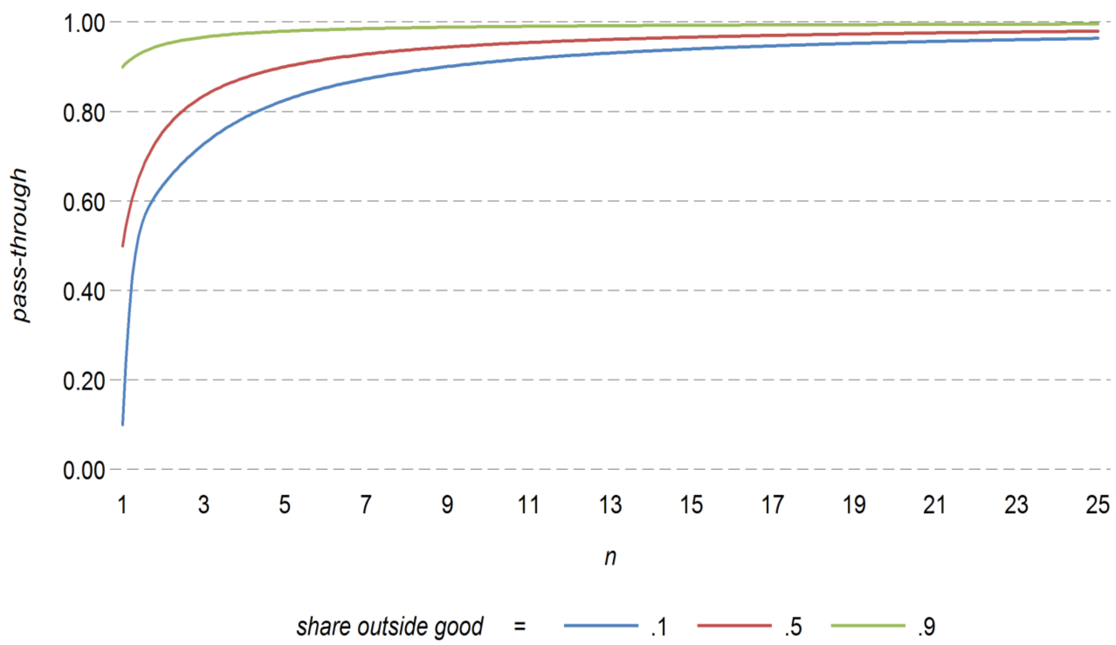
s_0 is the share of the 'outside' good; and

$T_i = \frac{s_i.(1-s_i)^2}{s_i+(1-s_i)^2} / \left(s_0 + \sum_{k=1}^{N} \frac{s_k \cdot (1-s_k)^2}{s_k+(1-s_k)^2}\right)$

It is evident from this formulation that, in general, firm-specific pass-through rates will depend in a complex way on the individual firm's 'market' share, and the distribution of the shares of other products, including between the 'inside' goods and the 'outside' good.

Supposing, however, that the 'inside' goods are symmetric and have identical shares as a result, the relationship between the number of products/firms and the firm-specific cost pass-through rate, for a given outside good share is plotted in the diagram below.

Figure 20: 'Own' price firm-specific cost pass-through



Source: RBB Economics

The diagram indicates that firm-specific pass-through in the logit case *increases* with the number of firms, and converges towards a pass-through rate of 100% as the number of firms becomes large. Moreover, the level of firm-specific cost pass-through is greater the greater the share of the 'outside' good, which implies more intense competition between the 'inside' goods.

It is notable, therefore, that the firm-specific pass-through rate increases with the number of firms for logit demand but decreases with the number of firms for the linear demand specification considered by Zimmerman and Carlson. This suggests that a wide range of pass-through rates may be realised in differentiated product settings, depending on the exact specification of the setting concerned.

A more detailed analysis of pass-through rates with logit demand is provided in the numerical case study presented in Chapter 6.

4.3. A nesting formulations for industry-wide cost pass-through

In preceding sections of this study we have identified pass-through expressions for a number of different models of competition. Weyl and Fabinger (2013) usefully establishes a generalised formulation for industry-wide cost pass-through with symmetric firms. This allows the different pass-through expressions derived above to be related to each other, thereby identifying the underlying factors at work in shaping pass-through rates.

4.3.1. A generalised approach: Weyl and Fabinger (2013)

Weyl and Fabinger (2013) assesses pass-through in detail. It sets out a general expression for industry-wide cost pass-through with symmetric firms which nests the specific expressions considered in this and previous chapters – including perfect competition, monopoly, homogeneous goods Cournot competition, and differentiated product Bertrand competition. That general expression is:

$$\frac{dp}{dt} = \frac{1}{1 + \frac{\varepsilon_D - \theta}{\varepsilon_S} + \frac{\theta}{\varepsilon_\theta} + \frac{\theta}{\varepsilon_{ms}}}$$

where:

θ is a conduct parameter which ranges from 1 for monopoly to 0 for perfect competition and reflects the elasticity of market demand multiplied by the percentage mark up over marginal cost. For symmetric Cournot, $\theta = \frac{1}{n}$, where n is the number of firms. For Anderson et al.'s model with price setting behaviour, $\theta = \frac{\varepsilon_{DD}}{\varepsilon_{dd}}$. This is also equal to $(1 - D)$, where D is the aggregate diversion ratio.

ε_D and ε_S are the elasticities of demand and *competitive* supply respectively. If competitive supply would be perfectly elastic (constant marginal costs) the second term in the denominator of the general expression disappears

ε_θ is the elasticity of the conduct parameter. Its inclusion in the general expression allows for the possibility that the intensity of competition will change as quantity/price varies, though this will not always be the case.[110]

ε_{ms} is the elasticity of the inverse marginal consumer surplus, and provides a measure of demand curvature. Whilst this measure is different to the elasticity of slope of inverse demand (ε_{SID}) considered in this study, the underlying curvature effect is unchanged. Weyl and Fabinger (2013) notes that the $qp'(q)$ component of the marginal revenue term is also the marginal change in consumer surplus. Thus, $\frac{1}{\varepsilon_{ms}}$ is equal to $1 + \frac{qp''(q)}{p\prime(q)} = 1 + \varepsilon_{SID}$. Observe that the weight given to this curvature term diminishes as the conduct parameter becomes smaller, i.e.

[110] The Weyl and Fabinger (2013) formula above equals that provided by Anderson et al. (2001), as noted above, provided that $\frac{\varepsilon_D - \theta}{\varepsilon_S} + \frac{\theta}{\varepsilon_\theta} = 0$, i.e. where marginal costs are constant and the conduct parameter does not change as output changes.

conduct is more competitive. Depending on the sign of the curvature effect, pass-through may therefore increase or decrease with more intense competition.

With perfect competition ($\theta = 0$), for example, the general expression reduces to the form seen previously:

$$\frac{dp}{dt} = \frac{1}{1 + \frac{\varepsilon_D}{\varepsilon_S}}$$

For monopoly ($\theta = 1$):

$$\frac{dp}{dt} = \frac{1}{1 + \frac{\varepsilon_D - 1}{\varepsilon_S} + \frac{1}{\varepsilon_{ms}}}$$

This formulation of the monopoly pass-through relationship facilitates comparison with the perfect competition benchmark. There are two evident differences between the two expressions. First, the relationship between the elasticities of demand and supply is different in the monopoly case, essentially because price involves a mark-up over marginal cost in this case.[111] (Weyl and Fabinger (2013) explains that the term $\varepsilon_D - 1$ can be thought of in the context that the monopolist would not choose to operate on the inelastic part of its demand curve, i.e. the elasticity of demand will exceed 1.) Second, the curvature of demand is relevant to the monopoly case, but not in the perfect competition scenario, as we have seen.

4.3.2. An extension to Cournot: industry-wide pass-through in the case of conjectural variations

In principle, quantity setting games can be generalised by the addition of a conjectural variation parameter.[112] A straightforward extension of the Cournot case above is then to allow for the possibility that a firm conjectures that its output change will be met by an output change by its rivals. Assuming that all firms have identical conjectures, and denoting (1 + sum of firm conjectures) to be equal to an intensity of competition parameter, the following pass-through expression can be derived:

$$\frac{dp}{dt} = \frac{n}{n + \gamma(1 + \varepsilon_{SID})}$$

where ε_{SID} is the elasticity of slope of the inverse demand curve, identified previously.

[111] As explained in the previous footnote, $\frac{c'}{p} = 1 - \frac{1}{\varepsilon_D}$ in the monopoly case. In the perfect competition case price equals marginal cost, so $\frac{c'}{p} = 1$.

[112] Note that a conjectural variations approach raises the theoretical issue that in a one-shot, simultaneous move game the concept that a firm conjectures that a rival will react to its output is not consistent with the mechanism of the game itself. Further, the approach can be criticized in the sense that outside of perfect competition, Cournot conduct and monopoly, the parameters are hard to underpin in theory. Conjectural variations are discussed in detail in the RBB report on that subject prepared for the OFT. (See RBB Economics (2011).)

Perfect competition is modelled by setting the parameter, $\gamma = 0$ in the above formula. The Cournot result is obtained by setting $\gamma = 1$, and the monopoly result with $\gamma = n$. In other words, to the extent that the parameter has meaning outside of the preceding cases, an increase in competition can be thought of as a *reduction* in γ.

It can be shown that pass-through becomes greater as the degree of competition increases (whether measured by a reduction in γ or an increase in the number of firms, n), *provided that* the demand curve is not too convex (i.e. $\varepsilon_{SID} > -1$). This result is reversed when the demand curve is sufficiently convex (i.e. $\varepsilon_{SID} < -1$).[113] Linking this back to the general model from Weyl and Fabinger (2013) set out above requires setting $\theta = \frac{\gamma}{n}$ and assuming that $\frac{\theta}{\varepsilon_\theta} = 0$.

4.4. The effect of entry and exit

Besley (1989) extends the Cournot framework developed by Seade (1985) to allow for long-run variation in the number of firms. Specifically, he considers an equilibrium where not only are firms' first order conditions satisfied (as in Seade, 1985) but also the number of firms is assumed to adjust to satisfy a 0 profit condition, i.e. entry/exit ensures that all firms make 0 profits in equilibrium. (A fixed production cost ensures a finite number of firms.)

Besley finds that an increase in a per unit tax/cost always decreases total output and increases price. This result is in line with Seade's short-run analysis, which holds the number of firms fixed, but the underlying effects are very different. Contrary to the short-run case, the outputs of individual firms may increase. This will occur whenever demand is concave. At the same time, there will also be market exit so that there will be a reduction in overall output. If demand is convex then a tax increase will bring about a reduction in individual firm output. If demand is sufficiently convex, there will also be market entry in response to an increase in tax, which is consistent with Seade's finding that individual profits increase under this condition. Very convex demand implies that a unit tax increase will induce a very large increase in price. This increases profits, inducing entry.

Summing up, concave demand always induces an increase in individual output and market exit. A moderately convex demand induces a decrease in individual output and market exit. A sufficiently convex demand induces a decrease in individual output and market entry.

Pass-through depends on the curvature of demand. Concave demand implies a tax pass-through rate that is less than 100%, whereas convex demand implies a tax pass-through rate above 100%. Significantly, compared to Seade's short run (fixed n) case, the condition for overshifting is less demanding when the number of firms also adjusts. Specifically, demand does not have to be as convex for overshifting to occur when the number of firms is allowed to vary.

Anderson et al. (2001) also allows the number of firms to vary in equilibrium, but in a differentiated Bertrand setting. Nevertheless, the long-run analysis is consistent with Besley (1989), in the sense that a tax/cost increase is more likely to increase producer prices in the

[113] This can be seen by differentiating the expression for pass-through with respect to φ or N.

long-run than in the short-run. In other words, less convexity is needed in demand for overshifting to occur when the number of firms is allowed to adjust than when the number of firms is fixed.

4.5. Summary: Oligopoly

- In oligopoly settings, the extent of pass-through depends on the nature of the strategic interactions between firms. These will be affected by the intensity of competition, the extent of product differentiation, and industry concentration.
- Differences between industry-wide and firm-specific cost pass-through arise and can be significant, both in magnitude and for competitive assessment.
- The extent of industry-wide pass-through in a symmetric oligopoly depends in general terms on:
  - the curvature of demand: pass-through is increased if demand is convex and reduced if demand is concave;
  - the intensity and 'type' of competition: pass-through increases as competition intensifies unless demand is very convex;
  - the elasticity of that conduct (i.e. how the competitive interaction changes with output); and
  - the relative values of the elasticities of demand and of competitive supply (i.e. the percentage change in the quantity supplied under competitive conditions given a percentage change in marginal costs), if marginal costs are not constant.
- Pass-through rates can exceed 100% and, if demand is sufficiently convex, firms may profit from an industry-wide increase in costs as a result.

Pass-through with (Cournot) quantity competition

- In homogeneous goods settings with Cournot competition in quantities, industry-wide and firm-specific cost pass-through rates diverge as the number of firms in the market increases, with the former converging on 100% while the latter converges on 0.
- However, the distribution of market shares between firms does not affect pass-through.
- When Cournot competition involves differentiated products, non-monotonic relationships between firm-specific pass-through rates and the number of firms are possible.

Pass-through with price ('Bertrand') competition between differentiated products

- Since prices are so-called strategic complements, cost pass-through effects are re-enforcing in this case.

- A key factor affecting industry-wide cost pass-through in differentiated product settings with price competition is the aggregate diversion ratio.
- Predictions in respect of firm-specific cost pass-through rates are sensitive to assumptions, with theoretical support for a wide range of potential outcomes. For example, in some settings firm-specific pass-through rates may increase with the number of firms in the market, whilst in other settings they are predicted to decrease.

Entry and exit

- When the number of firms in the market can respond to changes in unit costs, the scope for pass-through rates in excess of 100% is increased.
- In a quantity setting context with concave demand, the outputs of individual firms are predicted to increase in response to a cost change when exit is possible, contrary to the ‘short-run’ results. On the other hand, with sufficiently convex demand, individual firm outputs may decrease though market entry also occurs.

5. Pass-through and vertical supply relationships

The process of supplying goods and services to end consumers frequently involves multiple steps, with an 'upstream' firm supplying intermediate goods or services to a 'downstream' firm which may transform those goods or augment the services offered before supplying end consumers, or customers at a further, intermediate stage in the overall supply chain. The economics of pass-through in this context, and the extent to which a cost change at a particular point along the supply chain is passed on to end consumers will, therefore, generally depend on the nature of the vertical linkages between different stages of supply and the horizontal structures of supply at each stage.

There is an extensive literature considering the effects of vertical integration and vertical contractual restraints in this context. A comprehensive review of that literature is beyond the scope of this study. However, in this chapter we draw out some of the principal themes as they relate to the pass-through issue, illustrated largely in the context of the simplest monopoly set-up..

5.1. Monopoly

In this section, we will consider the simplest vertical set-up, involving one monopolist – the upstream firm – supplying an input to another – the downstream firm – which uses it to produce output sold to consumers. For simplicity, we will assume here that it is a one-to-one relationship between a unit of input and a unit of output.

5.1.1. Double marginalisation

When supply involves more than one vertically-related step, the relationship between costs and end-user prices will depend on the combined effect of the separate mark-ups set by the vertically-related firms. Following Spengler (1950), the effects of so-called double marginalisation have received considerable attention in the economics literature.

Pass-through and mark-ups

The standard mark-up condition for profit maximisation means that a downstream monopolist will set the proportionate mark-up of its price p over marginal cost, including any unit wholesale price, equal to the inverse of the elasticity of demand. In terms of the *absolute* mark-up, m_D, this means that:

$$p - w - c_D = m_D = \frac{p}{\varepsilon(p)}$$

where w is the unit wholesale price paid to the upstream firm, c_D is the downstream firm's own (constant) marginal cost of production, and $\varepsilon(p)$ is the elasticity of demand.[114]

As can be seen, the downstream firm's choice of p depends on w, the wholesale price set by the upstream supplier, amongst other factors. In setting this wholesale price, the upstream monopolist will take account of this link, and the impact that the choice of wholesale price will have on the price set and volume of sales consequently made by the downstream monopolist, since the latter will determine the upstream firm's own sales. The greater the pass-through rate on the downstream market, the greater the impact that a given increase in the wholesale price will have on the price set by the downstream monopolist and, hence, on the sales secured by the upstream firm. Thus, the downstream pass-through rate will affect the upstream firm's choice of mark-up.

To see this, suppose the downstream pass-through rate is ρ_D. (In this instance, that rate will be the monopoly expression, as described in section 3.2 of this study.) An upstream monopolist that supplies on the basis of a unit wholesale price only will take account of this link in setting that price, w, as follows:[115]

$$w - c_U = m_U = \frac{p(w)}{\varepsilon(p(w))} \cdot \frac{1}{\rho_D}$$

where c_U is the upstream firm's (constant) marginal cost of production and m_U is its absolute margin.[116] Note that the value of the retail price, p, in this expression is identical to that in the equivalent downstream version. Hence:

$$(w - c_U) = \frac{1}{\rho_D} \cdot (p - w - c_D)$$

The greater is pass-through at the downstream stage, the smaller the margin set by the upstream firm relative to the margin set by the downstream firm. Moreover, the upstream margin will be larger (smaller) than the downstream margin when the pass-through rate is less (greater) than 100%.

Combining upstream and downstream mark-up expressions, we can see that the overall absolute mark-up over costs caused by the double monopoly will be sensitive to the downstream pass-through rate:

$$p - c_D - c_U = \frac{p}{\varepsilon(p)} \cdot \left(1 + \frac{1}{\rho_D}\right)$$

[114] See Weyl and Fabinger (2009).

[115] To see this, observe that the upstream monopolist's profit maximising first order condition is given by:

$$(w - c_U) \cdot q'\big(p(w)\big) \cdot \frac{dp}{dw} + q\big(p(w)\big) = 0$$

where $\frac{dp}{dw}$=ρ_D is the downstream pass-through rate.

[116] This can also be expressed in term of the downstream pass-through elasticity, $\varepsilon_{\rho D} = \frac{w}{p}\frac{dp}{dw}$, as follows: $\frac{w-c_U}{w} = \frac{1}{\varepsilon(p)} \cdot \frac{1}{\varepsilon_{\rho D}}$

Comparing this with the profit maximising condition for the vertically integrated firm (which excludes the bracketed term including ρ_D) indicates that the overall mark-up will be greater if the upstream and downstream monopolists are vertically separated than if they are vertically integrated, confirming the familiar double marginalisation result. The extent of the difference is shaped by ρ_D. The greater the pass-through rate, the closer the non-integrated outcome to the integrated case.

Overall pass-through of upstream costs to downstream prices

In this context, it is interesting to consider too the impact that vertical integration or separation has on extent to which a change in the upstream firm's marginal production costs would be passed through to final consumer prices, rather than be absorbed by the upstream and/or downstream firms. We term this the *overall* pass-through of upstream costs.

As noted, the downstream monopolist will pass through any increase in wholesale prices at the rate ρ_D - according to the standard monopoly formulation that is relevant our example. However, the overall pass-through rate under vertically separated monopolies will depend on both the upstream and downstream pass-through rates. Thus:[117]

$$overall\ pass\ though\ = upstream\ pass\ through\ \times\ downstream\ pass\ through = \ \rho_U \cdot \rho_D$$

We have explained above that the mark-up adopted by the upstream firm will depend on the downstream pass-through rate. The upstream pass-through rate will, similarly, be linked to the downstream pass-through rate. The relationship between upstream and downstream pass-through rates depends on how the downstream pass-through rate changes as price increases. If that pass-through rate increases with price, then the upstream pass-through rate ρ_U will be greater than the downstream rate ρ_D. On the other hand, if the downstream pass-through rate decreases with price, then the upstream pass-through rate ρ_U will be less than the downstream rate ρ_D.

With a constant downstream pass-through rate, i.e. one that is independent of price, the upstream pass-through rate will be identical to the downstream rate. One implication of this is that in that case the overall pass-through rate of upstream costs to final prices is given by:

$$overall\ pass\ through = \rho^2$$

It then follows that the overall pass-through rate will be less than upstream pass-through in this case if $\rho < 1$ (cost absorbing scenario), and greater than upstream pass-through if $\rho > 1$ (cost amplification scenario). In other words, the extra stage in the supply chain will reduce overall pass-through if $\rho < 1$ but increase it if $\rho > 1$.[118]

By way of comparison, changes in costs will be passed through to retail prices at a rate ρ when the upstream and downstream monopolists are vertically integrated.[119] Thus, the overall extent

[117] To see this, observe that $\frac{dp}{dc_U} = \frac{dp}{dw} \cdot \frac{dw}{dc_U}$

[118] More generally, this will also depend on the level of the absolute mark-up and on whether pass-through increases or decreases with price.

[119] The profit-maximising vertically integrated monopolist firm will transfer inputs internally at marginal cost, c_U.

to which a change in upstream costs would be passed through to final prices will also be greater or less in the vertically separated case than in the vertically integrated case depending on whether ρ is less than or greater than 1.

5.1.2. An example

Suppose that demand for the downstream product is given by the linear form:

$$Q = 1 - p$$

Suppose too that $c_D = 0$ and $c_U = c$.

Vertical separation

In this case, it is easily shown that the downstream monopolist sets a price p which is given by:

$$p = \frac{1+w}{2}$$

In this case, a £1 increase in the wholesale price, w, would bring about a £0.50 increase in the retail price. In other words, the downstream pass-through rate is ½.

The upstream firm chooses the wholesale price, w, to maximise its own profit, taking into account the effect that this wholesale price will have on the final price set by the downstream firm and, therefore, on demand for its product. Taking account of the relationship between w and the retail price p, upstream demand is given by $Q = \frac{1-w}{2}$. The profit maximising upstream firm will set a wholesale price w given by:[120]

$$w = \frac{1+c}{2}$$

Thus, the upstream pass-through rate is also ½; a £1 increase in c will bring about a £0.50 increase in w.

Combining expressions:

$$p = \frac{1+w}{2} = \frac{1}{2} + \frac{1}{2}\left(\frac{1+c}{2}\right) = \frac{3+c}{4}$$

The rate at which a change in upstream costs would be passed through to final price is ¼; i.e. the product of the upstream and downstream pass-through rates.

Vertical integration

In the integrated case, the monopolist would set its price p to maximise:

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[120] The upstream firm then maximises: $\frac{1}{2}(w-c)\cdot(1-w)$.

$$\pi_{VI} = (p - c) \cdot (1 - p)$$

It is easily shown that this profit-maximising price is:

$$p_{VI} = \frac{1 + c}{2}$$

In this case, the overall pass-through rate of a change in the upstream cost would be ½. Hence, increases in upstream cost will be passed through to retail prices in the vertically separated case at half the rate of the vertically integrated case.

5.1.3. Vertical restraints

In the first section of his chapter we highlighted the double marginalisation inefficiency that arises when upstream and downstream firms transact on the basis of a unit wholesale price. We also noted the inter-relationship between the extent of double marginalisation and pass-through. However, where the upstream monopolist has access to a richer set of contractual solutions, these double-marginalisation problems can be ameliorated or eliminated. The introduction of such restraints will have implications for pass-through too.

5.1.3.1. Overcoming double marginalisation

We illustrate the impact of vertical restraints in resolving double-marginalisation issues by considering the use of two-part tariffs and resale price maintenance.

Two-part tariffs

Suppose that the manufacturer can make use of two-part tariffs, whereby the retailer pays both a unit wholesale price w for each unit of the product purchased and also a fixed fee, F, paid irrespective of the volume of wholesale purchases made. In the circumstances described above, the optimal two-part tariff from the manufacturer's perspective would involve a wholesale price set equal to upstream marginal cost, c_U, with a fixed fee set to extract (all) profit from the retailer. In this case, the retailer's individual profit maximising behaviour would lead to it setting a retail price p^* which maximises the aggregated profit of the manufacturer and retailer. (The level of the fixed fee will not affect the retailer's pricing decisions, though it could affect the willingness of the retailer to accept the manufacturer's terms in the first place.) Thus:

$$Unit\ wholesale\ price\ set\ at\ marginal\ upstream\ cost\text{:}\ \ w = c_U$$

$$p^* chosen\ by\ retailer\ to\ maximise\ \pi = (p - c_D - w) \cdot Q(p) - F = \ (p - c_D - \ c_U) \cdot Q(p) - F$$

$$Fixed\ fee, F, set\ to\ extract\ profit\ from\ retailer$$

In summary: in this case the two-part tariff arrangement allows the manufacturer to earn a profit whilst setting the wholesale price at cost, thereby eliminating one of the margins that gives rise to the double marginalisation problem.

In this case, the level of the wholesale price that is set by the manufacturer will vary on a one-to-one basis with the manufacturer's marginal costs, i.e. there will be 100% pass-through of any changes to those costs (that occur prior to the wholesale price being fixed).

$$Upstream\ pass\ through, \frac{dw}{dc_U} = 1$$

Any change in the retailer's marginal costs (including unit wholesale charges) will cause an adjustment to its profit maximising pricing decision.[121] Wholesale price changes will also be passed through to retail prices according to the downstream pass-through rate. Hence, in this case:

$$Overall\ pass\ through\ of\ upstream\ costs = downstream\ pass\ through$$

$$\frac{dp}{dc_U} = \frac{dp}{dc_D} = \rho_D$$

This is the same as in the vertically integrated case.

Resale price maintenance[122]

As a matter of economic theory, resale price maintenance (or a price ceiling, at least) offers an alternative solution to the double marginalisation problem in the simple monopoly case. Specifically, suppose that the manufacturer is able to fix the retail price charged by the retailer directly. In this case, it could set the retail price at the level which maximises profit over the entire supply chain, and then use the wholesale price and/or a fixed fee to extract that profit from the retailer. In other words:

$$p^*\ fixed\ by\ manufacturer\ to\ maximise\ \pi_{VI} = (p^* - c_D - c_U) \cdot Q(p^*)$$

$$Fixed\ fee, F, and\ wholesale\ price, w, used\ to\ extract\ profit\ from\ retailer$$

In order to maximise profits, the retail price set would respond to changes in upstream and/or downstream marginal costs according to the pass-through rate for the integrated firm.

Alternatively, the manufacturer might fix the margin available to the retailer, e.g. capping it to be no more than the downstream production cost, c_D. (This margin would therefore have to be adjusted to reflect any changes in the retailer's cost, in order to ensure the retailer's willingness to accept the terms on offer.) The choice of wholesale price would then translate into a retail price, given the cap on the retail margin, and would be set to ensure the best retail price from the manufacturer's perspective. If p^* is that best retail price, the wholesale price w will be given by:

$$w = p^* - c_D$$

---

[121] The fixed fee paid by the retailer will also have to be adjusted in response to the effect of any increase in unit wholesale charges or retailer costs, c_D, in order to ensure the retailer breaks even, since retail profits will decline if the wholesale price or its own cost increases, all else being equal. However, the level of this fixed fee should not affect prices.

[122] See comment on the legal treatment of resale price maintenance at footnote 2.

Changes in either upstream or downstream costs, which will cause the manufacturer's preferred retail price to change, will necessitate a change in the wholesale price too. If there is no change in downstream costs, this adjustment will maintain the retail margin, given the change in the preferred retail price. If downstream costs have changed, a change in the downstream margin will need to be accommodated too.

For changes affecting upstream costs only, the wholesale price would be adjusted to match the change in the optimal retail price on a one-to-one basis, so as to maintain the absolute retail margin. That implies 100% observed pass-through between wholesale price changes and retail price changes.

$$Upstream\ pass\ through\ = overall\ pass\ through\ of\ upstream\ cost, i.e.$$

$$\frac{dw}{dc_U} = \frac{dp}{dc_U}$$

On the other hand, where cost changes affect the downstream firm, the wholesale price would be adjusted to take account of both (1) the change in the overall profit-maximising price this necessitates, and (2) the wider absolute retail margin required to ensure that the retailer can cover its costs. The pass-through effects of such changes would then be given by:

$$Adjustmentfor\ downstream\ cost\ change = downstream\ pass\ through - 1, i.e.$$

$$\frac{dw}{dc_D} = \frac{dp}{dc_D} - 1$$

In this case, changes in downstream costs would be passed through to retail prices as in the vertically integrated case. However, changes in *downstream* costs would also have an impact on *wholesale* prices in this case.

5.1.3.2. Uncertainty

The previous discussion assumes a world of perfect certainty. In practice, the businesses of both the manufacturer and retailer may be subject to *ongoing* uncertainty after supply terms are set. To illustrate the implications, consider the effects of such uncertainty regarding the level of costs.[123]

Two-part tariffs

Once wholesale terms are fixed, changes in manufacturer or retailer costs will not affect those terms. As a result, there won't be any pass-through of changes in manufacturer costs to wholesale prices until those prices are revised.[124] (Such contracts therefore provide an explanation for pricing rigidities.) However, with just a two-part tariff structure in place, the retailer has the flexibility to adjust its prices in response to changes in its own costs (or in demand conditions). Retail cost changes will be passed through to retail prices, therefore.

[123] Uncertainty may also affect demand conditions too.

[124] In principle, a richer setting might also allow for the possibility of renegotiation of wholesale terms.

The firms' attitudes to risk are also a relevant factor in this context. If the retailer, say, is risk averse, then this will affect the design of wholesale terms.[125] Specifically, if the wholesale price is set equal to upstream marginal costs and the fixed fee is the same irrespective of outcomes, then the retailer will be exposed to variations in its profit as its own costs vary. The risk-averse retailer would require better fixed fee terms from the manufacturer in order to accept such risk.[126] A less risk-averse manufacturer can profit in these circumstances by varying the amount paid out by the retailer according to whether retail costs turn out to be low or high. In practice, it may not be able to condition payments directly on such costs. However, it can do this indirectly by setting a wholesale price that exceeds upstream marginal cost and reducing the fixed fee component of the two-part tariff.

An increase in wholesale prices will cause retail prices to increase, as shown above; the extent of this increase depending on the retail pass-through rate.

Resale price maintenance[127]

If the retail price is fixed, then the retailer will not be able to adjust its prices in response to subsequent changes in retail costs. (Contrast that with the situation absent resale price maintenance, where the retailer has the flexibility to adjust its prices in response to such changes.) Equally, if the wholesale price is also fixed, then changes in the manufacturer's costs will not be passed through to that wholesale price, or onwards to retail prices, either. In other words, there will be no subsequent cost pass-through at either the retail or the wholesale levels, whilst the terms of the vertical arrangement remain in place.

If it is retail *margins* rather than prices that are fixed, then changes in manufacturer costs could be passed through to changed wholesale prices, and these altered wholesale terms would translate into changed retail prices too. However, whilst the retail cap remains fixed, there will be no pass-through of retail cost changes.

5.1.3.3. Incentives

It is straightforward to envisage situations where a retailer is able to influence the level of demand for a product through marketing efforts, for example, as well as through its pricing decisions. Similarly, the retailer might be able to reduce retailing costs through appropriate initiatives. However, if such efforts are themselves costly, and cannot be contracted upon directly, the retailer will need to be incentivised to take appropriate actions.

In general, since the manufacturer will need to influence price and effort in this case, it will typically require additional instruments in its vertical contracting arrangements to do this. For example, resale price maintenance on its own will not solve both the pricing and effort problems. Adding a quantity target as well would be one way of doing so.[128]

[125] Rey and Tirole (1986) provides a classic exposition of this issue.

[126] Otherwise, the retailer would not be prepared to accept the wholesale terms on offer, given the risks involved.

[127] See comment on the legal treatment of resale price maintenance at footnote 2.

[128] See, for example, Mathewson and Winter (1984).

However, the manufacturer could incentivise effort and pricing decisions using a two-part tariff with a unit wholesale price set equal to upstream marginal cost and a fixed fee which extracts profit from the retailer, as before (albeit making allowance for the additional effort cost incurred by the retailer).[129] Since the wholesale price is fixed at upstream marginal cost, the retailer will retain the full benefit of any incremental sales generated by its efforts. Moreover the fixed fee component must be paid in all eventualities, it will not distort this choice.

However, this arrangement would expose the retailer fully to any uncontrollable variations in its costs (or in demand). If the retailer is risk averse, it will only be willing to enter into such an arrangement if it is compensated sufficiently, via a reduction in the fixed fee payable to the manufacturer. As before, a risk neutral manufacturer will generally find it profitable to increase the wholesale price above its own marginal cost in these circumstances, so that the retailer makes a bigger contribution to the manufacturer's profit when retail sales are relatively high (because demand is relatively high or its costs are relatively low). The optimal arrangement from the manufacturer's perspective will offer the retailer some insurance for the uncontrollable uncertainty, whilst also retaining incentives for effort, albeit that these incentives will be diminished by the increased wholesale price.

5.1.4. Negotiated wholesale prices

The discussion of supply arrangements in the previous sub-sections has supposed that the terms for the wholesale arrangement are set unilaterally by the upstream firm. In many situations, however, those wholesale terms will be agreed through negotiation between a manufacturer and retailer, and the outcome will depend on their relative bargaining strengths. In this section, we consider the impact of the terms of such negotiation on pass-through of changes in the manufacturer's marginal cost to the wholesale price, i.e. 'wholesale' cost pass-through.

In order to keep the analysis relatively simple while retaining some important intuition, we continue with the stylised scenario considered above, involving an upstream monopoly manufacturer selling to a downstream monopoly retailer. We also suppose that the retailer's only marginal cost is the wholesale price that it pays. If negotiations between the manufacturer and retailer break down, there is no wholesale supply, and both the retailer and manufacturer receive nothing. In other words, the disagreement payoff for both parties are taken to be 0.

The Nash bargaining solution provides an axiomatic solution to this bargaining problem. The outcomes it predicts maximises the following expression:

$$[Retailer\ profit]^{\alpha} \cdot [Manufacturer\ profit]^{1-\alpha}$$

where α captures the relative bargaining strength of the retailer. Thus, if the retailer has all the bargaining power ($\alpha = 1$), the solution maximises the retailer's profit, whilst if the manufacturer has all the bargaining power ($\alpha = 0$), the solution maximises the manufacturer's profit.

[129] Depending on the exact setting, more complex incentive structures might also be contemplated.

We examine three different bargaining scenarios, in which the manufacturer and retailer negotiate over, respectively:

- the unit wholesale price and a fixed fee, i.e. over a two-part tariff, as described above;
- the wholesale price and the retail price, i.e. where retail price maintenance is possible; and
- the wholesale price only.

5.1.4.1. Negotiation over two-part tariffs

Where the manufacturer and retailer can negotiate over fixed fees as well as the wholesale price, the optimal bargaining outcome will involve a wholesale price set equal to the manufacturer's marginal cost, and a fixed fee that splits the resulting profits according to the parties' bargaining strengths. In this case, the retailer will set a retail price which maximises the aggregate profit, as explained above.[130] (That is to say, the bargaining process is "efficient".)

Since the wholesale price is set at marginal cost, absolute pass-through at the wholesale level is 100%.

5.1.4.2. Bargaining over the wholesale and retail prices

In the case where manufacturer and retailer negotiate over the wholesale *and* the retail price (to the extent this is allowed), the retail price is set at the profit maximising level that would arise if the manufacturer supplied its product at marginal cost (thereby replicating the outcome generated by a vertically integrated firm). However, absent a two-part tariff, negotiations over the unit wholesale price will determine the split of the overall profit between the manufacturer and the retailer. In this case, the greater the manufacturer's bargaining strength, the closer the wholesale price will be to the retail price. The weaker the manufacturer's bargaining strength, the closer the wholesale price will be to the manufacturer's marginal cost.

The solution to the bargaining problem results in the parties splitting the maximised overall margin $(p - c)$ according to their relative bargaining strengths. Thus:

$$\frac{Retailer\ margin}{Wholesaler\ margin} = \frac{(p - w)}{(w - c)} = \frac{\alpha}{(1 - \alpha)}$$

In other words, the parties split the maximised overall margin $(p - c)$ according to their relative bargaining strengths. Re-arranging, this means that the wholesale price, w, is given by:

$$w = \alpha c + (1 - \alpha)p$$

[130] In other words, the outcome of the bargaining process is "efficient".

This is a weighted average of the value in the scenario where the manufacturer appropriates the whole margin and the value in the scenario where the retailer appropriates the entire margin. When the retailer has all the bargaining strength, $\alpha = 1$ and $w = c$. When the manufacturer has all the bargaining strength, $\alpha = 0$ and $w = p$. Where bargaining strength is distributed more evenly, α will lie between 0 and 1 and w will, therefore, lie between c and p.

Totally differentiating the above expression for w with respect to the upstream marginal cost, c, we obtain an expression for the upstream pass-through rate:

$$\frac{\partial w}{\partial c} = \alpha \cdot 1 + (1 - \alpha)\frac{\partial p}{\partial c}$$

There are two effects at work here. On the one hand, the greater the retailer's bargaining strength, the greater the degree to which the wholesale price reflects marginal cost, and the greater the extent to which changes in those costs will be fully passed through. (Full pass-through occurs when $\alpha = 1$.). On the other hand, the greater the bargaining power of the manufacturer, i.e. the smaller is α, the closer the wholesale price to the profit maximising downstream price. In this extreme, cost pass-through to the wholesale price will reflect the change induced in the profit-maximising retail price. We can think of this as the overall pass-through rate of a vertically integrated firm (i.e. $\frac{\partial p}{\partial c}$). Wholesale pass-through in this situation would exceed 100% only if $\frac{\partial p}{\partial c} > 1$.

In sum, when bargaining over the wholesale and retail price is permitted, wholesale pass-through will be the rate when the retailer has all the bargaining power (i.e. 100%) weighted by the retailer's bargaining strength plus the rate where the manufacturer has all the power (i.e. $\frac{\partial p}{\partial c}$) weighted by the manufacturer's bargaining strength.

5.1.4.3. Bargaining over the wholesale price only

Finally we turn to the more complex case in which the manufacturer and retailer negotiate over the wholesale price only. The retailer sets retail prices subsequent to this so as to maximise its profits, taking the agreed wholesale price as given. Negotiations over the wholesale prices therefore take place in the knowledge that the outcome will have a bearing on that retail pricing decision.

If bilateral negotiations result in a wholesale price w, the profit of the retailer and manufacturer respectively are then given by:

$$Retailer\ profit = (p - w)Q(p)$$

$$Manufacturer\ profit = (w - c)Q(p)$$

In this setting, the Nash bargaining solution implies:

$$\frac{(p - w)}{(w - c)} = \frac{\alpha}{(1 - \alpha)} + \frac{\partial p}{\partial w}.$$

As can be seen, the outcome of the negotiation is altered compared to the case where the manufacturer and retailer negotiate over both the wholesale and retail prices, on account of the $\frac{\partial p}{\partial w}$ term. This is the *retail* pass-through rate – the rate at which wholesale price changes are passed through to retail prices.

What this says is that the greater the degree pass-through by the *retailer*, the stronger its negotiating position. Intuitively, the greater this pass-through rate, the greater the knock-on effect on the retail price, and hence on the manufacturer's sales, of any increment in the negotiated wholesale price. Hence, the manufacturer's incentive to push for a higher wholesale price is muted as a result. This is in line with our earlier intuition that double marginalisation is smaller (i.e. wholesale pass-through is reduced) when the *retail* pass-through rate is higher, other things being equal.

5.1.4.4. Retailer bargaining power and merger price effects

Froeb et al. (2005b) considers how the effect on consumer prices of an (upstream) merger between manufacturers of differentiated goods depends on the extent to which the price effects of that merger are passed through at the retail stage, and how this is affected by the character of manufacturer transactions with a monopoly retailer. It shows that different manufacturer-retailer interactions, by affecting pass-through, can have a significant impact on the consequences of the upstream merger for final prices.

The authors consider two single-product manufacturers that compete upstream to sell their products to a monopoly retailer. The manufacturers' marginal costs are assumed constant, while the retailer's only marginal costs are the wholesale prices paid to the manufacturers. Final demand depends only on the retailer's prices. The authors consider three scenarios for the wholesaler-retailer relationship, namely where: (1) the retailer has no bargaining power; (2) the retailer has a measure of bargaining power over the manufacturers, because it can choose to sell the products of one manufacturer exclusively rather than dealing with both; and (3) manufacturers are obliged to rely on per unit wholesale prices, giving rise to double marginalization effects.

In the case where the monopoly retailer is assumed not to have bargaining power, it will behave as a perfectly competitive retailer would. As a result, all profits are passed back to the manufacturers. (This is equivalent to a case where the manufacturers can use a two-part tariff to extract all surplus from the retailer.) The manufacturers therefore behave as if there were no retail stage and they were dealing directly with consumers. In this scenario, the existence of the retail stage entails no consequences for pass-through. The merged manufacturers internalise the cannibalisation cost of competition between them, and this price effect is passed through to retail prices.

In the second scenario, the ability of the retailer to deal with one or other of the manufacturers exclusively, as well as with both manufacturers, gives it a degree of bargaining power when the manufacturers are not merged. That bargaining is assumed to take place in relation to the fixed fee components of efficient two-part tariff arrangements with each manufacturer. Since the retailer sets prices to maximise total profits before and after the merger, the merger entails no effect on retail prices, i.e. there is no merger pass-through effect. The only effect of the merger is a transfer of surplus from the retailer to the merging manufacturers.

Finally, a double mark-up arises where the manufacturers must rely on wholesale prices that are independent of the quantities purchased by the retailer. This causes the retailer to raise prices after the manufacturer merger, in response to the consequent increase in wholesale prices. However, if the retail pass-through rate is less than 1 (e.g. with the linear) the retail price will be increased by less than the manufacturers' price increases, i.e. the retailer will absorb some of the wholesale price effect.

5.2. Competition

So far, our analysis of pass-through issues in the vertical context has focused (with the partial exception of the horizontal merger context considered in section 5.1.4.4) on monopoly supply. Other chapters of this study have considered the effect on pass-through of replacing a monopolistic industry structure with an oligopolistic or competitive one, albeit at a single level in the supply chain. In this section, we briefly consider the implications of competition for vertical market structure and pass-through.

5.2.1. Double marginalisation , pass-through and competition

The consideration of double marginalisation set out in Section 5.1 extends naturally to a scenario where an upstream monopolist supplies a number of competing downstream firms on the basis of a unit wholesale price. The impact of double marginalisation will depend, inter alia, on the nature of competition on the downstream market and the upstream monopolist will set its wholesale terms to take account of this.

To illustrate, consider a scenario in which n symmetric retailers supplying a homogeneous product engage in quantity (Cournot) competition at the downstream level. In that case, the retail margin will be given by:

$$p - w - c_D = m_D = \frac{p}{\varepsilon(p)}\frac{1}{n}$$

As shown in Section 4.1: the smaller the number of competing retailers, the closer the pricing outcome will be to the monopoly case; the greater the number of firms, the closer the outcome will be to the competitive benchmark, with price set equal to marginal cost. Given the downstream pass-through rate ρ_D implied by that competition – Cournot competition between n firms in this instance – the upstream monopolist will continue to set the wholesale price w (as described in Section 5.1.1) so that:

$$w - c_U = m_U = \frac{p}{\varepsilon(p)}\frac{1}{\rho_D}$$

However, in this case the ratio of upstream to downstream mark-ups, and the magnitude of the overall mark-up, will now depend on the number of downstream firms as well as the downstream pass-through rate, which in this case will also depend on the number of downstream firms. Thus:

$$(w - c_U) = \frac{n}{\rho_D} \cdot (p - w - c_D)$$

If, instead of a retail monopoly, there was vigorous competition at the retail level, e.g. because the number of firms was large, then that competition could be expected to eliminate the double marginalisation problem. Pass-through at the retail stage would be 100%, as discussed above. The upstream monopolist would set the wholesale price as if it were an integrated monopolist in this case, and pass-through of upstream cost changes would reflect this.

Similarly, if there is Cournot competition between manufacturers at the upstream stage, for instance, wholesale mark-ups and pass-through at the upstream stage will vary with the number of manufacturers, N. As in the monopoly case, the overall transmission of industry-wide upstream cost changes to retail prices will depend on the combined effect of upstream and downstream pass-through.

5.2.2. Strategic effects

Vertical contractual (or ownership) structures can also be used strategically to shape competition between firms. The nature of pass-through may affect, and be affected by, these structures.

Vickers (1985) observes that the owner of a firm may prefer the results obtained when decision-making is delegated to an agent with different preferences to that owner. He illustrates with an example in which the manager of firm i maximises M_i - a linear combination of profit and sales volume:

$$M_i = \pi_i + \theta_i q_i$$

Vickers notes that, faced with profit-maximising rivals, firm i will do better by choosing $\theta_i > 0$; i.e. incentivising the manager to give positive weight to sales volume as well as profit. However, if each competing firm i chooses θ_i in this way, profits for all firms in symmetric equilibrium will be lower as a result.

Ritz (2009) considers the implications of delegation for cost pass-through in this context. He models a situation where incentivised managers take decisions on how fir will compete on the product market on behalf of those firms' owners. (The model does not involve information asymmetries.) Competition between the firms, which is affected by the managers' decisions, is preceded by a stage where the firms' owners choose the relative weight to be given to profits, on the one hand, and revenues, on the other, in the performance-related incentives given to the managers. Delegation to a manager commits a firm to compete not only with the objective of maximising profits but also with the aim of pursuing revenues. In fact, a firm may benefit from the more aggressive behaviour on the product market that is encouraged by the manager's revenue maximising incentive compared to a setting where only profits were considered. Consequently, there may be an overall profit gain from delegating decisions to an agent whose payoff does not depend uniquely on profit, but rather on both profit and revenue. Importantly, the model assumes that that any commitment to delegate is fully credible, i.e. that the principal is able to commit to an objective function that is different from its own, even though it would subsequently wish that the manager would behave differently. This critical ability to commit to delegation may not hold in practice.

The model considers a two stage setting involving n identical quantity-setting firms with positive, constant marginal cost. Inverse demand is assumed to have a slope of constant elasticity. However, this encompasses a range of demand specifications, including linear as well as convex and concave shapes.

In a first stage, each firm's shareholders choose the weight to be given to profits and to revenues in the manager's compensation scheme. In the second stage, the firms engage in quantity (Cournot) competition. It is a standard result of the Cournot model that it is optimal to give positive weight to revenues in the manager's incentives. The effect of delegation is that each firm will produce greater output, leading to outcomes that are closer to perfect competition than absent delegation.[131] As such, the delegation choice has the character of a Prisoner's Dilemma. Firms would be collectively better off without delegation, but each has an incentive to engage in such delegation, resulting in more intense competition overall.

In terms of cost-pass-through, delegation causes the firms to compete more aggressively and the pass-through rate to be greater as a result. Delegation effectively causes the firm to behave as if there were more firms in the market than there actually are.

The assumption of inverse demand with constant slope elasticity allows for a range of values for industry-wide cost pass-through, as discussed in previous chapters of this study. As explained, the effect on prices of a change in marginal cost will depend on the relative slopes of marginal revenue and demand, assuming constant marginal cost. Notably, as demand becomes more concave, the slope of marginal revenue becomes steeper relative to the slope of inverse demand, and the pass-through rate is reduced. Indeed, absent delegation, cost pass-through can take any value between 0 and 100% in Ritz's model. Delegation changes this, as it introduces a second, strategic, effect as demand becomes more concave. Specifically, the scope for strategic effect increases and pushes pass-through in the opposite direction, i.e. towards 1 (with the firm acting as if there were more rivals in the market). For sufficiently concave demand this strategic effect offsets the 'basic' pass-through effect and results in a 50% lower bound on the pass-through rate.

5.2.3. Vertical restraints

Retail competition

The preceding discussions imply that upstream firms may delegate decision-making to downstream retailers/agents because they want to draw on their superior information or ability to market, or because they positively value the strategic advantages of an arm's length

[131] Moreover, as the number of firms increases, the outcome of Cournot competition with delegation will converge towards the perfect competition outcome more quickly than without delegation.

relationship. Both factors are relevant in the design of vertical contracts, as is the nature of the downstream competitive environment.

As highlighted by Rey and Tirole (1986), for example, retail competition can ensure that retail mark-ups reflect retail marginal costs in the absence of contractual constraints, whilst offering an effective mechanism for adjusting those retail prices for common (industry-wide) cost variations.

The design of vertical restraints can also be used to shape downstream competition. For example, when an upstream firm sells via multiple retailers, competition between those retailers is liable to dissipate profits. A two-part tariff structure which sets the unit wholesale price equal to upstream marginal cost, in order to address the standard double-marginalisation concerns, will not now maximise the manufacturer's profit, since it will enable competition between retailers to push prices down. Instead, the manufacturer will find it optimal to set the unit wholesale price above marginal cost, in order to dampen such competition. However, in doing so, and reducing the retail margin, the manufacturer will re-introduce the double marginalisation problem, thereby dampening retailer incentives to engage in sales-expanding effort, for example.

The introduction of additional restraints can overcome this effect. For instance, a combination of two part tariffs and resale price maintenance would eliminate downward competitive pressure on retail prices whilst allowing the manufacturer to set unit wholesale charges equal to upstream marginal costs, thereby incentivising effort by retailers.[132]

Manufacturer competition

As illustrated by the discussion of Ritz (2009) in the preceding section, upstream firms may also use delegation, and the terms of their contractual relationships with downstream firms, to influence competition with upstream competitors. In that case, the outcome of delegation was more intense competition between firms. However, the terms of vertical restraints may also have the effect of dampening competition between upstream firms.

Rey and Vergé (2010), for example, considers an environment in which competing manufacturers utilise the same retailers. In that context, it shows that manufacturers may internalise the effects of inter-brand competition via the terms of their vertical restraints with retailers. Rey and Vergé (2010) demonstrates that two part tariffs alone may not support the (joint) profit-maximising outcome in this case, but a combination of two-part tariffs and resale price maintenance can.[133] The potential impact of such combinations of restraints for pass-through has been considered empirically by Bonnet et al. (2013), as discussed in Chapter 8 below.

[132] See comment on the legal treatment of resale price maintenance at footnote 2. Moreover, other vertical restraints may have similar effects to a price floor in specific circumstances. (See, e.g., Rey (2012)).

[133] Rey and Vergé (2010), and the impact of resale price maintenance more generally, is discussed extensively in the report on anti-competitive effects of RPM prepared by Greg Shaffer for the OFT. (See Shaffer (2013).)

5.2.4. The effects of vertical integration in a monopolistic competition setting

To conclude this chapter, we describe the use of a theoretical model utilised extensively in the international economics literature to model the impact of vertical integration on pass-through of upstream (manufacturer) cost changes to retail prices. The model draws on intuition established earlier in this chapter and will provide a useful backdrop for the discussion of empirical analysis in Chapter 8.

Following Dornbusch (1987), much of the international economics literature on pass-through supposes monopolistic competition within a sector characterized by CES demand. The model adopted by Hong and Li (2013) follows this approach. Importantly, the larger a retailer's market share, the lower is its perceived elasticity of demand. Intuitively, a firm with a large market share will recognise that when it increases its price it will also increase the average market price. Since, in their model, demand for a particular product depends on the retail price <u>relative</u> to the market price (averaged across all retailers), the effect is to reduce the perceived elasticity of demand for the large firm's product, since the relative effect of any price increase will be somewhat offset by the impact on the average market price.

Hong and Li (2013) extends the basic retail set up described above to allow for a manufacturing level. According to the standard condition, when setting its wholesale price, a manufacturer equates its percentage margin to its perceived elasticity of demand. With unit tariffs, as is assumed here, the manufacturer's perceived elasticity of demand is simply the *downstream elasticity of demand multiplied by the downstream pass-through elasticity*. Intuitively, suppose that the downstream pass-through elasticity equals 0.5. This means that a 1% increase in the wholesale price leads to a 0.5% increase in the downstream price; in turn, this will lead to a percentage reduction of retail volumes equal to 0.5 multiplied by the retail price elasticity of demand. In other words, the upstream elasticity of demand is one half of the downstream elasticity of demand.

As noted earlier in this chapter, with unit prices, the overall pass-through rate of an upstream cost change into retail prices equals the upstream pass-through elasticity multiplied by the downstream pass-through elasticity.[134] Further, we explained that *if the former were less than 1*, vertical integration would increase the pass-through rate. Intuitively, the integrated firm supplies the upstream input to itself at cost, so we can think of the upstream pass-through rate increasing to 1 in the integrated case. It follows that vertical integration increases the pass-through rate from an upstream cost change to the retail price.

However, in Hong and Li's model, there is also a countervailing force at work. The integrated firm is more efficient (since double marginalisation is removed). An integrated firm therefore gains market share at the expense of rivals, and this dampens its incentive to pass-through higher costs at the retail level. The model therefore indicates that vertical integration has an ambiguous impact on the pass-through elasticity (and by implication absolute pass-through rate) in a context where firm-specific pass-through decreases with market share.

[134] We presented the results in terms of absolute pass-through rates but it is straightforward to convert these to pass-through elasticities.

5.3. Summary: vertical settings

- It is well understood that separate ownership of upstream and downstream firms can lead to so-called ‘double marginalisation’ when wholesale supply is characterised by simple unit prices, with attendant consequences for pricing and efficiency. The greater the pass-through at the downstream stage, the smaller the margin set by an upstream monopolist relative to the margin set at the downstream stage in these circumstances. Moreover, the greater the downstream pass-through rate, the smaller the overall pricing distortion relative to the vertically integrated case.

- The extent to which an upstream cost change will be passed through to retail prices will depend on the product of upstream and downstream pass-through rates. If that product exceeds 100%, the effect of the cost change will be amplified (i.e. above 100%). If the upstream pass-through rate multiplied by the downstream pass-through rate is less than 100%, the effect of the upstream cost change will be absorbed (i.e. less than 100%).

- The impact of vertical integration is usually to give rise to an effective upstream pass-through rate of 100%, i.e. the upstream division of the integrated firm passes through inputs at marginal cost and so no upstream mark-up is applied.

- A variety of vertical contractual restraints can be used to overcome the double marginalisation problem, as well as to address other ‘externalities’ that arise between a manufacturer and retailer, and between retailers. The design of those restraints will also affect cost pass-through. In particular:

  – Such restraints may allow the vertically integrated outcomes for price and pass-through to be replicated; i.e. with unit wholesale prices set at marginal cost, and 100% upstream cost pass-through.

  – However, short-term cost pass-through at the downstream level may be inhibited by fixed contract terms such as resale price maintenance.

- In many situations, upstream and downstream firms will arrive at wholesale terms through a process of negotiation. The outcomes of those negotiations, and the implications for pass-through, will depend on the relative bargaining strengths of the parties and the scope of the negotiations.

  – Where a manufacturer and a retailer can agree two part tariffs, an efficient negotiation will focus on the terms of the fixed fee – which will not affect pass-through. The unit wholesale price will be set at the manufacturer’s marginal cost, ensuring 100% pass-through at the wholesale (upstream) stage.

  – Where a manufacturer and a retailer negotiate only over a unit wholesale price, the greater the scope for retail (downstream) level pass-through, the weaker the manufacturer’s incentive to increase its wholesale level mark-up, all else being equal.

- Where the manufacturer and retailer can agree on a final retail price,[135] as well as the wholesale price, the extent of wholesale cost pass-through will range between 100% (retailer has all the bargaining power) and the vertically integrated pass-through rate (manufacturer has all the bargaining power).

- Since the structure of the vertical relationships will affect pass-through rates, with implications for pricing behaviour, those relationships may be set strategically as part of the competitive interactions between firms.

[135] See comment on the legal treatment of resale price maintenance at footnote 2.

Numerical case study

6. A simulation exercise

In this chapter, we set out a case study to illustrate and test some of the features of cost pass-through relationships identified in our review of relevant theory. Specifically, we use numerical methods to consider the impact of discrete cost changes on equilibrium prices in an oligopolistic market. We draw on this case study to explore the impact on cost pass-through levels, and on the relative values of firm-specific and industry-wide cost pass-through rates, of:

- the shape of demand; and
- market structure.

6.1. Basic set up

Our market set-up comprises five initially symmetric firms, each producing a single differentiated product. The five firms are assumed to operate initially using the same constant marginal cost production technologies. The firms compete on the basis of price-setting (Bertrand) behaviour.

One of the objectives of the case study is to provide a comparison of the implications for pass-through of using different demand specifications. We therefore consider three different specifications of consumer demand, namely:

- linear demand;
- multinomial logit demand; and
- demand derived from constant elasticity of substitution (CES) consumer preferences.

These demand specifications exhibit increasing degrees of convexity. Details are provided in Annex C.

The (symmetric) industry equilibrium that arises before cost changes are considered is computed for each specification of demand. To produce meaningful comparisons between the three demand scenarios, we calibrate the parameters of demand in each case so as to achieve identical equilibrium outcomes.

We then perform two distinct experiments:

First, we suppose that the marginal cost of producing each of the five products is increased by an identical amount (which we set to be 10%). In other words, we assume an industry-wide cost change and compute the new equilibrium which results.

Second, we suppose that the marginal cost of one of the firms is increased, again by 10%. (We arbitrarily assume Firm 1 is affected.) In other words, in this case we suppose the cost change is firm-specific. Again, we re-compute the market equilibrium following this cost change.

Having computed equilibrium prices before and after the cost change, we compare these to derive estimates of:

- the industry-wide cost pass-through rate;
- the 'own' price firm-specific cost pass-through rate for the affected firm (Firm 1);
- the 'cross' price firm-specific cost pass-through rate for the unaffected firms; and
- the (volume-weighted) average firm-specific cost pass-through effect for the market as a whole.

6.2. Equilibrium price effects

In the following table, we report the industry-wide and firm-specific cost pass-through rates obtained for each specification of demand, distinguishing between the 'own' price pass-through effect for the firm affected by the firm-specific cost change (Firm 1 by assumption), and the 'cross' price pass-through effect on the prices of the firms that are not directly affected by the cost change. (Recall that this 'cross' effect arises because those other firms' prices will be raised in equilibrium as a result of Firm 1 increasing its price in response to the cost change.)

Table 2: Pass-through rates

Demand type	Industry-wide cost change	Firm-specific cost change		
		'Affected' firm price change	'Unaffected' firm price change	Average market price change
Linear	70%	51%	4.6%	9.6%
Logit	96%	89%	2.4%	9.4%
CES	110%	96%	3.8%	11.0%

Source: RBB analysis

More detailed results are provided in the Annex.

6.2.1. Industry-wide cost pass-through

The industry-wide cost pass-through rates obtained range from 70% in the linear case to 96% for the multinomial logit specification to 110% for the CES specification.[136] These results are consistent with the predictions from theory that industry-wide cost pass-through rates:

- will be no less than 50% in the linear case with constant marginal costs;
- will increase as demand becomes more convex, all else being equal; and
- may exceed 100% for highly convex demand.

6.2.2. Firm-specific cost pass-through

As explained, we investigate the pass-through effects of a firm-specific cost change by supposing that such a cost change affects Firm 1 only. The pass-through effects for all other firms are identical, given the symmetric nature of our pre-change market environment. We therefore report separate pass-through rates for Firm 1 (the 'affected' firm) and for the other firms (the 'unaffected' firms).

Unsurprisingly, the largest pass-through effect is observed for Firm 1. This 'own' price firm-specific cost pass-through ranges from 51% for the linear demand case to 96% for CES demand. Again, these differences are consistent with the effects of increasingly convex demand.

The impact on the prices of rival products is much more modest. Indeed, these 'cross' price effects are an order of magnitude smaller for all demand specifications. (These values are sensitive to the degree of differentiation in our model.) Nevertheless, it is notable that the prices of these products have increased as a result of the cost change affecting Firm 1, even though none of these products was affected directly. This is explained by the strategic interaction between firms. Since prices are so-called strategic complements, an increase in one firm's prices causes competitor firms' prices to increase too. The numerical results indicate the pass-through effect to competitors' prices is greatest under linear demand and smallest under logit demand in our case.

The last column of Table 2 reports market average price changes. In each case, the average price change is less than would be suggested if individual price effects were weighted according to the initial, symmetric share positions of the firms. This is because the effect of the differences in pass-through rates is to cause sales to switch from Firm 1 to its rivals. As a result, the shares of the 'unaffected' firms are increased relative to that of the 'affected' firm – Firm 1. Increased weight in the market average is given to the relatively small price effects experienced by these 'unaffected' firms, therefore.

[136] It can be straightforwardly verified for the linear case, for example, that the pass-through rate obtained matches the predictions of theory, given the parameters chosen.

6.2.3. Comparison of industry-wide and firm-specific cost pass-through

For each specification of demand, the industry-wide pass-through rate is greater than the corresponding firm-specific pass-through rates. Even for the affected firm, a clear difference is evident. Moreover, when we compare the effect on average market prices, the difference between industry-wide and firm-specific pass-through effects is even more pronounced. Put differently, the impact on the average market price of a firm-specific shock can be significantly smaller than the effect of an industry-wide shock.

6.3. Market concentration and pass-through (with logit demand)

We have also used our model set-up to examine the impact of industry concentration on pass-through rates. For this exercise, we adopt the multinomial logit demand specification only.

The precise outcomes of this numerical simulation analysis will, inevitably, depend on the (strong) assumptions adopted. First, the modelling assumes that consumer demand can be represented using a multinomial logit specification. It is well-known that this function imposes important restrictions on consumer substitution patterns. Second, the numerical simulation is based on a given set of parameter values. As a result, we cannot draw robust inferences from the detailed results. Nevertheless, the simulation highlights some interesting and relevant effects of market structure on firm-specific pass-through.

6.3.1. Market configurations

As before, we assume a 5 product market. Each product is assumed to have the same constant marginal cost of production in the initial configuration, and if all products were priced at the original benchmark price, they would each secure an identical share of sales.

However, in order to explore the effects of concentration within this basic market configuration, we suppose that a single firm may supply more than one of the five products. In other words, we allow for the possibility of multi-product firms. The industry configuration considered in the previous section, namely one with five single-product firms, represents one extreme of these organisational possibilities. At the other extreme is a scenario in which one firm supplies all five products; i.e. the industry is monopolised. Overall, there are twelve different industry configurations that are relevant to our pass-through analysis. (In some of these, the overall industry configuration is identical. However, it will matter for firm-specific cost pass-through whether the ‘affected’ firm is relatively large or relatively small, so the identities of individual firms within an asymmetric industry configuration may matter for the result.) The configurations are summarised in the table below.

Table 3: Market configurations

Scenario	# of firms	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5
1	**5 firms**	1 product	1 product	1 product	1 product	1 product
2	**4 firms**	1 product	2 products	1 product	1 product	X
3		2 products	1 product	1 product	1 product	X
4	**3 firms**	1 product	2 products	2 product	X	X
5		1 product	3 products	1 product	X	X
6		2 products	2 products	1 product	X	X
7		3 products	1 product	1 product	X	X
8	**2 firms**	1 product	4 products	X	X	X
9		2 products	3 products	X	X	X
10		3 products	2 products	X	X	X
11		4 products	1 product	X	X	X
12	**1 firm**	5 products	X	X	X	X

Even in the relatively simple setting considered, therefore, there are a number of different aspects of concentration that could affect industry-wide cost pass-through rates, notably:

- the number of firms;
- the concentration of sales; and
- (in the case of firm-specific cost pass-through) the distribution of products between the 'affected' firm (Firm 1) and other firms.

Evidently, the analysis is not as straightforward as in the homogeneous good case. This is because firm size varies with market concentration, which implies that individual firms tend to control more or fewer products. For example, in a duopoly market, in one configuration one firm controls two products, while the rival controls three products; in another, one firm controls four products and a rival controls one. Our affected firm – Firm 1 – may therefore control one, two, three or four products within this overall duopoly setting. These differences will have a bearing on the extent of firm-specific cost pass-through.

It is important to note that, even before a firm-specific cost change is considered, the asymmetries in these ownership configurations will result in asymmetric pricing outcomes in equilibrium. Hence, benchmark prices will be different in each case.

6.3.2. Industry-wide cost pass-through (in a logit setting)

First, we consider the effect of a 10% industry-wide increase in costs. The absolute pass-through rates are summarised in Table 4.

Table 4: Effects of concentration on industry-wide cost pass-through rates

Market scenario	Initial HHI	Pass-through rate
5 firm	2,000	95%
4 firm (one 2-product firm)	2,645	93%
3 firm (two 2-product firms)	3,476	89%
3 firm (one 3-product firm)	3,876	87%
2 firm (one 3-product firm; one 2-product firm)	5,050	80%
2 firm (one 4-product firm)	5,599	78%
1 firm	10,000	48%

Source: RBB analysis

More detailed results are provided in Annex C.

The results indicate that industry-wide cost pass-through rates decrease as the industry becomes more concentrated (higher HHI; fewer firms). As such, it mirrors the pattern observed when the number of identical single-product firms supplying a market is reduced (with the textbook perfect competition case, in which an industry-wide cost increase will be fully passed on to prices, at one extreme, and the monopoly case, in which the pass-through rate is significantly smaller, though not zero, at the other).

It is notable too that with 5 distinct firms, the industry pass-through rate in our case is close to 100%, though the market is moderately concentrated by conventional competition standards. Indeed, the rate of change of the pass-through rate as the market becomes more concentrated is relatively gradual until monopoly, when there is a more significant reduction.

6.3.3. Firm-specific cost pass-through (in a logit setting)

To examine the pass-through effects of firm-specific cost changes, we again consider the consequences of a cost change which affects Firm 1 only. We will be interested in firm-specific cost pass-through effects on:

- Firm 1 (the 'own' price effect);
- other firms in the market (the 'cross' price effect); and
- average market prices as a whole.

In our multi-product setting, the proportion of the products in the market and overall supply affected directly by the cost change will vary significantly from configuration to configuration, depending on the number of products controlled by Firm 1.

'Own' price firm-specific pass-through

Table 5 below presents the 'own' price pass-through results obtained from the numerical simulation for the different market concentration scenarios.

Table 5: Effects of concentration on 'own' price firm-specific cost pass-through

# Firm 1 products	Market scenario	Initial HHI	Pass-through rate
1	5 firm	2,000	89.20%
	4 firm (one 2-product firm)	2,645	88.60%
	3 firm (two 2-product firms)	3,476	87.80%
	3 firm (one 3-product firm)	3,876	87.20%
	2 firm (one 4-product firm)	5,599	84.40%
2	4 firm (one 2-product firm)	2,645	79.60%
	3 firm (two 2-product firms)	3,476	78.60%
	2 firm (one 3-product firm)	5,050	76.20%
3	3 firm (one 3-product firm)	3,876	70.20%
	2 firm (one 3-product firm)	5,050	68.60%
4	2 firm (one 4-product firm)	5,599	60.20%
5	1 firm	10,000	47.60%

Source: RBB analysis

We have organised the results for the various configurations in descending pass-through order.

In the context of this logit example, the follow features are observed:

- The biggest influence on the pass-through effect on Firm 1's prices is the number of products controlled by Firm 1. The greater this number is (all else equal), the smaller the pass-through rate. Specifically, holding HHI constant, as Firm 1 controls more products, the 'own' price pass-through rate falls. For example, if we consider HHI equal to 3,476, the pass-through rate is 87.8% when Firm 1 owns one product and 78.6% when it owns two products. Likewise, holding HHI constant at 3,876, the pass-through rate is 87.2% when Firm 1 owns one product and 70.2% when it owns 3 products.

Further, holding HHI constant at 5,599, the pass-through rate is 84.4% when Firm 1 owns one product and 60.2% when it owns 4 products.

- If we consider the impact of Firm 1 acquiring Firm 2, and then Firm 3 and so on (leaving other firms to be single product firms), the impact is to reduce the rate of pass-through. For example, pass-through is 89.2% when Firm 1 owns one product, declining to 79.6% when Firm 1 owns two products, falling to 70.2%, 60.2% and 47.6% as Firm 1 owns three, four and five products respectively.

Given the evident correlation between the size of (or number of products supplied by) Firm 1 and industry concentration, the exact role of each in determining pass-through levels is not straightforward to discern from these data. Indeed, it is notable that a ranking according to HHI measure does not provide a perfect ranking of pass-through rates, indicating that a somewhat more complex relationship with the distribution of market shares is at work in practice.

However, our preceding two examples shed some light on the interplay of these effects. We note that as Firm 1 controls more products, the shock becomes more like an industry-wide shock (which would act to increase pass-through all else equal) because the shock applies to *all* products owned by Firm 1. However, there is also a concentration or market power effect. This acts to reduce pass-through, all else equal. It appears that the latter market power effect generally dominates the former effect as Firm 1 controls an increasing proportion of products.

'Cross' price product-specific pass-through

The cost increase affecting Firm 1, and the increase in Firm 1's prices that this brings about, will cause other products' prices to increase too (since prices are strategic complements). Moreover, this general increase in prices will encourage further individual price increases, until a new equilibrium is reached.

In Table 6 below, we report the 'cross' price pass-through rates for Firm 1's rivals. In some settings, the industry comprises both larger and smaller firms, depending on the number of products they supply. We report pass-through rates separately for these large and small firms.

Table 6: Effects of concentration on 'cross' price product-specific cost pass-through

# Firm 1 products	Market scenario	Initial HHI	Pass-through (Large rival)	Pass-through (Small rival)
5	1 firm	10,000	--	
2	2 firm (one 3-product firm)	5,050	16.40%	
1	2 firm (one 4-product firm)	5,599	15.20%	
3	2 firm (one 3-product firm)	5,050	14%	
2	3 firm (two 2-product firms)	3,476	9.60%	5.60%
4	2 firm (one 4-product firm)	5,599	9.20%	
1	3 firm (one 3-product firm)	3,876	9.00%	4.20%
3	3 firm (one 3-product firm)	3,876	6.80%	
1	3 firm (two 2-product firms)	3,476	6.60%	
1	4 firm (one 2-product firm)	2,645	5.20%	3.00%
2	4 firm (one 2-product firm)	2,645	4.40%	
1	5 firm	2,000	2.40%	

Source: RBB analysis

The first thing to note is that, for our parameter specifications at least, the magnitudes of the 'cross' price pass-through effects are substantially less than the 'own' price effects.

Second, it is apparent that these 'cross' pass-through effects are, broadly, larger the more concentrated is the market. This is consistent too with the observation that, for a given industry structure, the cross pass-through effects are larger for the bigger rival firms. Further, conditional on facing symmetric rivals, it can be seen that as the HHI increases, the cross pass-through rate increases. Likewise, conditional on facing rivals of different sizes, it can be seen that as the HHI increases, the pass-through rates for both the larger and smaller rivals increase.

Third, we note that the relationship between 'cross' price effects and the number of products supplied by Firm 1 is not clear cut.

Average market price effects of product-specific pass-through

Finally, we report the effect of the firm-specific cost change on average market prices in Table 7.

Table 7: Effects of concentration market average price effect of product-specific cost pass-through

# Firm 1 products	Market scenario	Initial HHI	Market average pass-through rate
5	1 firm	10,000	47.60%
2	2 firm (one 3-product firm)	5,050	36.60%
1	2 firm (one 4-product firm)	5,599	36.20%
3	2 firm (one 3-product firm)	5,050	32.40%
4	2 firm (one 4-product firm)	5,599	28.00%
2	3 firm (two 2-product firms)	3,476	22.00%
3	3 firm (one 3-product firm)	3,876	19.40%
1	3 firm (one 3-product firm)	3,876	18.00%
1	3 firm (two 2-product firms)	3,476	17.40%
2	4 firm (one 2-product firm)	2,645	15.00%
1	4 firm (one 2-product firm)	2,645	12.40%
1	5 firm	2,000	9.40%

Source: RBB analysis.

We have, again, organised the data in descending pass-through rate order. It is evident from comparing the market average cost pass-through rates and the various indicators of market concentration that there is – in the context of this example – an apparent relationship between market average pass-through rates and industry concentration, with smaller pass-through rates being observed for relatively less concentrated market configurations. In this respect it is notable that the monopoly outcome provides an upper-bound on these market average pass-through rates. However, the ranking of pass-through does not correlate perfectly with the HHI ranking, which suggests subtler effects of market structure at work too, as noted above.

It is notable that even though 'own' price firm-specific pass-through rates tend to *increase* as industry concentration decreases, the market average pass-through rates (resulting from a firm-specific shock) *decrease* as industry concentration decreases. It is also evident, therefore, that industry-wide and firm-specific market-average pass-through rates diverge as industry concentration decreases.

6.4. Summary

In this chapter we considered some theoretical case studies using numerical simulations. Comparing linear demand, logit demand, and CES demand (convex), we demonstrated that, in the context of our parameter choice:

- Industry-wide cost pass-through increases as the convexity of demand increases and may exceed 100% with convex demand.
- Industry-wide cost pass-through rates exceed own price firm-specific pass-through rates, which in turn exceed cross price pass-through rates.

In the context of a logit model, our specific parameter choice demonstrated that:

- Holding HHI constant, as a firm owns more products, its firm-specific pass-through rate falls.
- If, starting from a symmetric five single product firm structure, one firm acquires incrementally the other firms, that acquirer's firm-specific pass-through declines as it owns more firms (and hence more products).
- 'Cross' pass-through effects are, broadly, larger the more concentrated is the market and, for a given industry structure with asymmetric rivals, the cross pass-through effects are larger for the bigger rival firms.
- Even though 'own' price firm-specific pass-through rates tend to *increase* as industry concentration decreases, the market average pass-through rates (resulting from a firm-specific shock) *decrease* as industry concentration decreases.

Empirical evidence

7. Quantitative evidence on pass-through effects

Overall, there is a paucity of empirical industrial organisation work that has quantified the extent to which firms pass on changes in costs to prices. The literature is, however, growing and recent examples include amongst others Kim and Cotterill (2008), Bonnet, Dubois, Villas-Boas and Klapper (2013), and Fabra and Reguant (2013). There are also a number of papers that quantify the impact of taxes on prices.[137] Typically, these studies consider the effects of changes in the tax regime, by comparing prices before and after the introduction of a new tax or the repeal of an existing tax.

Most of the empirical findings in relation to pass-through come from the international economics literature, in which there is a long tradition of estimating exchange rate pass-through; that is, the price response of internationally traded goods to changes in exchange rates.[138] This literature's growth has been spurred in particular by the interest of macro-economists in uncovering micro-level explanations for incomplete adjustment of nominal prices to exchange rate changes.[139] While, for this reason, the evidence from the literature on exchange rate pass-through rarely sheds direct light on questions of competition interest, some of the findings offer useful insights nevertheless.[140] The main findings of this literature are discussed below.[141,142,143]

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[137] See Doyle, J. and Samphantharak (2006) and fn. 146 below for an overview of pass-through findings from the tax incidence literature.

[138] In theory, if the law of one price holds, exchange rate pass-through should be complete. That is, variations in the price of traded goods expressed in the local currency should move with the exchange fluctuations. To fix ideas, consider the example of a German car importer in the US. The price of a German car model in USD should be equal to the price in euros times the bilateral exchange rate (USD/euro). Therefore, if the exchange rate fluctuates, we expect the price expressed in USD to adjust accordingly, as the US importer passes-through its marginal cost change (in USD). The empirical evidence however indicates that the price expressed in USD does not vary with exchange rate fluctuations, suggesting a very low pass-through.

A related concept to the law of one price is relative purchasing power parity, which implies that changes in prices of goods across locations should be the same when converted into a common currency (and failure for this to occur for individual goods is known as "pricing to market"). For example, if the same German car models are sold at different prices (when expressed in a common currency) in France and the US that violates the law of one price, but not relative purchasing power parity. If the exchange rate between Germany and the US changes (but not the France and Germany exchange rate because they both use the euro), and the price of the German cars in the US does not adjust, this violates relative purchasing power parity (and is known as pricing to market). The relative price of the same traded goods sold by the German exporter in France and the US, when expressed in a common currency, would have changed over time. There is a large international economics literature that examines pricing to market. See, for example, the seminal papers by Krugman (1986) and Dornbusch (1987) and, for a summary of this literature, Burstein and Gopinath (2013).

[139] For example, situations in which a 10% change in the exchange rate leads to a less than 10% change in the prices of traded goods. This could examine data on, for example, a consumer price index of traded goods and a trade-weighted exchange rate (i.e. an exchange rate weighted by the value of trade of the importing country with different exporting countries) or the price of an individual good and the exchange rate with the country from which that good is imported.

[140] In some economic models used in international economics, the price response to exchange rate variations is related to the price response to changes in marginal cost (namely the traded portion of cost). That is, the literature models exchange rate as a determinant of costs for importers. For example, Dornbusch (1987), one of the seminal papers in the exchange rate pass-through literature, models exchange rate shocks as input cost shocks for foreign firms selling in the US (because they increase the price of foreign labour). Alternatively, some papers model the exchange rate as a determinant of demand, by affecting the demand that an exporter obtains for any given price in its own currency. Sometimes, there may not be a clear distinction between whether a firm should be considered as an importer experiencing an input cost shock following an exchange rate shock, or as an exporter experiencing a demand shock following an exchange rate shock. In this report, we focus on papers that are more clearly exploring cost as opposed to demand shocks within the exchange rate pass-through literature.

[141] Historically, most international studies used aggregate data, such as examining the impact of exchange rate movements on the consumer price index of tradable goods (that is, those goods that can be imported or exported) of the destination country (most often the US). More recently, however, some studies provide results using firm level data to examine the impact of exchange rate

The evidence from the international economics literature is that exchange rate pass-through elasticities are typically less than 1. In other words, the prices of imported goods are found not to adjust in proportion to the changes in the exchange rates between the currencies in question. The international economics literature has offered a number of potential explanations for this, including the following, which we highlight due to their relevance for the consideration of the pass-through of marginal cost changes:

- Local distribution costs (or non-traded costs) will drive a wedge between import costs and prices that is unresponsive to exchange rate fluctuations. If local costs represent a large portion of total costs, even a substantial increase in the price of the imported factor of production would have little impact on marginal costs. According to Goldberg and Hellerstein (2008), this factor explains the bulk of the incompleteness in exchange rate pass-through.

- The dependence of pass-through rates in oligopolistic markets on the curvature of the demand curve, and also on horizontal market structure (for example, the number of competitors and market shares), which leads firms to vary their mark-ups as their costs change. In other words, one possible explanation for the finding that pass-through elasticities are less than one is that, for the industries concerned, the demand curve is not highly convex.

- Multi-national firms that seek to minimise costs may substitute inputs as a result of exchange rate variation. For example, multi-national firms that source inputs both internationally and domestically may decide to switch suppliers following an exchange rate shock. If the domestic currency depreciates, multinational firms may substitute away from foreign inputs in favour of using local firms, which would minimise costs. This strategy limits the impact of a change in exchange rate on the cost of imported inputs, and as result dampens the pressure to increase prices in the domestic currency. In other words, the ability for a firm to arbitrage easily between different sources of the same input may diminish the degree to which it passes on a price rise affecting *one* of its sources of supply. This is analogous to a firm-specific shock that impacts on a single supplier to a customer that has a choice of a number of alternative suppliers.

movements on the prices (in the destination currency) of individual goods in the destination country. See Burstein, A. and Gopinath, G., 'International prices and exchange rates' (2013), in Handbook of International Economics, Volume IV (edited by Gita Gopinath, Elhanan Helpman and Kenneth Rogoff), for a summary of the exchange rate pass-through literature.

[142] To date, micro exchange rate pass-through studies have examined a relatively limited number of datasets and these have been US-focussed. For example, several studies examine the monthly US Bureau of Labor Statistics border price data from 1994 to 2005. Other studies examine wholesale and retail price data from Dominick's Finer Foods, the second-largest supermarket chain in the Chicago metropolitan region, from 1991 to 1994. Several studies examine wholesale and retail price data from a large retail chain that operates in the US and Canada from January 2004 to June 2007. Auer and Schoenle (2013), Gopinath, Itskhoki and Rigobon (2010), Gopinath and Itskhoki (2010), Nakamura and Steinsson (2008), with an earlier start year of 1988 but the same end year of 2005, and Peltzman (2000), using data from 1978 to 1996, use Bureau of Labor Statistics border price data. Besanko, Dubé and Gupta (2005), Goldberg and Hellerstein (2008), Goldberg and Hellerstein (2013), Hellerstein (2008), and Peltzman (2000), with an earlier start year of 1989, use Dominick's Finer Foods data. Hong and Li (2013) uses US and Canada retailer data. These papers are all discussed in this report.

[143] Four studies from outside the US are Fitzgerald and Haller (2013), which examines monthly data from Irish exporters to the UK for 1995-2005, Berman et al. (2012), which examines annual data for French exporters from 1995 to 2005, Amiti et al. (2013), which examines data for Belgian exporters from 2000 to 2008, and Goldberg and Verboven (2000), which examines annual data on European car prices from 1980 to 1993. However, these studies examine the impact of exchange rates on exporters rather than importers and so examine the impact of exchange rate changes that are perceived as demand, as opposed to cost, shocks. As a result, we do not examine these papers further in this report.

The finding that exchange rate pass-through elasticities are below 1 does not shed much light on absolute cost pass-through. That the exchange rate pass-through elasticity (which gives the relationship between a 1% increase in the exchange rate and the percentage change in price) is less than one does not imply that the absolute cost pass-through rate (which is the absolute change in price caused by a change in the absolute level of marginal cost) is less than 100%, for the following two reasons.

First, in most industries, the cost components affected by exchange rates will represent only a portion of the total marginal costs of supplying imported goods. It is therefore not surprising that the exchange rate pass-through elasticity is less than 1. Put another way, even if the absolute change in marginal cost resulting from the exchange rate change were passed on in full, this would not have a marked impact on price if the change in marginal cost was very small in absolute terms.

Second, even if the exchange rate shock affected all the components of marginal costs, the pass-through elasticity would typically still be less than the absolute pass-through rate, because firms typically earn positive margins. In particular, a pass-through elasticity of less than one occurs when a proportionate change in marginal costs leads to a less than proportionate change in price (i.e. a 10% increase in marginal costs leads to a less than 10% increase in price). However, if price exceeds marginal cost by a significant margin, 100% absolute pass-through of a cost change will bring about a smaller percentage change in price than the observed percentage change in cost.[144]

The literature has also found that nominal price rigidities offer limited explanation for incomplete exchange rate pass-through, although these rigidities help explain why even incomplete price adjustment is delayed. Possible explanations include firms not passing through small changes in cost, or delaying passing through cost changes because of adjustment or menu costs (for example, costs associated with renegotiating prices or updating price lists).

In the remainder of this chapter we report the most relevant findings from the empirical literature. In summary, the available evidence reveals a wide range of pass-through rates or elasticities. Absolute industry-wide pass-through can be as low as 20% but can also reach well over 100%. Pass-through elasticities may fall close to zero but in some cases they come close to one. However, there is not enough empirical evidence to tie these variations in pass-through to specific market features, as predicted by the theory described in the preceding chapters. In sum, we are able to draw little by way of solid conclusions in this respect.

Our review of empirical work in relation to pass-through leads to the following observations:

- In the round, the available empirical evidence reveals a wide range of pass-through rates across industries. Moreover, because different studies use a range of pass-through measures (absolute pass-through, pass-through elasticity, exchange rate pass-through), findings are not always comparable.

[144] For example, if a firm has price equal to $200 and marginal costs equal to $100, it earns a margin over marginal costs of $100. If the firm's marginal costs increase by $10 to $110 and it increases its price by $10 to $210, this implies a pass-through elasticity of 50% (5% divided by 10%) whereas absolute pass-through is 100% ($10 divided by $10).

- Firm-level (or product-level) evidence indicates that, even when facing an industry-wide cost change, individual firms adjust their prices at different rates.

- The available empirical evidence confirms the prediction that price responses to firm-specific cost changes are smaller than to industry-wide cost changes.

- Few studies investigate empirically the impact that the curvature of demand has on pass-through. The available evidence, however, confirms that it is an important factor affecting the magnitude of the price response to cost changes.

- There is some limited evidence that greater market power is associated with smaller industry-wide cost pass-through rates. However, not all findings we have identified are conclusive. We have not identified relevant evidence on the relationship between market power and firm-specific cost pass-through.

- Finally, there is some evidence of asymmetries in cost pass-through rates; in particular, that prices respond more quickly to cost increases than to cost decreases. However, the available evidence shows that eventually this asymmetry vanishes, but there is no clear rule about how long this process may take.

7.1. How large is pass-through: evidence from the literature

Several studies have investigated pass-through using firm-level data drawn from specific industries, including the coffee market, the oil industry, the processed cheese market, the automotive industry, wholesale electricity, and the retail market for stationery supplies, as well as groceries.[145] We have also reviewed a number of contributions to the tax incidence literature. However, only a few of these studies use firm-level data, and as such can shed light on issues relevant to competition economics. In the study we do report tax incidence studies, in particular Doyle and Samphantharak (2006), Hanson and Sullivan (2009), Harding et al. (2012) and Bergman and Hansen (2013), which provide relevant evidence on differences in the effects of firm- or group-specific cost changes on the one hand, and industry-wide cost changes, on the other.[146] Finally, we have surveyed the large exchange rate pass-through literature. However,

[145] In particular, Bonnet et al. (2013) examines coffee commodity cost shocks using weekly wholesale and retail price data from Germany for 2001 and 2002; and Leibtag et al. (2007) and Nakamura and Zerom (2010) use monthly wholesale and retail price data for the US from 2000 to 2004. Doyle and Samphantharak (2006) studies the US gasoline industry using daily retail price data for 2000 and 2001 and Borenstein et al. (1997) examines weekly spot crude oil, spot gasoline and branded terminal gasoline prices and semi-monthly retail gasoline prices from 1986 to 1992. Kim and Cotterill (2008) examines processed cheese in the US using quarterly retail price data from 1988 to 1992. Gron and Swenson (2000) studies the US automotive industry using annual retail list price data from 1984 to 1994 while Ashenfelter et al. (1998) uses monthly retail price and variable cost data from two large US stationery suppliers from 1995 to 1996. These studies are discussed below.

[146] The tax incidence literature finds a wide range of pass-through estimates from incomplete pass-through to "overshifting" (pass-through of over 100%) across both per unit excise taxes and ad valorem sales taxes, and across different sectors, such as cigarettes, alcoholic beverages, non-alcoholic beverages, groceries and gasoline. In particular, some of the key findings from this literature, which are not discussed in more detail in this report, are as follows. Besley and Rosen (1999) provides early evidence of overshifting for some products (such as bread) but not others (such as Big Macs) using disaggregated quarterly US data from 1982 to 1990. Young and Bieliska- Kwapisz (2001), using US data from 1997, and Kenkel (2005), using Alaskan data from 2002, find evidence of over-shifting of taxes to alcoholic beverage prices. Chouinard and Perloff (2004), using US gasoline data from 1989 to 1997, finds that a 1 cent federal tax increase raises the retail price by 0.47 cents and decreases the wholesale price by 0.56 cents. On the other hand, a 1 cent increase in the state specific tax causes a 1.01 cent increase in the retail price and a 0.02 cent increase in the wholesale price. More recently, Berardi et al. (2012) finds that the French tax on drinks with added sugar or sweetener, introduced in January 2012 was

we report only the results that are most relevant to the present study – that is, studies which examine exchange rate pass-through using product level data and oligopolistic models of competition in differentiated product settings (for example, Nakamura and Zerom (2010) and Goldberg and Hellerstein (2013)).

As we discuss in more detail below, taken in the round, the evidence we have identified indicates a wide range of pass-through rates. The tables below summarise the results of the studies we have reviewed in detail, by industry and by pass-through measure. We categorise the studies as follows:

- Table 8 summarises results in relation to absolute pass-through, i.e. the proportion of an absolute cost change that is passed through to an absolute change in prices.[147]

- Table 9 summarises pass-through elasticity results, i.e. the percentage change in price for a percentage change in marginal costs.[148]

- Table 10 summarises exchange rate pass-through elasticity values, i.e. the percentage change in price for a percentage change in the exchange rate.[149]

Care needs to be taken interpreting the results as different studies report different measures of pass-through, and it is generally not possible to compare these results, as information is often not available to convert elasticities into absolute pass-through rates.

In addition, most of the evidence reviewed addresses the magnitude of industry-wide pass-through. There are very few studies that examine firm-specific cost pass-through.

Overall these studies reveal a wide range of pass-through rates or elasticities. For instance, absolute industry-wide cost pass-through can be as low as 20% but can also reach well over 100%. Pass-through elasticities are estimated to be close to 0 in some cases but close to 1 in others. Note that because firms earn a mark-up over cost in most markets, this implies that any pass-through elasticities close to 1 equate to absolute pass-through rates above 100%. This is because the percentage change in price is surely higher in absolute value than the change in cost.

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generally not fully passed through to consumers, with full pass-through of the tax to soft drink prices but only about 85% for flavoured waters and 60% for fruit drinks. By contrast, using a structural model, Bonnet and Requillart (2013) predicts more than 100% pass-through for tax or cost changes for French soft drinks. Finally, Espinosa and Evans (2013) using US cigarette price data from 2001-2006 across 29 states, finds 100% pass-through of excise tax changes.

[147] For example, an absolute pass-through of 50% indicates that 50% of a marginal cost increase is passed through to the price. If the cost increased by $10, the price would increase by $5.

[148] For example, a pass-through elasticity of 0.5 indicates that a 10% change in marginal costs leads to a 5% change in price. If the cost were $10 and the price $100, and if the cost then increased from $10 to $11, the price would increase from $100 to $105. That is, the pass-through elasticity is 0.5 but the pass-through rate is 500%.

[149] For example, an exchange rate pass-through elasticity of 0.5 indicates that a 10% depreciation in the relevant exchange rate leads the price of a domestic imported good to increase by 5%. If a good is imported to the US from France and initially the price in the US is $100, and then the US dollar declines by 10% against the euro, the price would increase to $105.

Table 8: Summary of empirical absolute pass-through findings, ordered by year

Study	Industry	Pass-through	Comments
Borenstein et al. (1998)	US gasoline	Crude oil price increase to retail prices in first two weeks: **55%** Crude oil price increase to retail prices after ten weeks: about **81%** Crude oil price decrease to retail prices: slower adjustment but after ten weeks is also about **81%**	Industry-wide Crude oil prices; spot gasoline prices; terminal prices; and retail prices Reduced form
Besanko, Dubé & Gupta (2005)	US grocery chain	Product level: **22% to 558%**	Firm-specific but does not control for rival firms' cost changes Product level Wholesale to retail Reduced form
Leibtag et al. (2007)	US coffee	Short-run to manufacturer prices (same quarter): **21%** Short-run to retailer prices (same quarter): **14%** Long-run to manufacturer prices (after six quarters): **86%** Long-run to retail prices (after six quarters): **90%** Short-run pass-through from manufacturer to retail prices: **102%**	Industry-wide Commodity to wholesale to retail Reduced form
Kim & Cotterill (2008)	US processed cheese	Nash-Bertrand competition: **73% to 103%** across all brands Perfect collusion: **21% to 31%**	Industry-wide Brand-level Wholesale to retail Simulation
Hanson & Sullivan (2009)	US cigarettes	**108% to 117%** across brands and econometric specifications Reduction for generic cigarettes near Minnesota border (which has lower taxes): **9-13%** Increase for generic cigarettes near Michigan border (which has higher taxes): **16-26%** Almost no significant difference in pass-through for branded cigarettes near the border	Brand-specific Wisconsin state-specific per unit excise tax change Reduced form
Nakamura & Zerom (2010)	US coffee	Short-run to manufacturer prices (same month): **22%** Short-run to retail prices (same month): **14%** Long-run to manufacturer prices (after 6 months): **85%** Long-run to retail prices (after 6 months): **92%**	Industry-wide Commodity to wholesale to retail Reduced form Simulation

Marion & Muehlegger (2011)	US gasoline	Industry-wide: circa **100%**	Industry-wide State and federal taxes to retail gasoline and diesel prices Reduced form
Harding et al. (2012)	US cigarettes	Average: **90%** On lower-tax border: **49%** Ten miles from lower-tax border: **66%**	Firm-specific State-specific per unit excise tax change Reduced form
Bergman & Hansen (2013)	Danish alcoholic beverages and soft drinks	No significant difference in pass-through close to German border	Firm-specific Product-level Country-specific per unit excise tax change Reduced form
Fabra & Reguant (2013)	Spanish electricity	Industry-wide: circa **80%**	Industry-wide Emissions costs to wholesale prices Reduced form

Note: absolute pass-through results are rounded to the nearest per cent.

Table 9: Summary of empirical pass-through elasticity findings, ordered by year

Study	Industry	Pass-through	Comments
Ashenfelter et al. (1998)	US office supplies chain	Firm-specific: **0.15** Industry-wide: **0.85**	Firm-specific and industry-wide Firm level Wholesale to retail Reduced form
Gron & Swenson (2000)	US automotive imports	Firm: **0.12** Industry: **0.47**	Firm-specific and industry-wide Wholesale to retail Reduced form
Peltzman (2000)	US imports US grocery chain	Input cost (+) to producer price (same month): **0.24** Input cost (-) producer price (same month): **0.13** Input cost (+) to producer price (eight months later): **0.51** Input cost (-) producer price (eight months later): **0.35** producer price (+) to retail price (same month): **0.19** producer price (-) to retail price (same month): **0.07** producer price (+) to retail price (five months later): **0.52** producer price (-) to retail price (five months later): **0.34**	Firm-specific but does not control for extent of local competition or number of importing countries in import data and does not control for rival firms' cost changes in grocery data[150] Input cost to producer price to retail price Reduced form
Doyle & Samphantharak (2006)	US gasoline	Repeal and reinstatement: around **0.60-0.80** Reinstatement, at the border: **0.64** Reinstatement, between thirty and sixty minutes away: **0.66** Reinstatement, sixty to ninety miles away: **0.86** Reinstatement, over ninety minutes away: **0.84**[151]	Firm-specific State-specific tax change to retail prices No significant differences for distance to border for repeal Reduced form
Hellerstein & Villas-Boas (2010)	US automotive	Reduced form: mean **0.38** and range **0.00 to 0.90** across all vehicle models Fully outsourced simulation: median **0.13** and range **0.07 to 0.27**	Industry-wide Vehicle model level Wholesale to retail Reduced form Simulation

[150] For imports, the exchange rate shock would be firm-specific unless there was no local competition and only one importing country. Further, the proportion of an industry affected by an exchange rate shock would depend on both the extent of local competition and the number of other importing countries in that sector which are not affected by the exchange rate shock.

[151] Results converted to elasticities by dividing the percentage changes in retail prices by the percentage change in the sales tax, which was 5%. The percentage impacts on retail prices were 3% for the repeal and 4% for the reinstatement (although these results were not statistically significantly different from one another). The percentage impacts from the border following the reinstatement were 3.2% at the border, 3.3% between thirty and sixty minutes away, 4.3% sixty to ninety miles away, and 4.2% over ninety minutes away.

		Multinational simulation: median **0.54** and range **0.32 to 1.20**	
Nakamura & Zerom (2010)	US coffee	Short-run to manufacturer prices (same month): **0.12** Short-run to retail prices (same month): **0.06** Long-run to manufacturer prices (after 6 months): **0.26** Long-run to retail prices (after 6 months): **0.25**	Industry-wide Commodity to wholesale to retail Reduced form Simulation
Bonnet et al. (2013)	German coffee	Linear tariff, no resale price maintenance and no uniform pricing simulation: average **0.71**, and range **0.67 to 0.75** across brands Two-part tariff, no resale price maintenance and uniform pricing simulation: average **0.70** and range **0.66 to 0.74** Two-part tariff, no resale price maintenance and no uniform pricing simulation: average **0.70** and range **0.65 to 0.80** Two-part tariff, resale price maintenance and uniform pricing simulation: average **0.82** and range **0.78 to 0.86** Two-part tariff, resale price maintenance and no uniform pricing simulation: average **0.82** and range **0.79 to 0.86**	Industry-wide Brand level Wholesale to retail Simulation

Note: pass-through elasticities are rounded to the nearest two decimal places.

Table 10: Summary of empirical exchange rate pass-through elasticity findings, ordered by year

Study	Industry	Pass-through	Comments
Hellerstein (2008)	US beer imports	Reduced form retail: **0.11** Simulated manufacturer: median **0.32** and range **0.10 to 0.43** Simulated retailer: median **0.20** and range **0.01 to 0.27**	Firm-specific Manufacturer and retailer level Wholesale to retail Reduced form Simulation
Gopinath and Itskhoki (2010)	US imports	No significant relationship between pass-through and Herfindahl index or number of importers accounting for top 50% of trade	Firm-specific, but does not control for extent of local competition or number of importing countries Reduced from Exchange rate shock to import prices
Auer and Schoenle (2013)	US imports	Minimum of **0.02** for firms with market share of 72%	Firm-specific, but does not control for extent of local competition or number of importing countries Reduced form Non-linear specification Exchange rate shock to import prices
Goldberg & Hellerstein (2013)	US beer imports	Average retail: **0.07** Average wholesale: **0.05**	Firm-specific Wholesale to retail Reduced form

Note: exchange rate pass-through elasticities are rounded to the nearest two decimal places.

7.2. Evidence on firm-level pass-through

In the context of a competition law investigation, the extent of price adjustment to firm-specific cost changes is frequently of most interest, yet the empirical pass-through literature has focused largely on the responses of prices to industry-wide cost changes.

The most relevant empirical literature employs firm and product level data. As a result, these studies assess how prices of individual products or firms adjust to cost changes. Nevertheless, much of this literature is concerned with firm-specific variation in the price responses to industry-wide cost changes rather than with the effects of firm-specific cost changes.

The main insight from this research is that even when facing industry-wide cost changes, individual firms typically adjust price at different rates. The literature, however, does not investigate which factors could explain the asymmetric price response of competitors to the same cost change. Nevertheless, the practical implication is that the price response for one product (or for one firm) may not be taken as a close proxy for the price response of another product (or for another firm).

In the remainder of this section, we review some of the main evidence on product-level pass-through of industry-wide cost shocks. A large body of that literature is based on simulation techniques using oligopoly models in differentiated products markets (see Annex A for a detailed presentation of the methodology employed). Specifically, Kim and Cotterill (2008), Hellerstein and Villas-Boas (2010), Goldberg and Hellerstein (2013) and Bonnet, Dubois, Villas-Boas and Klapper (2013) rely on counterfactual simulations to investigate the impact of a uniform change in marginal cost on individual product prices. That is, these studies gauge the impact of a market-wide increase in marginal cost on each brand or each firm's price. The main conclusion is that although the change in marginal cost is the same, the pass-through rate may vary sometimes significantly from product to product.

Below we review in more detail the main findings of this literature.

Kim and Cotterill (2008) simulates the effect of a 1 cent increase in marginal cost per serving for all brands of processed cheese on retail prices in the US, which enables them to generate predictions of absolute cost pass-through rates. Table 13 below shows that under non-cooperative Nash-Bertrand price competition, absolute cost pass-through rates range from 77% (Lite Line) to 103% (Borden). Hence, even though a uniform industry-wide cost change is assumed, firms' retail prices are predicted to adjust differently.

Hellerstein and Villas-Boas (2010) uses data from the US automotive industry to estimate a reduced form model.[152] It finds that the pass-through elasticity varies significantly across models, from statistically indistinguishable from 0 for the Ford Explorer, the Honda Accord, and the Honda Odyssey to 0.90 for the Chrysler PT Cruiser. The average pass-through elasticity is 0.38 across models, with a standard deviation of 0.25.

The authors then estimate a differentiated product structural model in which price decisions are taken sequentially by parts suppliers and then by original equipment manufacturers (OEMs). The model's first order conditions are calibrated with the demand parameter estimates and observed prices to obtain an estimate of marginal costs.

Next they simulate a number of counterfactual scenarios in which the cost of foreign parts is increased by 10% under various assumptions regarding the degree of firm's vertical integration. In particular, they compare the price adjustment when firms fully outsource foreign parts and when the foreign parts are produced in-house as part of a multinational as follows:

- the first simulation examines how retail prices adjust following a 10% change in the cost of foreign parts when all upstream production is modelled as fully outsourced; and

- the second simulation considers how retail prices adjust following a 10% change in the cost of foreign parts if all upstream production is modelled as in-house.

Table 11 below summarises some of the results presented in this study.

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[152] They analyse monthly transaction data for 24 vehicle models sold in the US by six manufacturers, as well as the share of inputs sourced from abroad by model, from October 2002 to June 2006. The foreign proportion of inputs ranges from 18% for Ford to 57% for Toyota.

Table 11: Pass-through elasticities for 10% foreign cost increase for different levels of vertical integration

Manufacturer	Model	1. Fully outsourced	2. Complete integration	Difference
DaimlerChrysler	Grand Cherokee	0.11 (.03)*	0.51 (.13)*	0.40 (.12)*
DaimlerChrysler	PT Cruiser	0.27 (.04)*	0.45 (.19)*	0.18 (.09)*
Ford	Explorer	0.12 (.03)*	0.51 (.13)*	0.39 (.12)*
Ford	Mustang	0.14 (.03)*	0.39 (.11)*	0.25 (.09)*
Ford	Taurus	0.13 (.04)*	0.83 (.28)*	0.70 (.26)*
GM	Corvette	0.10 (.02)*	0.32 (.06)*	0.22 (.05)*
GM	Impala	0.13 (.04)*	0.73 (.23)*	0.6 (.22)*
Honda	Accord	0.08 (.03)*	0.50 (.21)*	0.41 (.15)*
Honda	Civic	0.12 (.04)*	1.09 (.47)*	0.97 (.30)*
Nissan	Altima	0.10 (.03)*	0.64 (.21)*	0.54 (.22)*
Nissan	Maxima	0.07 (.03)*	0.33 (.09)*	0.26 (.09)*
Toyota	Camry	0.09 (.03)*	0.59 (.22)*	0.50 (.22)*
Toyota	Corolla	0.13 (.05)*	1.20 (.71)	1.07 (.94)
Total		0.13 (.03)*	0.54 (.13)*	0.40 (.13)*

Source: Hellerstein and Villas-Boas (2010), excerpts from Table 8.

As Table 11 above shows, under the first simulation, the outsourced scenario, the median pass-through elasticity across all models is 0.13 (between the retail price and foreign cost shock). This ranges from 0.07 for the Nissan Maxima to 0.27 for the Chrysler PT Cruiser. For the second simulation, the in-house scenario, the median pass-through elasticity of the cost shock to the retail price is 0.54 but varies significantly across brands, ranging from 0.32 for the Chevrolet Corvette to 1.20 for the Toyota Corolla.[153]

Bonnet et al. (2013) examines pass-through in the market for coffee in Germany. They first estimate a reduced form regression to quantify the effect of a change in the price of raw coffee on retail prices, which provides the elasticity of the retail price with respect to the coffee commodity cost shock (i.e. the percentage change in price for a percentage change in the raw coffee cost). They control for brand and retailer fixed effects, manufacturer and retailer fixed effects, or product (defined by the brand and retailer) fixed effects. They adopt a log-log

[153] Note that there appears to be a slight mismatch between the numbers reported in Table 9 (p. 181) of the Hellerstein and Villas-Boas (2010) paper and those in the text. The numbers in the table show total pass-through declines from 0.26 in simulation 3 to 0.15 in simulation 4. However, the text refers to the table showing median pass-through declining from 0.25 to 0.14. We have referred to the numbers in the authors' tables where a discrepancy arises and assumed that "total" refers to "median" as is consistent with Table 8 (p. 180) and the relevant text.

specification, where log price is the dependent variable and the set of independent variables includes: log coffee cost; or log coffee cost and retailer interactions; or log coffee cost and manufacturer interactions.[154]

The reduced form regression indicates that a pass-through elasticity of a change in the cost of raw coffee beans to retail prices of 0.18. The authors do not find any variation in pass-through across retailers but they do find variation across manufacturers. The point estimates for the pass-through elasticity vary from 0.08 to 0.31 across the different coffee manufacturers.

Next, the authors estimate a structural model. On the demand side, they estimate a demand system (à la Berry, Levinsohn, and Pakes (1995)) and use the parameter estimates to calibrate the supply-side. Then they simulate the impact of a 10% increase in total marginal cost on equilibrium price. They allow for different vertical restraints between branded coffee suppliers and grocery retailers. Regardless of supply arrangements, the variation in pass-through estimates across suppliers is significantly narrower than suggested by the papers considered above. For example, under two-part tariffs, no resale price maintenance and uniform pricing, a 10% increase in total marginal cost is predicted to lead brand prices to increase by between 6.59% and 7.36% – implying a pass-through elasticity of 0.66 to 0.74 (see column 2 of Table 3 on page 509 of Bonnet et al. (2013)). We also note that these estimates are larger than the reduced-form estimates presented above.

7.3. Industry-wide versus firm-specific cost pass-through

As shown in Chapter 4 above, economic theory predicts that the price response to a firm-specific cost change will be lower than to an industry-wide cost change of the same magnitude. This prediction is confirmed by the available empirical evidence.

In principle, studies that have relied on structural models to simulate counterfactual scenarios in which the level of marginal cost is altered could be used to gauge the impact of firm-specific shocks. However, the economic literature has focused largely on examining the effect of industry-wide cost changes on equilibrium prices. As a result, the evidence on firm-specific pass-through is limited and based on different approaches.

We have identified two notable empirical studies that use reduced-form regression to compare industry-wide and firm-specific cost pass-through. In broad terms, these studies corroborate the theoretical prediction that industry-wide cost pass-through will exceed firm-specific cost pass-through. In fact, the empirical findings that we present below suggest that firm-specific cost pass-through can be significantly smaller than industry-wide cost pass-through in practice.

[154] As indicated by Bonnet et al. this reduced form approach may give rise to biased estimates. This is because the common cost shock affects firms' strategies, which in turn affect mark-ups and equilibrium prices. However, this effect is not controlled for, and is correlated with the cost shock, giving rise to an endogeneity issue, whereby the pass-through is capturing not only the direct effect of the firm's own cost increasing but also the indirect effect of the firm's price response to the change in other firms' prices following the common cost shock. The endogeneity problem motivates the adoption of a structural model, which accounts for changes in the competitors' strategies.

First, Gron and Swenson (2000) provides direct empirical evidence suggesting that the pass-through elasticity is higher when the cost change affects all products on the market than when the cost shock is product-specific.

Using data on the automotive industry, a basic reduced form equation is estimated:

$$\ln p_{i,t} = \gamma_i + \beta \ln c'_{i,t} + \epsilon_{i,t}$$

where $p_{i,t}$ is the price of car model i at time t and $c'_{i,t}$ is the marginal cost of model i. The marginal cost term depends on product characteristic and factor prices, and its functional form is given by:

$$c'_i = V_i(w_{US}, s_f w_f) e^{[I_i]}$$

$V_i(w_{US}, s_f w_f)$ is a measure of product-specific input costs expressed as a function of local factor prices, w_{US}, and foreign factor prices w_f multiplied by the exchange rate, s_f, for country f, and I_i is an index of product characteristics, which specifies which of the *n* potential car features are relevant to the car model in question. Simply put, the cost of a car is assumed to increase with power, size or other features.

In this model specification, β measures the pass-through elasticity. The regression model is estimated using data for the period 1984 to 1994 using a fixed-effects estimator.[155] The primary objective of the study is to demonstrate that ignoring input substitution tends to yield biased results.[156] The authors show that, by accounting for input substitution, the pass-through elasticity is 0.473 instead of 0.412 – in other words, the estimates are downward biased.

Interestingly, when Gron and Swenson (2000) introduces time effects into the model specification, the pass-through elasticity estimate falls to 0.117, which is a significant drop in comparison to 0.473 (a reduction of 75%). The introduction of the time effects in the model specification is critical in this case. Because the time effects are common to all firms, they capture the impact of common cost variations. As a result, the price responses measured by β are now limited to responses to firm-specific cost changes β.

Second, a study by Ashenfelter et al. (1998) estimates the pass-through elasticity of a major chain of office supplies superstores in the US by distinguishing the effects of firm-level and

[155] For an explanation of fixed-effects estimators see, for example, Woolridge: *Econometrics Analysis of Cross Section and Panel Data*.

[156] This aspect of their research has less relevance to this study. Nevertheless, the authors show that by not taking into account the exchange-rate effects on input decisions biases estimates of pass-through towards incomplete pass-through. Indeed, when the exchange rate fluctuates, this may raise the price at which some input suppliers sell parts, and in turn, the auto manufacturer would switch its requirements to other input suppliers. For example, consider a Japanese manufacturer selling cars in the US. When the exchange rate between the US Dollar and the Yen changes, this affects the cost of input components such as the car engine or body parts if those can be sourced both in Japan and the US. For instance, when the US Dollar depreciates with respect to the Yen, this tends to raise the price of Japanese cars in the US. However, the depreciation of the dollar may also trigger input substitution. That is, the Japanese manufacturer may consider purchasing an engine made in the US – now cheaper – instead of made-in-Japan engines. The cost of the car therefore increases by less. Note that if all of the car components were sourced in the US instead of Japan, then the cost of manufacturing the car would not increase at all. Input substitution reduces the manufacturer exchange rate pass-through. That is, this effect is a result of manufacturers being able to source from different international suppliers during exchange rate shocks. In other words, even if all suppliers are passing on 100% of any increase in the exchange rate, the final estimated pass-through by the final automotive manufacturer could be smaller than 100% if it sources one or more components from a manufacturer in a country that does not experience the exchange rate shock.

industry-wide input cost shocks on price. It also highlights the importance of controlling for industry-wide cost shocks when estimating firm-specific cost pass-through as failing to do so would lead to overstating the firm-specific cost pass-through rate. It concludes that Staples, the major chain at issue, had a pass-through elasticity of 0.15; that is, when the marginal cost of Staples falls by 10%, its average price declines by just 1.5%.[157]

The analysis uses the following reduced-form price regression, whereby Staples is assumed to adjust prices in response to industry-wide cost shocks, but also to changes in its own cost and to changes in its rivals' costs. The following baseline regression specification (in logs) allows for such a relationship (leaving aside demand shift variables to save on notation):

$$p^S = \beta_0 + \beta_1 c^S + \beta_2 c + \sum \delta^i c^i + e$$

where p^S is Staples' price and each firm's marginal cost is decomposed into two components: c is the industry-wide marginal cost component, and c^i is the firm-specific marginal cost for each rival firm *i*. Note that $k^i = c + c^i$ is the marginal cost for firm *i*.[158] The marginal cost for Staples is given by $k^S = c + c^S$. Moreover, because c is common to Staples and its rivals, it appears just once on left-hand side of the regression. e is the regression error term.

The equation above requires data not only on Staples' cost components, but also on industry-wide costs as well as rival-specific cost components. The authors could not observe cost components directly, but had proxy data on Staples' and Office Depot's marginal costs.

The above equation can be re-written as follows:

$$p^S = \beta_0 + \beta_1 k^S + (\beta_2 - \beta_1)k^D + (\beta_2 - \beta_1 + \delta^D)c^D + \sum \delta^i c^i + e,$$

where k^S is the marginal cost for Staples and k^D the marginal cost for Office Depot, another major chain of superstores. These two variables are observable. However, the firm-specific cost components, c^D and c^i are not observable.

Importantly, the authors assume that firm-specific and industry-wide cost components are independent. This implies that the firm-specific cost components are not correlated with each other, or with the industry-wide cost component. For instance, an increase in the cost of plastic for pens (industry-wide cost component) affects all firms, independent of the negotiating skill of a manager in bargaining with suppliers (firm-specific component). This assumption has the following one important implication. Omitting the firm-specific cost component of rivals in the regression does not raise any estimation issues. That is, because neither c^D nor c^i is correlated with k^S, this means that the marginal cost of Staples is not correlated with the residuals. However, omitting the marginal cost of Office Depot from the regression would bias the estimation, and thus the pass-through estimate β_1 would not be reliable. This is because

[157] This result was relied upon by the court in deciding to enjoin preliminarily the proposed merger of Staples and Office Depot, another office supply superstore. The parties claimed that two thirds of the cost reduction was historically passed through to consumers, which is substantially higher than the elasticity suggested by the regression results. Federal Trade Commission v. Staples, Inc., 970 F. Supp. 1066, 1090 (D.D.C. 1997) (Hogan J). The judge did not accept the parties' claim.

[158] The authors use monthly price and variable cost data on 30 identical products provided by Staples and Office Depot.

omitting k^D from the regression implies that k^S, the marginal cost of Staples, is correlated with the error term. Indeed, k^S and k^D are correlated as they include the industry-wide cost component. There is thus a clear omitted variable bias.

To test the hypothesis that omitting the cost of rivals in the regression leads to biased estimates, the authors estimate two different model specifications, one including Office Depot's variable cost and the other one excluding it.[159] In some model specifications, the authors also include a variable to account for local competition. Specifically the competitor variables control for the number of Staples, Office Depot, OfficeMax, Wal-Mart, Sam's Club, Computer City, Best Buy, Office 1 Superstore, Costco, BJ's, CompUSA, Kmart, and Target stores in the metropolitan statistical area (MSA). This results in four different model specifications overall, with two model specifications (Models 2 and 4) including the log of average Office Depot cost as an explanatory variable, whilst two specifications (Models 3 and 4) include competitor variables as explained above. The main regression results are presented in Table 12 below.

Table 12: Results of the estimates of log of costs and control variables on log staples price

	Model 1	Model 2	Model 3	Model 4
Separates firm-specific costs from industry-wide cost changes?	No	Yes, by including log of competitor (Office Depot) cost as explanatory variable	No	Yes, by including log of competitor (Office Depot) cost as explanatory variable
Inclusion of additional variable to control for the number of competitors in the MSA (i.e. X_{jt})?	No	No	Yes	Yes
Log Staples cost coefficient (a_1 or b_1)	0.571 (194.20)	0.149 (37.62)	0.571 (195.15)	0.149 (37.65)
Log Office Depot cost coefficient (b_2)	-	0.696 (150.25)	-	0.697 (151.22)
Implied firm-specific pass-through elasticity	57%	15%	57%	15%
Implied industry-wide pass-through elasticity	57%	85%	57%	85%

Source: Ashenfelter et al. (1998), Table 1. Note: t-statistics shown in parentheses.

Models 1 and 3 omit Office Depot's variable cost and thus do not control for industry-wide cost variations. The results for Model 1 and 3 are very similar: the estimated coefficient of interest is

[159] Ashenfelter et al. (1998) estimates the historical pass-through rate for Staples using monthly price and variable cost for 30 products (disaggregated at the Stock Keeping Unit (SKU) level). In addition, the regressions include a set of fixed-effects dummies for the store, product (SKU), and the month, to control for price variation due to differences across stores, products and months.

0.571, which implies that a 10% decrease in Staples' cost (firm-specific or industry-wide) would result in a 5.7% decrease in price.

In sharp contrast, the results of Model 2 and 4 show a much lower pass-through elasticity. These model specifications include Office Depot's variable cost. In this case, the coefficient of interest is 0.149. This result shows that omitting industry-wide cost can lead to severely biased results.

Model 2 and 4 also allow the authors to estimate approximately the pass-through elasticity in respect of industry-wide cost changes. They add the coefficient estimate on the variables for Staples and Office Depot respectively and find an elasticity of 0.85, which is higher than the price adjustment to changes in Staples' cost only. This approach is justified by the fact that the cost variables for Staples and Office Depot are closely correlated, suggesting that the industry-wide component is the main driver of cost fluctuations.

This study shows that to estimate firm-specific pass-through, the econometrician must account for industry-wide cost fluctuations. Furthermore, the results also confirm that the industry-wide pass-through elasticity is greater than the firm-specific pass-through elasticity.

Finally, we note that the literature on tax incidence also provides indirect evidence that firm-specific cost pass-through rates are smaller than industry-wide cost pass-through rates. Specifically, a number of studies examine how retail prices adjust to changes in local excise taxes. They quantify pass-through rates for retail stores that compete with stores that are equally affected by the local tax change (market-wide cost pass-through), on the one hand, and pass-through rates for stores that compete with stores not affected by the tax change (firm-specific cost pass-through), on the other. Typically, the firm-specific cost pass-through rates are derived for stores located near borders between affected and unaffected territories, which are potentially in competition with stores across those borders.

In the remainder of this section we present the main findings of four tax incidence studies which, taken together, provide some support for the prediction that industry-wide cost pass-through is greater than firm-specific cost pass-through.

First, Doyle and Samphantharak (2006) examines the effect of the repeal and reinstatement of a sales tax on the retail price of unleaded gasoline in two US states - Illinois and Indiana - in response to a temporary spike in the gasoline price in 2000. In particular, it compares the pass-through elasticity (i.e. the percentage retail price change relative to the percentage sales tax change) for petrol stations that were in competition with stations in other states which did not experience any change in the tax regime with pass-through elasticities for stations that were in competition with stations that experienced the same tax change.

Pass-through is estimated using both the repeal and reinstatement episodes. The sales tax was repealed in Illinois and Indiana at the same time in July 2000 and was reinstated again in October 2000 in Indiana and in January 2001 in Illinois. While within the Indiana and Illinois borders, the effect of the tax would be felt equally by each station, when compared to stations in other states (such as Iowa, which did not have the gasoline tax repealed and subsequently reinstated) the shock is firm (or state) specific. The results show that retail gas prices drop by

3% following the suspension of the 5% tax, while the reinstatement of the tax yields an increase of 4%.

With this in mind, the paper tests the effect of tax changes on pass-through rates for stations close to the state border, that are in competition with stations across the border. The intuition is that stations in the state that was subject to the tax change that were close to a border would have less pressure to pass on the tax saving (following the repeal) than stations that were far from a border. By the same token, stations in the other state that were close to the same border would face fiercer competition than stations far from that border, and may have had to match the reduction in prices caused by the tax change.

For example, stations situated at the Illinois side of the Illinois-Iowa state border would not have been subjected to the 5% gas tax when the tax was repealed, whereas a station just on the other side of the border would still have been subjected to this tax. This means that the Illinois station's costs would be lower than before while the Iowa station would have experienced no such cost reduction. To the extent that these two stations were competing before, the reduced costs for the Illinois station would give it a relative advantage over the Iowa station, which implies that the Illinois station would now place greater competitive pressure on the Iowa station. We would therefore expect to find that Illinois stations close to the Iowa border would pass-through a smaller proportion of the repealed 5% sales tax than those close to other Illinois stations which would have the same cost advantage. Similarly, Iowa stations close to the Illinois border might have needed to reduce their prices to compete with the Illinois stations.

As a result of these two effects, the impact of the tax change may change at different distances from the border. The authors therefore investigate whether the difference-in-difference estimates vary with different distances from the border. That is, they group stations in Illinois and Indiana according to distance from the border. Similarly, they group stations in neighbouring states (the control group) that have not experienced any tax reform according to their distance from the border with Illinois/Indiana. Next, on the one hand, they estimate the 'before/after' effect for the treated group as a function of the distance to the border and, on the other hand, they estimate the 'before/after' effect for the control group as a function of the distance to the border. The difference between these two estimates gives a difference-in-differences estimate.

The results for the repeal of the tax show no evidence that the difference-in-difference estimate varies with distance to the border. That is, there is no evidence that stations closer to the border adjusted prices downwards by less than stations further away from the border.

On the other hand, results for the tax reinstatement episode in October in Indiana show that distance to the border has a significant effect on the estimated pass-through. The price adjustments at the border and between thirty and sixty minutes away are 3.2% and 3.3% respectively, but increase to 4.3% and 4.2% for stations located between sixty to ninety and over ninety minutes away respectively. This suggests that stations located closer to the border passed on less of the tax increase than those located farther away. This result may be interpreted as suggesting that the industry-wide cost pass-through rate is greater than the firm- (or group-)specific cost pass-through rate (in the sense that pass-through was greater for those stations that were surrounded by other stations that were subject to the same tax shock than for stations which were near the border and hence near firms not subject to the same tax change).

Second, Hanson and Sullivan (2009) studies the effect on cigarette prices of a $1 increase in the state of Wisconsin's tobacco tax, which took place in 2008.[160] Using a difference-in-differences approach, with prices in the surrounding states as a control group, the authors find that the $1 increase in excise taxes increased prices by between $1.08 and $1.17 across branded and generic cigarettes and different econometric specifications.

The authors then assess empirically using a difference-in-differences approach how distance to the border affects pass-through. As in Doyle and Samphantharak (2006), this analysis may offer some insight into the difference between industry-wide and firm-specific cost pass-through rates. To the extent that firms near the border competed with firms that were unaffected by the tax change, the tax change was firm- (or group-)specific, because only firms in Wisconsin experienced it, while those on the other side of the border did not. In that study, there is no evidence that firms that experience a group-specific cost shock have lower pass-through rates than those that experience an industry-wide cost shock.

Third, Harding et al. (2012) uses a large micro-data set for the US to assess the incidence of cigarette taxes. Thanks to the rich nature of the data, it investigates the impact of excise taxes on price paid by individual consumers and prices recorded at stores. In general, it finds robust evidence that pass-through rates are lower at stores near borders with lower tax states. For example, it finds that the pass-through rate is 49% for consumers located on the border, while the pass-through rate increases to 66% for consumers ten miles from the border with a lower tax state, and to 86% beyond 120 miles from the border. It also finds a similar pattern of results when store prices are considered.

These findings suggest that pass-through is lower for firms that experience a specific shock that does not affect all competitors. Indeed, for stores close to a border, alternatives across the border provide a credible alternative for consumers seeking to avoid the excise tax increase. In turn, stores close to such borders absorb more of the excise tax than stores located away from the borders. For these latter stores, the pass-through rate is equivalent to an industry-wide shock, as all nearby stores experienced the same tax change.

Finally, we mention Bergman and Hansen (2013), which examines the impact of excise tax changes for alcoholic and non-alcoholic beverages in Denmark over the period 1997 to 2005. In relation to industry-wide vs firm-specific cost pass-through, its results are inconclusive. That is, it finds no significant evidence that pass-through is different for stores close to the German border, where excise taxes are significantly lower and which might compete with stores close to the border in Denmark.

7.4. Evidence on the curvature of the demand curve

As indicated in the preceding chapters, the shape of the demand curve is a key factor determining pass-through. However, very few empirical studies report on the role of the curvature of demand in explaining cost pass-through. This is because most of the studies

[160] The authors use a telephone survey of cigarette retailers in Wisconsin and surrounding states to collect information on prices of generic and branded cigarettes.

mentioned in the preceding sections employ a reduced-form approach (see Annex A for an introduction to reduced-form methods) and, as a result, they are not able to identify the key factors that determine pass-through, and in particular the role of the curvature of demand.

However, a few studies using structural models that introduce consumer heterogeneity to estimate pass-through yield estimates of the curvature of demand. Specifically, these studies report an estimate for the so-called super elasticity of demand, i.e. the elasticity of the elasticity of demand as price changes.

Below we first discuss how consumer heterogeneity relates to the curvature of demand, and second we present the findings of relevant studies on the super elasticity of demand.

7.4.1. Consumers heterogeneity and curvature of demand

In the standard demand models such as linear, multinomial logit or AIDS, the curvature of demand is fixed by the functional form. Little is gained by adopting these specific demand functions to estimate pass-through rates, therefore. In contrast, the random coefficient logit model, which introduces consumer heterogeneity, allows the *estimation* of demand curvature for each product. This is because this model allows for differences in individual consumer responses to price changes. In turn, the own price elasticity is a weighted average of individual consumers' price sensitivities, and not that of a single representative consumer. This implies that the price elasticity of a given product depends on the aggregate composition of demand, and this composition may vary with price changes, which in turn implies that demand elasticity will also change.

Consumer heterogeneity may be introduced in several ways. For example, price sensitivity may be related to income level. In most studies, higher income consumers tend to be less price-sensitive. This implies that products that are purchased disproportionally more by higher income consumers have a less elastic demand than others.

When the price of a product is increased, the composition of demand will be altered, and the elasticity of demand may change. For instance, following a price rise, price-sensitive consumers may 'drop out' first, which means that aggregate consumer demand will comprise a greater proportion of higher income consumers, and thus demand will become less elastic. In this case, inverse demand will be convex, and this gives rise to a higher pass-through rate.

The introduction of consumer heterogeneity in the random coefficient logit model need not give rise automatically to convex curvature. (See Annex A for an introduction on the random coefficient logit model.) Consumer heterogeneity also implies that tastes vary according to consumer characteristics. In discrete choice models such as the random coefficient logit model, consumers select the product that provides the highest level of utility. In particular, consumers buy a product in the market if they obtain more utility by doing so than by buying the outside good. For example, Nakamura and Zerom (2010) estimates demand for ground coffee in the US. In that study, the outside option is for consumers to drink coffee at a café. The estimation results show that higher income consumers tend to obtain relatively more utility from this outside option compared with purchasing ground coffee. This implies that as the price of ground coffee is increased, the proportion of higher income consumers that continue to purchase the product will fall, and demand will become more elastic. In this case, the curvature of demand may be concave, or linear, or slightly convex.

When consumer heterogeneity arises across several dimensions, it becomes harder to predict intuitively how a price change will affect demand elasticity without using a model such as the random coefficient logit model. Such a model compounds the effect of multiple factors on the price elasticity of demand. For example, Kim and Cotterill (2008) estimates pass-through rates for processed cheese in the US using such a random coefficient logit model. In that study, relevant consumer heterogeneity involves more than variation in income level: consumer price sensitivity varies not only with income level, but also with age and whether the household has children. Naturally, both individual consumer taste and price sensitivity vary with these characteristics, which makes it harder to predict the curvature of demand.

7.4.2. Positive super-elasticity of demand and pass-through

We have identified a number of papers that report empirical estimates of the "super elasticity of demand", which in turn provides some indication of the curvature of demand. The super elasticity of demand is the percentage change in the price elasticity of demand associated with a given percentage increase in price and is related to demand curvature.[161] In addition, the super elasticity is a key determinant of pass-through elasticity, but it is also related to the pass-through rate.[162,163]

When the super elasticity is positive, this indicates that as price increases, the elasticity of demand increases, and the pass-through elasticity is reduced. In other words, the firm adjusts its mark-up (or the Lerner index) down in response to a marginal cost increase. When the super elasticity is zero, this corresponds to the special case of constant elasticity of demand. Regardless of the cost change, the firm always keeps a constant mark-up (or Lerner index) in this case, and the pass-through rate exceeds 100%.

Nakamura and Zerom (2010), for example, develops a random coefficient logit model and estimates the median super elasticity of demand at 4.64 for the supply of coffee at the retail level in the US. That is, a 1% increase in prices leads to a 4.64% increase in the price elasticity of demand.[164]

To approximate the pass-through rate we use the formulation for a single-product firm set out in Bulow and Pfleiderer (1983), namely:

$$\frac{dp}{dc} = \frac{\varepsilon}{\varepsilon - 1 + \eta}$$

[161] The super elasticity is given by $\eta = 1 - \varepsilon + \frac{\partial Q}{\partial P}\left(\frac{\partial^2 Q}{\partial P^2}\right)^{-1} P$. That is, it depends on the curvature of demand $\left(\frac{\partial^2 Q}{\partial P^2}\right)$. If $\eta > 0$, a price increase leads to an increase in the elasticity of demand.

[162] See Stennek and Verboven (2001).

[163] See Bulow and Pfleiderer (1983).

[164] See, also, Hovhannisyan and Bozic (2013).

where ε is the price elasticity of demand and η the super elasticity. Applying this formula to the estimates presented in Nakamura and Zerom gives a pass-through rate of 0.49.[165]

Goldberg and Hellerstein (2011) reports a super elasticity between 0.8 and 1 for the demand of light beer in the US. This result indicates a higher pass-through elasticity than that found by Nakamura and Zerom (2010). Using Bulow and Pfleiderer's formula again, the approximate pass-through rate in this case is around 100%.[166]

In general, when the super-elasticity is positive, it is unclear to which value of the absolute pass-through this corresponds without additional information on the elasticity level. This is because a positive super-elasticity is consistent with concave, linear and also some convex demand curves. However, a greater super-elasticity implies inverse demand that becomes more elastic as price increases, giving rise to a lower pass-through rate.

7.5. Competition and cost pass-through

As indicated in the theoretical chapters, economics predicts that cost pass-through rates in oligopoly markets will depend in large part on the shape of the demand curve. Moreover, standard oligopoly models predict that as the intensity of competition increases, the industry pass-through rate will also increase, provided demand is not too convex, whilst for many (but not all) models, the firm-specific pass-through rate is predicted to diminish. However, we have identified very few articles that have tested these propositions empirically, and the limited evidence available does not allow a robust empirical appraisal of the theoretical results.

Below we present some of the main empirical findings in this area. For example, some international economic studies have sought to determine whether exchange pass-through is correlated with measures of sector concentration, whilst some industrial organisation studies have used structural models to simulate the effects of marginal cost changes under various assumptions about firms' conduct. Typically, the studies concerned report a variety of measures of pass-through, so that results are not easily compared. Moreover, results are anyway mixed, and often statistically insignificant. We note though that whilst one of the industrial organisation studies we have reviewed suggests that a shift to less competitive firm conduct is associated with a reduction in industry-wide pass-through, importantly, no clear evidence emerges as to how cost pass-through is linked to market concentration measures such as a firm's market share or the market HHI level.

In the remainder of this section, we present the main findings we have identified from this literature. We first present findings that attempt to relate pass-through rates to firm conduct, second we review evidence on the relationship between sector concentration and pass-through, and finally we present the evidence on retail competition and pass-through.

[165] Nakamura and Zerom (2010) reports a median price elasticity of 3.46, while the super-elasticity is positive 4.64.

[166] Golberg and Hellerstein (2013) does not report own and cross-price elasticities. However we infer the own price elasticities from the reported mark-up and price using the inverse elasticity rule. For most brands, the elasticity is around 12.

7.5.1. Firm conduct and industry-wide pass-through rate

In standard oligopoly models, firms supplying differentiated products may hold some degree of market power. One issue that has been investigated is what if, instead, firms were colluding. How would this alter the industry-pass-through rate? The evidence suggests that pass-through is greater when firms compete than when they collude.

To examine this question, using a structural oligopoly model in which firms supply differentiated products (see Annex A), Kim and Cotterill (2008) simulates a number of counterfactual scenarios to quantify absolute pass-through under different assumptions about firm conduct. Specifically, it compares the absolute pass-through for brands of processed cheese when firms are assumed to compete on price (Nash-Bertrand behaviour) with a scenario in which firms are assumed to collude perfectly (i.e. they maximise joint profit, as would a single supplier controlling the entire supply of processed cheese).

The results confirm the main predictions from economic theory, which is not overly surprising given that the authors employ a structural economic model to simulate the impact of a marginal cost change. The simulation results indicate that the degree of competition between firms has an impact on the extent to which industry-wide changes in cost are passed on. In competitive markets, an industry-wide increase (decrease) in marginal cost results in a greater increase (decrease) in prices than in less competitive markets.

Specifically, Kim and Cotterill (2008) simulates the impact on individual brand prices of an industry-wide marginal cost change - a cost increase of 1 cent per serving. Table 13 below presents the pass-through estimates. Under Nash-Bertrand assumptions, the brand level pass-through rates range between 73% and 103%. If instead, a perfect collusion (monopoly pricing) assumption is adopted, the range of pass-through rates is significantly lower, at between 21% and 31%.

Table 13: Pass-through rates (per cent) for different brands of processed cheese

	Nash Bertrand	Collusion
Kraft	93.61	30.42
Velveeta	91.56	28.74
Light N Lively	88.72	26.45
Kraft Free	90.12	26.98
Kraft Light	99.93	30.34
Velveeta Light	93.29	30.83
Borden	102.89	30.12
Lite Line	73.33	23.70
Land O'Lakes	88.36	21.25
Weight Watchers	76.86	25.45
Overall	82.67	27.04
MC shock (in cent)	1.0	1.0

Source: Kim and Cotterill (2008), Table 8. Notes: The pass-through rates are median values for all markets (defined as a city and quarter combination, of which there are 680, covering the first quarter of 1988 to the fourth quarter of 1992 and covering 28 cities in the first quarter to 43 in the final quarter). Marginal cost shocks are reported in cents per serving.

We observe that even though the hypothesised marginal cost change is the same, absolute pass-through varies between brands. Moreover, the absolute pass-through rates can be quite large under Nash-Bertrand competition. For example, for Kraft, which is the most popular brand of processed cheese in the dataset, a 1 cent marginal cost increase leads to an estimated price increase of 0.93 cents, indicating that most of the marginal cost increase is passed on. Using the estimated demand parameters, Kraft's Lerner index under Nash-Bertrand is estimated to be 42%. This indicates that even with a high level of profit margin, firms continue to have an incentive to pass-on a large portion of the marginal cost change.

Note that these results do not compare estimates of actual absolute pass-through rates across more and less competitive markets. Instead, the results are the outcome of counterfactual simulations, and thus naturally hinge on the modelling assumptions adopted. In this case, however, the functional form of the demand system should not affect the pass-through rate (for more detail see Annex A). This is because Kim and Cotterill (2008) estimates a random coefficient logit model (see Berry, Levisohn and Pakes (1995) and Nevo (2000)). The absolute pass-through rate is a function of the first-order and second-order derivatives of the demand function, which in this case depend on the empirical distribution of observable consumer characteristics and are estimated.[167]

However, the key to the counterfactual simulation is the supposed difference in firms' conduct. Firms are assumed to select price in a one-shot game. The model is then calibrated using the estimated demand parameters. In turn, to determine individual pass-through rates, Kim and Cotterill simulates the impact on price of a marginal cost increase of 1 cent. Depending on whether the firm conduct that is assumed is non-cooperative (Nash-Bertrand price competition) or fully cooperative (perfect collusion), the pass-through effect is different. Kim and Cotterill's predictions assume that firms interact in a simultaneous one-shot game. This raises the question, would the same predictions hold under different modelling assumptions? In particular, in economic theory collusive equilibria emerge only in repeated oligopoly games. How would a change in marginal cost change the collusive equilibrium in such models? Would collusion be undermined altogether if the cost change affected a subset of firms only?

7.5.2. Industry concentration and exchange rate pass-through.

Some international economic studies examine the relationship between exchange rate pass-through and market concentration. Before reviewing the nature of this evidence, it is important to highlight a few caveats when interpreting the results.

- First, the studies focus on how prices adjust with respect to exchange rate variation, not to the change in marginal cost implied by those exchange rate changes.
- Second, the market concentration measures are computed at the sector level, rather than using markets defined according to the standard hypothetical monopolist test. As a result, the standard market concentration measures employed in these studies (market share, HHI) may not correspond to any degree of market power.

Caution is therefore required in interpreting the results from a competition policy perspective.

A recent study by Auer and Schoenle (2013) analyses monthly import price data to test the prediction of a monopolistic competition model based on Dornbusch (1987)[168], which is itself is based on the Dixit and Stiglitz (1977) model of monopolistic competition. In Dornbusch's model,

[167] The results above use a mixed logit model to allow the product characteristics and the distribution of consumer characteristics to determine the curvature of the demand function. Kim and Cotterill (2008) checks the importance of this flexibility by using a logit model instead and comparing the results. The authors report that, under Nash-Bertrand pricing, the average pass-through rate is 12% lower (or 71%), and do not report the impact under collusion. This implies that consumer heterogeneity is important in estimating pass-through in this market.

[168] The authors use data at the good level from the Bureau of Labor Statistics and trade data from Feenstra et al. (2002) at the ten-digit Harmonized System level from the US Census Bureau which are at a detailed product category level. The authors are able to directly observe firm-level market shares for 61.2% of the firms in their sample and for the remaining firms they infer respective market shares based on their model predictions that suggest a relationship between a firm's market share and its price relative to its competitors in a given ten-digit sector. The authors treat a ten-digit sector as being synonymous with a "market", rather than defining relevant markets. Where there is more than one firm from one trade partner country, the authors infer each firm's market share using their model relationship between market share and relative prices: $s_{n,k} = m_{TP,k} \frac{p_{n,k}^{(1-\rho)}}{\sum_{j \in N_{k,TP}} p_{j,k}^{(1-\rho)}}$ where $m_{TP,k}$ is the sector import share of country TP observed in the trade data, and import prices are from the Bureau of Labor Statistics.

firms are assumed to be large, and consequently have an impact on the aggregate sector price index.[169]

As noted in the theory discussion above, firm-specific cost changes will affect equilibrium prices in two ways:

- first, the cost change will have a direct effect on the price choices of the affected firms; and
- second, all firms' equilibrium prices will also respond to changes in rivals' prices.

Auer and Schoenle (2013) decomposes the exchange rate pass-through elasticity into these two effects and investigates how the level of pass-through resulting from each effect depends on the market share of the affected firm.

The model predicts that the exchange rate pass-through elasticity is "U-shaped" in market share. Intuitively, a firm with a small market share has a lower mark-up, which in turn leads it to pass through more of a cost change. As the firm's market share increases, the revenue loss that results from a price increase also increases, and the firm absorbs more of the cost change. However, as the market share gets close to one, the firm becomes increasingly aware of the impact its price has on the sector price index. As a result, the impact of an increase in price on its sales share is diminished, and its pass-through elasticity is nearly complete.

By contrast, the model predicts a "hump-shaped" relationship between firms' responses to changes in competitors' prices and sector shares. A small firm (low market share) is relatively insensitive to changes in its competitors' prices. As market share increases, a firm may accommodate competitors' price increases by increasing its own price (prices are strategic complements). However, as a firm's market position approaches monopoly, competitors' prices have relatively little impact on the sector price index and the firm alters its own price less in response to competitors' prices.

The empirical results confirm the predictions of the model with respect to variation in the exchange rate.[170] The findings show that the rate at which a firm adjusts prices to changes in the exchange rate is U-shaped in market share, while the rate at which it reacts to competitors'

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[169] In the Dixit-Stiglitz model, firms' residual demand depends on the price of their good relative to the aggregate sector price for that good, and based on the relative price of their sector compared to the aggregate price for all sectors. Consumers have constant elasticity of substitution both between products within one sector and between product bundles of different sectors. However, each firm is assumed to be small and has as such no influence on the aggregate sector price. On the contrary, in Dornbusch (1987), firms are assumed to be large and consequently have an impact on aggregate sector price levels. This has the advantage of suggesting that firms may vary their mark-up depending on the impact of their price on the aggregate sector price level, which, in contrast to the standard Dixit-Stiglitz model where the pass-through elasticity is 100%, can lead to a pass-through elasticity of less than 100%.

[170] Auer and Schoenle (2013) uses the following base reduced form regression:

$$\Delta p_{i,TP,t} = \alpha_{TP} + \sum_{j=0}^{12} \beta_j \Delta e_{i,TP,t-j} + \eta Z_t + \epsilon_{i,TP,t}$$

where i denotes a good and TP the country the good is exported from (the trade partner). The change in the import price, $\Delta p_{i,TP,t}$, and the change in the bilateral nominal exchange rate, $\Delta e_{i,TP,t-j}$, are both in logs. The controls Z_t include contemporaneous and 12 lags of inflation in the source country, and various sets of fixed effects. They then estimate a regression with an exchange rate and market share interaction term, $m_i \Delta e_{i,TP,t-j}$:

$$\Delta p_{i,TP,t} = \alpha_{TP} + \sum_{j=0}^{12} \beta_j \Delta e_{i,TP,t-j} + + \sum_{j=0}^{12} \gamma_j m_i \Delta e_{i,TP,t-j} \; \eta Z_t + \epsilon_{i,TP,t}.$$

prices is hump-shaped in market share. In addition, the results show that the firms that react most to changes in their own cost (as affected by exchange rate variation) are the ones that react least to changes in competitor prices.

The exchange rate shocks in each sector could either be firm-specific or industry-wide, depending on the extent of local competition in the sector and the number of competing firms from countries not affected by the exchange rate variation. On the one hand, if all products originate from a single location, then variation in the bilateral exchange rate will constitute an industry-wide shock, as all the firms operating in the sector will be affected. On the other hand, if, as is more likely, there are local firms operating in the market or importers from other countries, then the exchange rate shock is firm- or group-specific. Given that the authors calculate average effects across many underlying sectors, the results are an average across a mix of sectors, of which most sectors are likely to experience firm-specific shocks.[171]

The regression results are presented in Table 14 below. The first three columns present the results of three different specifications in which the price of imported goods is related to the exchange rate. The first column reports estimates for a linear relationship between variations in exchange rate and import prices. The next two columns present regression results when the exchange rate is interacted with market share, which the authors proxy by using the shares of each firm at the ten digit sector level rather than for relevant markets defined using standard techniques such as the hypothetical monopolist test.[172] The authors are able to directly observe market shares for a majority of firms and they impute market shares for the remaining cases using the implied relationship in their model between a higher own price and a higher market share, as described above.

[171] Given that the authors do not control for the extent to which an exchange rate shock affects just some firms in the industry, or the entire industry, this could bias their results. This would arise, for example, if industries with a higher market share were more likely to have exchange rate shocks that were industry-wide rather than firm-specific, and the high pass-through rates for these industries reflected the shocks being industry-wide rather than the firms having high market shares.

[172] The Harmonized System ten digit sector level code defines products at a relatively detailed level. For example, there are separate categories for soy sauce, tomato sauce and mayonnaise.

Table 14: Market share and exchange rate pass-through elasticity results

	(1)	(2)	(3)	(4)	(5)
Δe	0.1476 (0.007)***	0.1938 (0.0195)***	0.2204 (0.0214)***	0.1123 (0.0165)***	0.1721 (0.0216)***
$\Delta e * m$		-0.1252 (0.0353)***	-0.5641 (0.1466)***		-0.6710 (0.1668)***
$\Delta e * m^2$			0.3901 (0.1442)***		0.6444 (0.2021)***
$\Delta \bar{p}^{com}$				0.5675 (0.0174)***	0.5135 (0.0.0243)***
$\Delta \bar{p}^{com} * m$					1.0210 (0.0.2014)***
$\Delta \bar{p}^{com} * m^2$					-1.1827 (0.2226)***

*Source: Auer and Schoenle (2013), Table 2. Notes: standard errors are shown in parentheses. *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * denotes significance at the 10% level.*

The key result is presented in column 3 above. The model specification includes two interaction terms with market share to allow for a quadratic relationship. The results show that the price response is U-shaped in the firm-specific market share. The coefficients of the linear and quadratic terms imply that the degree of exchange rate pass-through reaches its minimum of 0.02 for a firm with market share of around 72% and thereafter increases with market share.[173]

A regression of price changes on exchange rates and an index of competitors' price changes is then estimated which also includes non-linear interactions with market share (see column 5 in the table above). The results show a hump-shaped relationship between a firm's market share and the extent to which it reacts to competitors' prices.

Other studies find no statistical evidence that the degree of competition has any effect on the exchange rate pass-through elasticity. In particular, in a study using industry-level data, Gopinath and Itskhoki (2010) examines empirically the extent to which sector concentration affects exchange rate pass-through.[174] Its empirical analysis is based on the same import price data collected by the US Bureau of Labour and Statistics as used in Auer and Schoenle (2013), discussed above, although unlike Auer and Shoenle (2008) it does not account for a possible

[173] The first-order condition is $2 \times 0.3901m = 0.5641$, which implies m equals 72%.

[174] The authors use monthly good-level US Bureau of Labor Statistics import price data for 1994-2005. The authors estimate $\Delta\bar{p}_{i,k,t} = \beta\Delta_{\tau_1}e_{i,k,t} + \psi(\Delta_{\tau_1}e_{i,k,t} \times C_k) + Z'_{i,k,t}\gamma + \varepsilon_{i,t}$, where $\Delta\bar{p}_{i,k,t}$ is the log change in price for product i within sector k conditional on a price change, $\Delta_{\tau_1}e_{i,k,t}$ is the cumulative change in the log of the bilateral nominal exchange rate since the last price change, $\Delta_{\tau_1}e_{i,k,t} \times C_k$ is the interaction term between the cumulative exchange rate change and a measure of concentration, and $Z_{i,k,t}$ are controls for the concentration measure, the change in CPI inflation and country fixed effects. The regression specification indicates that the authors include a measure of concentration that does not vary over time.

non-linear relationship between concentration and the exchange rate pass-through elasticity.[175] Specifically, it tests separately whether the HHI level and the number of large importers at the sector level are related to the exchange rate pass-through elasticity. The results are largely inconclusive.[176] The results presented in table 6 of the paper show no significant statistical effect (even at the 10% level) between variation in exchange rate and price adjustment for different levels of concentration.

7.5.3. Retail competition and pass-through rate

We have identified two studies that examine the effect of local competition on the extent to which retailers pass through changes in variable cost.

Besanko, Dubé and Gupta (2005) investigates how retail competition affects the extent to which a US supermarket chain, Dominick's Finer Foods, passes through reductions in wholesale prices, stemming from manufacturer promotions, to retail prices. First, pass-through elasticities are estimated across 78 products, and translated to pass-through rates. The average category pass-through rate is above 60% for nine out of eleven product categories (toothpaste and paper towels are lower).[177]

Next, it attempts to determine whether the magnitude of Dominick's pass-through elasticity is related to the level of competition with other retailers. Specifically, it examines whether the distance to competitor supermarkets Jewel and to value supermarkets Cub Foods or Omni Stores (the latter owned by Dominick's) have any impact. However, it finds no significant evidence that having a rival Jewel store or a value Cub or Omni store nearby has any effect on Dominick's pass-through elasticity. Importantly, the authors do not know and cannot control for whether rival supermarkets receive manufacturer discounts at the same time as Dominick's and therefore whether the manufacturer discounts are specific to Dominick's or market-wide.

When estimating cost pass-through in the Staples case (see above), Ashenfelter et al. (1998) also controlled for the effect of local competition on prices. As indicated above it included the number of competitors in the metropolitan statistical area (MSA). Interestingly, the pass-through elasticity was the same whether or not a local competitor variable was included in the regression. Taken at face value, these results suggest that the intensity of local competition, as

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[175] Similar to Auer and Schoenle (2013), the method used by Gopinath and Itskhoki (2010) estimates an exchange rate pass-through elasticity for the dataset as a whole rather than for individual industries. This means that the exchange rate pass-through elasticity will be estimated based on a mix of sectors, some of which experience firm-specific shocks (when there are local firms or firms that import goods from other countries that do not experience the shock) and some of which experience industry-wide shocks (when firms from one foreign country supply the whole domestic sector, which is less likely).

[176] The concentration measures are constructed by the US Bureau of Census and include the Herfindahl Index (the sum of squared market shares for firms in each sector), also known as the Herfindahl-Hirschman Index ("HHI"), and the number of importers that make up the top 50% of trade for each sector, using census data on all imports entering the US. The concentration measures are calculated at the 2-4 digit level of the Harmonized Index used to classify imports and exports into different product categories. These represent relatively high levels of aggregation. For example, there is a four digit code for "[s]auces and preparations therefore; mixed condiments and mixed seasonings; mustard flour and meal and prepared mustard" under which are grouped, for example, soy sauce, tomato ketchup and (under "other condiments") mayonnaise. The full Harmonized Index list for 2014 is available at http://www.usitc.gov/publications/docs/tata/hts/bychapter/1400htsa.pdf.

[177] Toothpaste and paper towels are relatively unresponsive, with average pass-through rates of 22% and 37% respectively. On the other hand, beer, oat cereal and dish-detergent are highly responsive categories, with pass-through rates of 558%, 190% and 111% respectively.

measured by the number of competitors, had no impact on the extent to which Staples passed through cost changes, although as described above, the extent to which Office Depot experienced the same cost shock is critical to explaining the pass-through elasticity for Staples.

7.6. Asymmetric pass-through

A number of studies have examined the extent to which prices adjust more quickly to cost increases than to cost decreases. In the round, the data indicate that prices rise faster than they fall. However, the asymmetry eventually disappears, though there is no hard indication as to how long this process may take.

Economic theory says little about such pricing asymmetries. In fact, as explained in the previous theoretical chapters, in many situations, changes in marginal cost might be expected to affect prices symmetrically. The shape of the demand curve, however, may provide one potential explanation for the existence of asymmetric pass-through. That is, consumers may react differently to positive and negative price changes. This is the explanation put forward in a recent study by Bonnet and Villas Boas (2013) which examines cost pass-through in the French coffee market. The findings indicate that demand is less elastic when prices increase than when they decrease and the authors find an asymmetric pass-through elasticity (and hence asymmetric absolute pass-through) for the same level of cost change.[178] In sum, asymmetric consumer reactions to price changes in the French coffee market appear to explain asymmetric pass-through.

The literature has conjectured that several reasons might explain why prices adjust at different speed depending on the direction of cost changes, these include:

- menu costs,
- search costs,
- inventories; and
- market power.

Peltzman (2000) examines several large samples of data for diverse products in the US to gauge how long it takes for prices to go up and by how much prices rise following a cost increase. Similarly he examines the impact of cost reductions on prices. Overall, he finds that prices increase faster than they fall. Importantly, he also finds that prices adjust after several months. His analysis is based on a comparison of US producer and consumer price indices. He corroborates his findings using wholesale and retail price data from Dominick's, the second largest grocery retailer in Chicago.

[178] We know that for asymmetric differentiated Bertrand competition, the firm's optimal price depends not only on the elasticity of demand but also on other properties of the inverse demand curve (such as its first and second derivative) and how marginal costs change (if at all) as demand changes. The price at the new equilibrium following a marginal cost shock will depend on all these factors and not just on the elasticity of demand. This means that we cannot rely on a simple rule that pass-through to price will be greater when demand is more inelastic.

For example, using data from the US Bureau of Labor Statistics, Peltzman matches 77 Consumer Price Index (CPI) product categories with their Producer Price Index (PPI) counterparts, which allows him to estimate how segment-specific cost shocks are translated into prices faced by consumers. The empirical analysis shows that prices adjust more in an upward than a downward direction in the same month of the PPI changes, the asymmetry in response persists after one, three and five months. In the same month, the mean CPI response to a 1% PPI increase is 0.194% and to an equivalent decrease is 0.067%. After five months, price increases by 0.522% and decreases by 0.336%. The evidence indicates that a cost increase is transmitted more rapidly than a cost decrease.

Although, the asymmetries had not vanished after several months, Peltzman finds evidence suggesting that in the long-run there is no divergence between output and input price changes. This implies that ultimately up and down movements in cost are transmitted equally.

Finally, Peltzman (2000) considers whether market concentration explains the asymmetry in the price response to cost changes. His investigation is inconclusive. Similarly, there is no evidence that inventory holdings and menu costs explain price asymmetries.

A number of studies focus on specific industries to examine whether cost decreases or increases affect prices equally and the speed at which price adjust to these cost changes. We have identified numerous studies that focus on the oil industry and employ various econometric techniques (see Annex A) and datasets to assess asymmetric pass-through. To name a few, Johnson (2002), Chen, Finney and Lai (2005), Radchenko (2005), Al Guhea et al. (2007), Verlinda (2008), and Radchenko and Shapiro (2010) all examine pass-through in US retail gasoline markets. There are also a number of papers examining asymmetric pass-through in commodity markets. These include von Cramon-Taubadel (1998), examining pork in Germany, Boyd and Brosen (1988), examining pork in the US, and Goodwin and Holt (1999) and Pozo et al. (2013), which both examine beef in the US.

In the remaining of this section we focus on a handful of these papers. In particular, we review Borenstein et al. (1998), which represents one of the first studies to document asymmetric pass-through in US retail gasoline markets.

Borenstein et al.'s findings support the view that prices adjust more quickly in response to cost increases than they do in response to cost decreases. The authors assess the absolute pass-through from crude oil prices to retail gasoline prices. They adopt a dynamic model whereby the change in retail gasoline price depends on crude oil price changes in previous periods. This specification allows them to distinguish between short-run and long-run responses to fluctuations in crude oil prices. They find that an increase in the crude oil price of 1 cent leads consumer prices to increase by 0.55 cents in the first two weeks, and by a further 0.12 cents in the next two weeks After ten weeks the pass-through is about 0.81 cents, with no further significant effects thereafter. For price decreases, the absolute pass-through is slower, but after ten weeks is also about 0.81 cents.

The authors attempt to explain this asymmetry in the speed of adjustments. To this end they also estimate how changes in the crude oil price causes prices at intermediate levels of the supply chain to change (that is, spot gasoline prices and terminal prices), and also how changes in prices at these intermediate levels affect retail prices.

The authors conjecture that three mechanisms might explain why prices are sticky downward in the short-run, namely:

- The output price is a focal point for oligopolistic sellers; hence they stick to this price level even though the input price has fallen.

- Production lags and finite inventories would explain the asymmetry in the adjustment of spot gasoline price/terminal prices to changes in spot crude oil prices. The mechanics hinge on the short-run cost of increasing and decreasing inventories. If crude oil prices increase because of shortage upstream, oil companies would build up inventories to accompany the price increase. Alternatively, if crude oil prices decrease as the supply of crude oil expands, refineries, acting as a bottleneck, would reduce output, hence the impact on the downstream price would be more limited.

- Volatile crude oil prices create a signal extraction problem for consumers that reduces the expected payoff from search and results in retail outlets behaving less competitively. In a nutshell, the idea is that when crude oil prices are volatile, consumers are more likely to believe that an increase in retail price is the result of an increase in the crude price rather than a particular outlet's retail price. This implies that consumers will not search as much for alternatives, reducing the price elasticity of demand, which in turn allows retailers to increase margins. This temporary increase in retailers' market power reduces pass-through of falling crude oil prices but boosts the pass-through of crude oil price increases.

However, the authors do not reach a view on which (if any) of these mechanisms is relevant in explaining their findings.

Following Borenstein et al, other studies have investigated asymmetric gasoline price responses to crude oil price changes. This literature employs a variety of reduced-form dynamic regression models relating the price of gasoline to the price of crude oil in various countries. Grasso and Manera (2005) reviews this literature and concludes that, in general, studies in the oil sector have failed to provide strong evidence that prices rise faster than they fall in this sector. Indeed, Chou et al. (2013), using gasoline and diesel retail price data and crude oil price data for Taiwan, Japan, South Korea and Singapore, even finds that negative cost shocks are sometimes more quickly transmitted to retail prices than positive cost shocks - this was especially true for gasoline prices in South Korea.

Zachmann and von Hirschhausen (2008) examines the extent to which variations in carbon dioxide emission costs are passed through asymmetrically in the electricity wholesale market in Germany. It finds evidence that wholesale prices rise faster than they fall, however, the length of time series data available does allow the long-run relationship between emission costs and wholesale prices to be investigated. As result, this study cannot determine how long the asymmetric pass-through persists.

Similarly, Leibtag et al. (2007) finds inconclusive results regarding asymmetry in absolute pass-through. The authors estimate a dynamic regression model to gauge empirically absolute pass-through in the US coffee industry using quarterly data of wholesale green bean commodity prices, manufacturer wholesale coffee prices, and coffee supermarket retail prices from 2000 to

2004. They find that a 10 cent increase in the cost of a pound of green coffee beans translates into a 2 cent increase in manufacturer and retail prices in that quarter and that it is passed through one-for-one in absolute terms if it persists for several quarters (which, given fixed costs and mark-ups, represents a 3% change in the retail price for a 10% change in the commodity price). The authors adjust the regression to check for asymmetric absolute pass-through by including separate variables for cost increases and decreases. They find no statistically significant evidence to suggest that prices respond in greater magnitude or more quickly to cost increases than decreases.

7.7. Summary

- Taken in the round, the available empirical evidence reveals a wide range of pass-through estimates across industries. However, as different studies adopt different measures of pass-through (e.g. absolute pass-through, pass-through elasticity, exchange rate pass-through), findings are not always comparable.

- The empirical literature that draws on firm-level (or product-level) data reveals that, even when facing an industry-wide cost shock, individual firms may adjust price at different rates.

- The available empirical evidence supports the prediction that the price response to firm-specific cost shocks is lower than industry-wide cost shock.

- Few studies have investigated empirically the impact that the curvature of demand has on pass-through. The available evidence, however, confirms that it is an important factor that affects price responses to cost changes.

- There is some limited evidence that increased market power is associated with lower industry-wide pass-through. However, not all findings we have identified are conclusive. We have not identified relevant evidence in respect of the relationship between market power and firm-specific pass-through.

- Finally, there is some evidence of asymmetries in cost pass-through, in particular that prices respond to increases in costs faster than to decreases in cost. However, a number of studies find that this asymmetry disappears over time, though there is no clear finding about how quickly this takes place.

8. Empirical evidence on pass-through and vertical issues

In this chapter, we review the empirical evidence in relation to pass-through and vertical issues. In general, the economic literature contains few studies that investigate pass-through in a vertical context, though some recent contributions have started to shed light on some of the complex issues raised, as discussed in Chapter 5.

We will begin by outlining the principal insights to emerge from the empirical evidence.

First, a result found consistently in the (albeit limited) literature is that absolute pass-through and pass-through elasticity between the wholesale and retail stages can be very high; pass-through elasticities are often close to 1 (which surely implies an absolute pass-through rate of above 100%). It is important to bear in mind that these results concern industry-wide pass-through but not firm-specific pass-through.

On the other hand, wholesale prices appear more stable following a change in upstream costs than retail prices. While the literature claims that this is a sign that the pass-through between upstream cost shocks and the retail prices is low, this may to a large degree reflect the fact that the literature focuses on estimating the extent to which a 1% change in commodity prices is associated with a given percentage change in wholesale or retailer prices. Since costs affected by exchange rates, for example, need not account for a large part of either the wholesaler or the retailer's cost, this can explain the limited percentage impact on retail prices observed. On the other hand, the absolute level of pass-through may be substantially higher (and in the case of one study is complete).

Second, the relationship between two firms in the supply chain, or generally a business-to-business transaction, is often more complex than is considered by standard models. While the assumption of linear pricing might be reasonable with respect to retail markets, it is clear that non-linear tariffs are frequently applied in upstream markets between manufacturers or wholesalers and retailers. In addition, upstream manufacturers or wholesalers may consider imposing some restrictions on a retailer's conduct, for example by imposing a retail price.[179] The nature of the vertical contract that governs the relationship between upstream suppliers/wholesalers on the one hand and downstream retailers on the other may affect the extent of pass-through in an industry. The available evidence suggests (albeit based on simulation as opposed to comparing outcomes under different industry structures in practice) that applying a non-linear tariff may have little effect on pass-through of upstream cost shocks to retail prices, while the presence of resale price maintenance in combination with two-part tariff tends to raise pass-through.

Finally, we review the evidence on vertical integration and pass-through. As indicated in Chapter 5, eliminating double marginalisation via integration may boost pass-through in some cases, but have the reverse effect in other cases. As a result, there is no clear link between vertical integration and pass-through. Existing empirical studies confirm that vertical integration has an ambiguous relationship with pass-through.

[179] See comment on the legal treatment of resale price maintenance at footnote 2.

In the round, the existing empirical evidence in relation to vertical restraints and vertical integration remains very limited. Additional research is needed to draw more robust conclusions on the relationship between vertical structure and pass-through. Finally, we have not identified any studies that test empirically how bargaining power affects pass-through.

8.1. Pass-through in wholesale and retail markets

In this section we present some of the main findings of studies that investigate pass-through along the supply chain. These studies produce useful insights regarding the level of the supply chain at which price adjustment may be sluggish or incomplete.[180] The main findings are as follows:

- pass-through following changes in manufacturing costs is moderately higher for wholesale prices than for retail prices.

- pass-through of wholesale price changes to retail prices is often near complete.

Below we briefly discuss some of these studies. A recent study by Hong and Li (2013) examines the pass-through elasticity for thousands of products sold in a large US supermarket chain (without controlling for industry-wide cost changes). Specifically, using a reduced-form model, they estimate the pass-through elasticity between three price pairs, namely:

- wholesale prices to retail prices;

- commodity prices to wholesale prices; and

- commodity prices to retail prices.

Table 15 below presents the range of pass-through elasticities for each pair of prices listed above. The pass-through elasticity from wholesale to retail price is high, ranging from 0.569 to 0.695. In contrast, the pass-through elasticity from commodity prices to wholesale prices is much lower, ranging from 0.037 to 0.0476. As a result, it is not surprising to see that the pass-through elasticity between commodity prices and retail prices is even lower, between 0.050 and 0.064.

These results suggest a high pass-through rate between wholesale and retail prices. Indeed, as retailers have positive mark-ups, absolute pass-through could be above 100% even if the percentage change in price is less than the percentage change in cost.

[180] As explained in the summary above, we note that the focus of the literature on commodity cost pass-through down the supply chain is not wholly informative as regards, for example, the pass-through by retailers of higher wholesale prices (e.g. because a commodity may account for only a small share of a wholesaler's marginal cost and hence commodity price fluctuations may have only a very limited impact on wholesale prices such that a material impact on retail prices would not be expected).

Table 15: Pass-through elasticity at different level of the supply chain

	Range
Wholesale prices to retail prices	0.569 - 0.695
Commodity prices to wholesale prices	0.037 - 0.047
Commodity prices to retail prices	0.050 - 0.064

Source: Hong and Li (2013), Tables 5, 6 and 7.

A paper by Eichenbaum, Jaimovich and Rebelo (2009) that relies on scanner data for a large grocery retailer in the US, with over 1,000 stores in different US states, confirms very substantial pass-through between wholesale and retail prices (although it does not control for whether cost shocks are industry-wide). The analysis shows that the retailer tends to contain the mark-up of items in the same product category within tight bounds relative to a reference 10% mark-up. This suggests that wholesale cost changes are passed through into retail prices.

Nakamura and Zerom (2010) also corroborates this finding for the coffee market. It considers the impact of industry-wide variations in the cost of coffee beans on wholesale and retail coffee prices. The results are consistent with the finding of Hong and Li (2013). The authors find that that a 1% increase in commodity cost leads to a 0.262% increase in wholesale prices and a 0.252% increase in retail prices. Evidently, the effects of commodity price variation on wholesale and retail prices do not differ by much. The pass-through elasticity between wholesale price and retail price is close to 1.

8.2. Vertical restraints

Standard oligopoly models of differentiated price competition suppose that firms set unit prices. Although this assumption might represent a reasonable characterisation of pricing behaviour on many retail markets, the wholesale terms on which firms sell to other firms will frequently incorporate more complicated tariff structures. In addition, those relationships may also embody a variety of vertical restraints - such as exclusivity provisions and resale price maintenance.[181]

Importantly, in an environment in which there is competition between manufacturers and retailers, the structure of vertical restraints may serve a strategic purpose shaping the nature of the competitive interaction. As such, this structure may affect cost pass-through relationships too.

We have identified only one study that investigates empirically how non-linear tariffs and vertical restraints may affect pass-through of cost changes. Drawing on the predictions of theory – notably Rey and Vergé (2010), as extended by Bonnet and Dubois (2010) – Bonnet et al. (2013) simulates the effects of changes in vertical supply terms on cost pass-through in an

[181] See comment on the legal treatment of resale price maintenance at footnote 2.

environment in which the products of competing upstream manufacturers are carried by competing downstream retailers. Unlike the case with double monopoly, Rey and Vergé predicts that, in this environment with competitive rivalry, manufacturers using two-part tariffs only will set wholesale prices above upstream costs and retail prices will be below the monopoly level. In other words, they cannot address the double margin problem whilst also responding effectively to competition. In this context, adding resale price maintenance allows the impact of retail competition on manufacturer profits to be mitigated.[182] Wholesale prices may then be set equal to upstream costs, with downstream prices set equal to the monopoly level.

To explore the implications of these contractual structures for pass-through in practice, the authors set up a structural model calibrated using data for 2000 and 2001 for the market for coffee in Germany. Specifically, they investigate the extent to which the pass-through elasticity would change with vertical contract structure and, in particular, with the use of:

- non-linear pricing (specifically, two-part tariffs, which involve a fixed fee component, that does not depend on the quantity purchased, and a variable unit price component);
- resale price maintenance; and
- wholesale price discrimination.

It is important to note that the simulation exercise that is undertaken does not provide a test of the relevant theory. The authors do not compare realised pass-through rates in scenarios where two-part tariffs and resale price maintenance are used in practice with scenarios where they are absent. In fact, they compare the simulated pass-through rates with and without the vertical restraint in question, which boils down to comparing the simulated equilibrium prices of different vertical relation models that are calibrated using the same demand parameters.

To assess the impact on the pass-through elasticity of alternative vertical restraints, Bonnet et al. (2013) undertakes counterfactual simulations in which estimated marginal costs are subject to an industry-wide 10% change. First, it supposes that the cost change affects all marginal costs - at the manufacturer and retail levels. Second, it supposes that just the price of raw coffee (which constitutes around 90% of the total upstream marginal cost) is increased by 10%. Then it compares the equilibrium price changes predicted to arise from these cost changes across different vertical structures (with or without linear pricing, with or without resale price maintenance, with or without price discrimination). The results for the two cost change scenarios are qualitatively equivalent.

Table 16 below presents the main results of the simulation analysis. The first column presents the benchmark case with linear pricing, no vertical restraints and no wholesale price discrimination. In this case, prices are predicted to increase by 7.14% following a 10% increase in total marginal costs and by 5.42% following a 10% increase in the price of raw coffee.

[182] Two-part tariffs and resale price maintenance have the same effect of maintaining downstream monopoly prices when there is no downstream competition (e.g., between retailers). With competition in retailing, manufacturers have conflicting interests: lower upstream margins avoid inter-brand competition but at the same time wholesale prices need to be high in order to maintain high retail prices in spite of intra-brand competition. With resale price maintenance and two-part tariffs manufacturers can reconcile these interests better than with two-part tariffs only without resale price maintenance.

Comparing these results with those presented in column (3) indicates that the pass-through elasticity in the case with linear tariffs is somewhat smaller than in the case with non-linear two-part tariffs, but the difference is not large.

In contrast, a comparison of the predicted price changes reported in columns (2) and (4), on the one hand, and columns (3) and (5), on the other, indicates that resale price maintenance (RPM) – with or without price discrimination – increases pass-through elasticity substantially. For example, the price increase following the simulated 10% increase in cost is 7% in column (2) (without resale price maintenance) but 8.2% in column (4) (with resale price maintenance). These differences are statistically significant too.

Table 16: Percentage change in retail price arising from 10% cost increase

	(1)	(2)	(3)	(4)	(5)
Pricing	Linear	Non-linear	Non-linear	Non-linear	Non-linear
RPM	No	No	No	Yes	Yes
Price discrimination	No	Yes	No	Yes	No
10% total marginal cost increase	7.14 (0.40)	7.00 (0.40)	7.00 (0.46)	8.20 (0.32)	8.20 (0.33)
10% raw coffee cost increase	5.42 (1.70)	5.13 (0.98)	5.31 (2.07)	6.03 (1.18)	6.03 (1.18)

Source: Bonnet et al. (2013), Tables 3 and 4. Notes: A 7.14% increase in price, for example, following a 10% increase in total marginal costs, indicates that the pass-through elasticity is 0.714. Note: Standard errors are shown in parentheses.

The authors suggest their results are explained by the dampening impact of double-marginalisation on pass-through. On this view, since resale price maintenance mitigates the double marginalisation problem, it will cause pass-through rates to increase.

In addition, the authors investigate if the role of resale price maintenance is accentuated when the intensity of competition in the upstream market is altered. This analysis shows that resale price maintenance continues to influence pass-through elasticity positively even though upstream manufacturers have more market power. The authors simulate several counterfactual scenarios in which they alter the level of competition by varying the number of firms while the number of brands in the market stays the same. For a given number of brands, a decrease in firm numbers is equivalent to increased concentration as a result of horizontal mergers between upstream manufacturers.

The authors find that when competitive intensity decreases (they also arbitrarily reduce demand elasticity), the cost pass-through elasticity decreases as well. This holds for all contractual and pricing schemes identified above. However, the contribution of resale price maintenance to increasing pass-through elasticity is particularly large where the intensity of competition is low.

8.3. Vertical integration

As indicated in Chapter 5, eliminating double marginalisation via integration may boost pass-through in some cases, but have the reverse effect in other cases. Existing empirical studies show that vertical integration has an ambiguous relationship with pass-through. The evidence is based on two papers that we discuss in turn, namely:

- Hong and Li (2013), which examines pass-through elasticities for thousands of products sold in a large US supermarket; and

- Hellerstein and Villas Boas (2010), which investigates the impact of vertical integration on pass-through elasticities in the automotive sector.

Hong and Li (2013) examines the combined impact of horizontal market structure (market concentration) and vertical structure (level of vertical integration) on the rate of cost pass-through. As explained in Chapter 5, according to the predictions of their theoretical model, the relationship between vertical integration and pass-through rate is ambiguous. It investigates empirically this relationship using scanner data from a large American supermarket chain. First, it estimates product level pass-through elasticities for thousands of products, and second assesses how these rates vary with the vertical and the horizontal market structure.[183] The authors compare three levels of vertical integration, namely:

- retailers producing for themselves ("vertical integration");

- an intermediate case where products are produced by independent firms, but labelled under the supermarket's brand ("third-party manufacturers"); and

- upstream suppliers selling on an arm's length basis to retailers ("arms' length").

The authors seek to explain the wide range of pass-through elasticities across thousands of products. Specifically, they investigate the extent to which vertical integration explains the level of pass-through relative to arm's length negotiation with branded manufacturers.

Below we present the results of this analysis at different levels of the supply chain: (i) wholesale price to retail price, (ii) commodity price to wholesale price, and (iii) commodity price to retail price. As we see below, vertical integration is associated with <u>lower pass-through</u> between wholesale and retail price,[184] but <u>higher pass-through</u> between commodity price and wholesale/retail price.

Table 17 below introduces the main regression results in relation to pass-through elasticities between wholesale prices and retail prices. Unambiguously, vertical integration reduces pass-through elasticities from wholesale prices to retail prices by about 0.60 to 0.80. The results are consistent across different time horizons; that is for the four and twelve month rolling window

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[183] They use product level data from one large supermarket chain in the US with 250 stores across 19 states from January 2004 to July 2007. Additionally to sold quantities and revenues per product identified by UPC (Universal Product Category) barcodes (from which they derive prices on a weekly basis).

[184] Hong and Li allow for the upstream and downstream levels to have costs other than those that are subject to the cost shock. The percentage change in upstream costs is therefore less than the percentage change in the commodity price.

pass-through (with regressions comparing to prices and costs four months and twelve months earlier respectively).

For a lower degree of vertical integration (third party manufacturing), pass-through is slightly higher but still considerably lower than for the case of arms' length negotiation with branded manufacturers.

Table 17: Pass-through - wholesale price to retail price (dummies relative to national brands)

	4 lags		12 lags		
	Without market shares	**With market shares**	**Without market shares**	**With market shares**	**With market shares (and median price control)**
Vertical integration	Not reported	-0.632***	-0.810***	-0.799***	-0.815***
Third party manufactured	Not reported	-0.472***	-0.506***	-0.511***	-0.523***
Product market share		-0.643***		-0.543***	-0.526***
Brand market share		-0.013		0.100	0.101
Log (Med. Price)					-0.050

Source: Hong and Li (2013), Table 5. Notes: "market shares" are product and brand revenue category share controls and the log of the median product price controls for the median product price across stores and periods. Stars indicate if the coefficient is significant at the 1%(***), 5%(**) or 10%(*) level.

The following two tables present the regression results in relation to the pass-through elasticities from commodity price to wholesale price and then from commodity to retail price. In sharp contrast to the previous results, the regression analysis shows that vertical integration leads to higher pass-through elasticities.

Table 18 presents the regression results that explain variation in the pass-through elasticities between commodity prices and wholesale prices. The effect of vertical integration is positive, implying that vertical integration is associated with higher pass-through elasticity. Vertical integration increases the pass-through elasticity by about 0.30 to 0.40, with a slightly smaller effect for third part manufacturing.

Table 18: Pass-through - commodity price to wholesale price (dummies relative to national brands)

	4 lags		12 lags		
	Without market shares	With market shares	Without market shares	With market shares	With market shares (and median price control)
Vertical integration	Not reported	0.392***	0.347***	0.416***	0.392***
Third party manufactured	Not reported	0.300***	0.264***	0.288***	0.271***
Product market share		-0.372***		-0.454***	-0.440***
Brand market share		-0.687***		-0.290***	-0.280***
Log (Med. Price)					-0.072**

Source: Hong and Li (2013), Table 6. Notes: "market shares" are product and brand revenue category share controls and the log of the median product price controls for the median product price across stores and periods. Stars indicate if the coefficient is significant at the 1%(***), 5%(**) or 10%(*) level.

Finally, Table 19 examines the relationship between vertical integration and pass-through from commodity prices to retail prices. Again, vertical integration increases the level of pass-through, and more strongly so for full vertical integration. As before, controlling for market shares increases the effects of vertical integration, while market shares themselves have clear negative effects.

Table 19: Pass-through - commodity price to retail price (dummies relative to national brands)

	4 lags		12 lags		
	Without market shares	With market shares	Without market shares	With market shares	With market shares (and median price control)
Vertical integration	Not reported	0.418***	0.306***	0.416***	0.350***
Third party manufactured	Not reported	0.205***	0.120***	0.150***	0.100**
Product market share		-1.113***		-0.918***	-0.873***
Brand market share		-0.473***		-0.431***	-0.414***
Log(Med. Price)					-0.208***

Source: Hong and Li (2013), Table 7, panel A. Notes: "market shares" are product and brand revenue category share controls and the log of the median product price controls for the median product price across stores and periods. Stars indicate if the coefficient is significant at the 1% (***), 5% (**) or 10% (*) level.

Hellerstein and Villas-Boas (2010) investigates how much the pass-through elasticity of an exchange rate change depends on the extent of vertical integration. The analysis, which focuses on the US automotive industry, shows that vertical integration is associated with higher pass-through elasticities.

Unlike Hong and Li (2013), which employs a reduced form approach, Hellerstein and Villas-Boas's analysis relies on a structural model to simulate the effect of exchange rate variation under different vertical structures. The structural model is calibrated with data from 2002 to 2006 for the automobile market in the US. In this industry, the so-called tier-one parts suppliers (TOPS) that provide intermediate goods to original equipment manufacturers (OEM) can be (partly) integrated. The level of integration is measured by the share of total value added delivered by an automaker relative to its total sales.

In the counterfactual simulation, the industry-wide cost of foreign parts in the production of cars is increased by 10%. To establish how strongly the pass-through of this cost increase depends on the level of vertical integration, the authors consider four (counterfactual) scenarios: (i) all value-added is outsourced; (ii) vertical upstream integration is complete; (iii) upstream integration according to observed values, and (iv) upstream integration one standard deviation below the observed values. For each of these scenarios, the pass-through elasticity is estimated for 24 different car models.

In general, the greater the extent of vertical integration, the greater is the pass-through elasticity. For car manufactures that fully outsourced the provision of parts, the median elasticity is 0.13. On the other hand, for manufacturers that are completely integrated, the elasticity is higher, at 0.54. For observed cases of integration, the pass-through elasticity is 0.26. However, there is considerable variation between car models. Table 20 below summarises Helerstein and Villas-Boas's results.

Table 20: Pass-through elasticity for 10% foreign cost increase for different levels of vertical integration

	Fully outsourced	Complete integration	Difference	Observed	one SD below observed	Difference
Average	0.13 (0.03)*	0.54 (0.13)*	0.40 (0.13)*	0.26 (0.08)*	0.15 (0.04)*	0.12 (0.04)*
Minimum	0.08 (0.03)*	0.33 (0.09)*		0.02 (0.01)*	0.01 (0.02)	
Maximum	0.27 (0.04)*	1.20 (0.71)		0.63 (0.26)*	0.31 (0.12*)	

Source: Hellerstein and Villas Boas (2010), Tables 8 and 9. Notes: standard errors for the simulated coefficients are computed in 200 bootstrap simulations of the structural model and are reported in parentheses. Starred coefficients are significant at the 5% level.

8.4. Summary

- The (limited) available evidence points to high industry-wide cost pass-through elasticities between the wholesale and retail stages. Cost pass-through elasticities between production/commodity prices and the wholesale stage are much smaller.

- Even where pass-through elasticities are relatively low, it cannot be inferred that absolute pass-though is also low. This is because the cost changes identified may only account for a small percentage of wholesale marginal costs, and so a small absolute change in prices could be consistent with a high absolute pass-through rate.

- The results of one notable study confirm the predictions of theory that the effects of vertical restraints are liable to be sensitive to the setting and the combination of vertical restraints deployed.

- The empirical results reviewed suggest that the impact of vertical integration on pass-through is ambiguous.

Assessing horizontal mergers

9. Pass-through and horizontal merger price effects

In recent years there has been growing use by the UK competition authorities of 'price pressure tests' in the assessment of horizontal mergers, in particular in retail markets.[185] One such approach uses the 'Gross Upward Price Pressure Index' or GUPPI, in conjunction with a firm-specific pass-through rate, to arrive at a so-called 'illustrative price rise' (IPR).[186] Proponents of this approach would argue that it allows an IPR to be derived without having to assume a form of demand, whereas other approaches to deriving IPRs require the analyst to presume demand is of a certain type (e.g. linear or isoelastic).[187] We discuss GUPPI and IPRs in this section, and how these measures relate to pass-through. We note the sensitivity of such measures to the assumed form of demand and summarise briefly some more recent alternative proposals for approximating the price effects of horizontal mergers.

9.1. GUPPI

Consider two single product firms, respectively firm j and firm k, supplying substitute products j and k in a differentiated Bertrand oligopoly. If these firms merge, the prices of those products - p_j and p_k respectively - will each be changed to maximise the merged entity's profits. Insight into the impact of the merger on the price of product j can be obtained by noting that the merger creates an additional cost of lowering the price of product j, namely that if the price of j falls, some of the volumes that will be won by j will be won from the merged firm's other product, k. After the merger, one can therefore think of this price cut as *cannibalising* volumes (i.e. j wins volumes from k) that the merged firm would have achieved anyway, absent the price cut.

The 'cost' of this cannibalisation equals the unit margin earned on product k multiplied by the units that switch from k to j when j's price is lowered. Formally, this can be written as:

$$d_{jk} \cdot (p_k - c_k)$$

where $p_k - c_k$ is the unit margin earned on product k and d_{jk} is the relevant diversion ratio, here defined to be the percentage of j's gained volumes (following a price cut by j) that are won from k.[188]

[185] See, for example, Chapter 12 of Parker and Majumdar (2011). See also the report on conjectural variations prepared by RBB Economics for the OFT (RBB Economics (2011)). In this report we do not debate the merits or otherwise of using price pressure tests, rather, in line with our remit, we discuss the role of pass-through in those tests.

[186] GUPPI was proposed by Steven Salop and Serge Moresi as an extension of UPP (Farrell and Shapiro (2010)). The measures are closely related to Werden (1996).

[187] Given the link between the pass-through rate and the form of the demand curve discussed in the theory overview above, it would be erroneous to say that the measure would be entirely free of an assumption about the underlying demand curve.

[188] It is worth noting that this diversion ratio is usually expressed as the diversion from product j to product k following a price rise on j. In theory, the diversion ratios are the same – if a small price increase on product j causes a loss of 100 units of which 10 are lost to k

We can therefore think of the term $d_{jk} \cdot (p_k - c_k)$ as a firm-specific 'cost' increment associated with the supply of product j, i.e. as if it were a raw material cost increase. As set out in Farrell and Shapiro (2010), this additional merger-specific cost will cause p_j to be increased, unless this price-raising impact is offset by price-relevant merger specific efficiencies.

Identical reasoning applies to product k. The merger will, symmetrically and *simultaneously*, imply an incremental cannibalisation cost of supply for this product too.

Note that the full impact of the merger on market prices will depend on the equilibrium interaction of the changes to p_j and p_k induced by the simultaneous cannibalisation effects with the pricing of all products in the market. In other words, the change in the price of product j that results from the merger-induced cannibalisation effect will also change the magnitude of the cannibalisation effect for product k, and vice versa. Moreover, the changes to p_j and p_k will generally cause a change in the prices of all products in the market. Since prices are strategic complements, these changes will be re-enforcing.

Nevertheless, a 'first approximation' of the merger price effect can be obtained by estimating the magnitude of the effect on the price of each of the merging firms' products, holding the prices of all other products constant at their pre-merger levels. The Gross Upward Pricing Pressure Index or GUPPI provides a measure of the 'gross' cost of cannibalisation effect, i.e. without taking account of offsetting efficiencies, expressed in terms of the cannibalising firm's price.[189] (Put differently, it is the cannibalisation cost of lowering the price of j as a percentage of j's price.) The GUPPI for firm j following a merger with firm k is given by:

$$GUPPI_j = d_{jk} \cdot \frac{(p_k - c_k)}{p_j} = d_{jk} \cdot \frac{(p_k - c_k)}{p_k} \cdot \frac{p_k}{p_j}$$

where these terms are evaluated at pre-merger levels, recognising that this is an approximation only.

Just as a raw material cost is passed through, so, in theory, is the merger specific cannibalisation cost (absent efficiency gains). Hence, the GUPPI can be combined with a measure of cost pass-through to obtain a first estimate of the price rise for firm j that would result from the merger (again absent efficiency savings). In simple terms, if Δc is the cannibalisation cost effect of the merger, and the cost pass-through rate, ρ, provides a measure of the way this will be translated into a price change Δp, i.e. $\rho \approx \frac{\Delta p}{\Delta c}$, then GUPPI and ρ can be combined to provide an estimate of the proportionate post-merger increase in price:

$$\frac{\Delta p}{p} \approx \frac{\rho \Delta c}{p} = \rho \cdot GUPPI$$

(i.e. a diversion ratio from j to k of 10%) then a small price decrease for product j should cause j to win 100 units, of which 10 would be won from product k.

189 GUPPI has been adopted in the 2010 US Horizontal Merger Guidelines and has been used increasingly in UK merger cases too. See, for example, OFT: *Anticipated acquisition by Shell UK Limited of 253 petrol stations from Consortium Rontec Investments LLP*, February 2012.

A measure of pass-through might be obtained directly from pre-merger estimates (although note that this will, generally, not be the 'correct' rate to give the theoretically precise equilibrium post-merger outcome), or by combining information on pre-merger elasticities (or margins and diversion ratios) with assumptions on the form of demand to, in effect, simulate the post-merger change in the price of product j. For example, if the merged firm, when setting the price of j, is assumed to treat all other prices as constant, then with linear demand the relevant pass-through rate simplifies to $\rho = \frac{1}{2}$, i.e. the monopoly pass-through rate for linear demand.

However, in order for this approach to provide meaningful estimates of the price effects of a merger (prior to consideration of any supply side responses), not only must it be appropriate to approximate competition by the Bertrand model of price setting with differentiated products, but also the pass-through estimates used should reflect the realities of pass-through in practice, and how the merger would affect them. In particular, those price effects are liable to depend on the way the pass-through rates are affected by:

- the change in ownership brought about by the merger;
- the equilibrium price responses of all competing firms; and
- the changes in underlying price levels (and hence on the curvature of demand).

9.2. Pass-through, GUPPIs, and IPRs

As noted, the single firm GUPPI described above presumes that all other prices are held constant whereas, in equilibrium, the impact of firm-specific cost changes will depend on the effect that they have on *all* pricing behaviour, including that of competitors. Specifically, where firm j and firm k's prices are increased, competitors' best response prices will change which, in turn, will imply a further adjustment of firm j and firm k's profit-maximising prices.

In order to take (some of) these effects into account, one might assume a form of demand (e.g. linear or isoelastic) and then compute the equilibrium outcome. In a market wide simulation, one would model the reaction of all firms in the market to the merger. However, simplified 'first order' estimates can be obtained assuming that the prices of rivals are held constant and modelling the impact on the merged firm's prices only given the assumed form of demand. If products are symmetric and demand is linear, this approach gives rise to a simple formula that allows an 'illustrative (or indicative) price rise' (IPR) to be calculated, namely.

$$\frac{md}{2\,(1-d)}$$

In the above expression, d is the diversion ratio between the products of the merging firms (the assumption of symmetry means it is the same for both products) and m is the percentage margin over marginal cost.

Another way to think about the above formula is in terms of a GUPPI and pass-through. Recall that if the merged firm, when setting the price of j, is assumed to take no account of any other firm's pricing responses, the relevant pass-through rate in the linear demand case is $\rho = \frac{1}{2}$. However, the formula takes account of the fact that the merged firm sets the prices of both j and k (assuming all other prices to be constant). In this case, pass-through $\rho = \frac{1}{2\,(1-d)} > \frac{1}{2}$. Combining this pass-through expression with the (symmetric) GUPPI, which equals md, yields the formula.

We have explained in earlier chapters that the rate of pass-through is closely linked to the form of demand. The preceding discussion provides a further example. The price increase predicted using the modified GUPPI formula in this second case (where pass-through is modified to allow for changes in the prices of both products supplied by the merging entity) can be linked directly to the corresponding symmetric case IPR that has been used extensively by the OFT in retail merger cases. A similar relationship can also be derived between the GUPPI and the IPR assuming isoelastic demand (as has also been considered frequently by the OFT), albeit that the difference in the demand assumption gives rise to a different pass-through effect and, as a result, quite different price rise predictions.[190] Specifically, isoelastic demand is substantially more convex than linear demand and therefore gives rise to a much higher pass-through rate.[191]

9.3. Sensitivity to demand assumptions

As established above, the shape of demand plays a critical role in pass-through. Moreover, as illustrated, this has potentially significant implications for predicted merger price effects. Crooke et al. (1999) undertakes a simple, illustrative merger simulation exercise to explore the sensitivity of predicted merger price effects to the specification of demand. Specifically, they compare the implications of four different demand forms, namely (1) AIDS, (2) logit, (3) linear, and (4) log-linear.

The authors focus on a very simple symmetric case involving a duopoly to monopoly merger. Prices, quantities and elasticities are calibrated to be the same for each in a pre-merger differentiated Bertrand setting.[192] Post-merger (monopoly) outcomes are then computed. Those prices are substantially higher in the log-linear (constant elasticity) case than for the linear and logit forms, with the AIDS specification forming an intermediate case.

The authors highlight the key role of the curvature of demand in determining the level of post-merger price increases. The own price elasticity is constant in the log-linear case, but increases to different degrees in the other cases as prices increase, with the Linear form exhibiting the greatest change. Whilst, post-merger elasticities for the logit and AIDS forms are similar, the cross-elasticities are quite different, explaining the observed difference in the post-merger price. Significantly, as Crooke et al. (1999) notes, "[t]*hree of the four demand systems have no flexibility as to curvature once* [pre-merger] *elasticities have been specified, and the fourth, AIDS, has very little*".[193] Moreover, Crooke et al. (1999) also observes that "[t]*hree of the four*

[190] $IPR_{Isoelastic} = GUPPI \cdot \frac{1}{(1-m-d)} = \frac{md}{(1-m-d)}$.

[191] See RBB Economics: *The Joint OFT / CC Commentary on Retail Mergers: FAQs*, November 2011, for a discussion of this issue.

[192] They also extend this to simulation of more complex 'asymmetric' mergers involving different patterns of concentration.

[193] Crooke et al. (1999), p. 209.

demand systems [- the exception is the Logit -] *can be considered first-order approximations to the unknown demand surface in the neighborhood of the premerger equilibrium, because they are sufficiently flexible that they can be calibrated to fit precisely an arbitrary matrix of premerger demand elasticities".*[194] This implies that any can be fitted to pre-merger observations, suggesting that the basis for selecting between demand specifications may be limited.

Fabinger and Weyl (2012) also notes the key role played by demand specification in the formulation of pass-through, and observes that many commonly used demand functions are implausibly restrictive with respect to the level and slope of pass-through. As such, they do not provide a good basis for evaluating and estimating pass-through effects in practice. This is a significant deficiency, given the importance of pass-through to many economic problems. In that context, as Fabinger and Weyl observes, one would "*wish to be more agnostic about pass-through and its slope than [is] allowed by existing demand forms*". To address this challenge, they propose a demand system - Adjustable-pass-through (Apt) demand - that yields flexible elasticities and pass-through rates, generalising the constant pass-through demand class to allow flexibility in the slope and level of pass-through.

Over recent years, industrial organisation economists have been increasingly adopting a more flexible demand system, namely the random coefficient logit model in applied work. (See Annex A.) Unlike the multinomial logit and the other demand forms reviewed by Crooke et al. (1999), this model does not restrict consumer substitution and, importantly, the curvature of demand is not imposed by functional form but is determined by the data. In practice, however, estimation of this model is not without its own challenges. First, this demand model requires a relatively rich dataset, including product attributes as well as information on consumer characteristics. Second, the estimation procedure is relatively complex.

9.4. Alternative 'first order' approximation approaches

The previous discussion highlights the potential problems associated with utilising counterfactuals which rely on specific functional forms, where the 'correct' functional form cannot be reliably established using observable, i.e. pre-merger, information.

Froeb et al. (2005a) considers the gross (upward) price effect of a merger and the (downward) price effect due to synergies, in the context of a Bertrand oligopoly. The authors find that both these effects vary greatly with the structure of assumed demand, in particular the second order (curvature) conditions. As noted, this is a significant issue where demand specification cannot be pinned down due to the lack of sufficient relevant information. Importantly, the demand conditions that cause a merger to result in large price increases also imply a substantial pass-through effect.

The authors consider Newton's approximation, which still relies on the second order derivatives of the demand function. Further, they highlight that pass-through depends on both prices and ownership, therefore pass-through rates in the pre-merger equilibrium are typically different from the post-merger ones. They also show how a change in the demand assumption dramatically

[194] Ibid.

changes the predicted merger effect and the pass-through rate for the proposed WorldCom-Sprint merger.

They further observe that the compensating marginal costs reductions approach (Werden (1996)) avoids the problems of second order derivatives. This approach contemplates the marginal cost reductions necessary to keep prices constant after the merger. One positive aspect of this approach is that it depends only on first derivatives – so no assumption on the curvature of demand is needed. A comparison between the likely cost reduction and the compensating marginal cost reduction may be used to predict whether a merger would (given the validity of the theoretical assumptions) increase or decrease prices. However, the magnitude of any price effect that would arise is not established.

The development of the UPP and GUPPI approaches represent an attempt to derive a 'first order' estimate of the direction of merger pricing effects which does not depend on such functional forms (as does the compensating marginal cost reduction approach). Nevertheless, the UPP approach has been criticised for its dependence on specific assumptions, notably a 'differentiated Bertrand' assumption in respect of the nature of the strategic interaction between firms, and because it does not give predictions of the magnitudes of merger price effects. Jaffe and Weyl (2013) responds to these difficulties by developing a theoretical framework for approximating price effects that (1) seeks to generalise some of the underlying assumptions for UPP, e.g. by allowing greater flexibility in the way firms are assumed to take account of the behaviour of their rivals,[195] and (2) uses pre-merger pass-through conditions to derive estimates of post-merger price effects. In this respect, Jaffe and Weyl highlights the distinctions and relationships between (observable) pre-merger pass-through, merger pass-through - relevant to the impact of the internalised cannibalisation effect, and post-merger pass-through - relevant to the impact of merger efficiencies.

Miller at al. (2013), for example, builds on Jaffe and Weyl's approach, showing how a 'first order' approximation of the price effects of a merger (or other 'policy' intervention) can be obtained using pre-merger (or pre-policy) information. In particular, the authors consider how pre-merger pass-through information and first derivatives of demand may be used to identify the second derivatives of demand generally required for such an approximation. They also identify the circumstances where pre-change pass-through information can be combined directly with a measure of the cost change itself to obtain an approximate estimate of the price effect of the change. Significantly, they find that price changes caused by a vertical shift in marginal cost can be approximated in this way. Indeed, if pass-through rates are constant, this approach gives an exact prediction.

The authors then use Monte Carlo studies to evaluate the performance of merger price predictions made using this 'first order' approximation method. Specifically, they compare those predictions with those which result from merger simulation which uses mis-specified demand; e.g. using a linear demand specification when the 'true' demand is log-linear. For this comparison they consider four common alternative demand specifications, namely linear, logit, AIDS, and log-linear. They find that the prediction errors that arise when demand is mis-

[195] See RBB Economics (2011),

specified are often substantial, and that their first order approximation approach generally out-performs those mis-specified simulations.

Furthermore, Miller at al.(2013) evaluates the performance of the simplification of the general approach which combines pre-merger estimates of pass-through with measures of the cost of cannibalisation (i.e. the GUPPI). It finds that even this simplified method would usually be more accurate than guessing the form of demand - e.g. linear or isoelastic - and predicting a post-merger price on that basis.[196]

Interestingly, Miller et al. (2013) also considers the case where the pass-through rate is unknown and simply assumed to be 100%. Their simulations indicate that even this measure may typically be better than guessing the form of demand. However, the prediction is considerably less accurate than the case where the pre-merger pass-through rate is known.

The method presented in Miller et al. (2013) is based on local approximation. The error in this approximation (which is of second order) is liable to increase with the size of the cost change considered, therefore. Moreover, as the authors point out, the method only delivers exact predictions of price changes when cost pass-through is constant, which is the case with linear demand, suggesting significant drawbacks in many situations in practice. To address this problem, additional information would be required on how the cost pass-through rates change with the level of costs. In practice, however, obtaining such information is likely to be challenging. It is also relevant, in this context, to consider whether the information requirements to obtain ever more sophisticated pass-through estimates are consistent with the objective of obtaining easy-to-calculate ‘first order’ approximations.

9.5. Summary: pass-through and horizontal mergers

- A horizontal merger can be thought of as creating a cannibalisation cost for each of the merging parties, since price reductions by one party which win sales from the other will not contribute to the profits of the merged entity. Viewed in this way, the price effect of the merger will depend on the way that these cannibalisation costs are passed through to prices.

- In general, the magnitude of the cannibalisation cost will depend on how the prices of all firms in the market adjust to the post-merger environment. Equally, the extent of cost pass-through will also depend on the ownership effects of the merger and the price adjustments of competitors. Nevertheless, a ‘first order’ approximation of the price effects of the merger can be obtained using pre-merger information.

- Indicative estimates of post-merger price changes can be obtained by assuming specific functional forms for demand. However, assuming a particular shape for demand implicitly also implies a choice of pass-through assumption. An alternative is to work with estimated

[196] An exception arises where the true demand is isoelastic and the assumed (simulated) demand is almost ideal. In that particular case the assumed demand performs better than the simple approximation approach. However, if the true demand is isoelastic but the assumed demand is linear or logit, the first order approach performs better.

pass-through rates directly, e.g. in combination with a measure of upward pricing pressure - a 'GUPPI'.

- Recent research suggests that merger price predictions based on first-order approaches, such as the GUPPI-based method, which draw directly on pre-merger pass-through information may perform better than predictions based on simulations which assume the wrong specification of demand.

Annex A: A review of empirical methodologies

To estimate cost pass-through the economic literature has employed a number of econometric techniques. In this annex we briefly outline the main approaches.

- First, a number of studies employ a static reduced-form econometric model, which basically consists of estimating a regression of price on cost variables or variables that proxy cost changes, such as exchange rates, for example.

- Second, other studies extend the reduced-form approach, applying a difference-in-differences estimator, which compares the price adjustment from a treatment group with the price change of a control group which, unlike the treatment group, has not experienced any cost shock.

- Third, some studies develop a dynamic reduced-form model to account for delay in pass-through but also to quantify short-run and long-run cost pass-through as well as asymmetric pass-through patterns.

- Fourth, relying on a structural model, a number of studies develop counterfactual scenarios in which marginal cost is altered to assess the extent to which equilibrium price adjusts. In general, the structural model includes a demand-side (i.e. the model assumes a demand function that represents consumer behaviour) and a supply-side (i.e. the model assumes a particular cost function as well as firms' conduct). First, the demand system is estimated using product level data. Second, the parameter estimates of the demand system are used to calibrate the model and uncover product marginal costs. This process employs the firms' first order conditions that relate price, marginal cost and the sensitivity of demand to price change. The price is given by the data and the sensitivity to price change is estimated econometrically with the demand system. Using these two inputs, the practitioner can obtain each product's marginal cost. Once the model is calibrated, the analyst can perform simulation experiments to measure cost pass-through by altering marginal costs to obtain new equilibrium prices.

We review these methods in turn.

A.1 The standard reduced-form approach

If price and cost data are available, the practitioner may seek to estimate the relationship between price and cost. The details of the model specification will depend on the nature and the availability of data, but the typical reduced-form regression to quantify the cost pass-through rate for firm *i* can be written as follows:

$$p_{it} = \alpha + \beta mc_{it} + z_{it}\theta + \varepsilon_{it},$$

where p_{it} is the price of firm i at time t and mc_{it} the marginal cost of firm $i.$ The vector z_{it} includes other explanatory variables that affect the price level of firm i, which are also correlated with mc_{it}.

The parameter β represents the absolute rate of cost pass-through. If, instead, the regression is expressed in logs, this parameter would represent the pass-through elasticity; that is, if the marginal cost increases by 1%, the price would change by β%.

In general, depending on the dataset, the model may be estimated using a number of different types of econometric techniques. We distinguish data samples as follows.

- Cross-section: the practitioner has data on price and cost for several products or firms during the same period.

- Time-series: the practitioner has data on price and cost for one product or one firm over several periods.

- Panel-data: the practitioner has data on price and cost for several products over time.

A reduced form regression may be estimated using a limited data set. That is, the practitioner may regress prices on the relevant cost variables, while accounting for some of the confounding factors using fixed effects. Unlike a qualitative assessment, this approach may control for other influences on prices that could mask the relationship between price and cost.

Although the reduced-form approach is popular, it has several drawbacks that the practitioner must take into account when weighting the regression results against other type of evidence. First, although the interpretation of the coefficient estimates may appear straightforward, when the model is not derived from a structural model, it is not always clear cut what the regression parameters are actually measuring.

Second, the regression functional form may be restrictive. For example, if the reduced-form regression is linear in marginal cost as shown above, the model assumes that margins are constant, as the price response is always the same regardless of the magnitude of the cost shocks. However, in reality, pass-through may vary according to the magnitude of the cost shock.

Third, in oligopoly markets firms react to their competitors' price adjustments to marginal cost variations. The reduced-form approach ignores this competitive interaction, yet this also determines firms' mark-ups. The competitive interaction is obviously correlated with the marginal cost change, yet if omitted it only appears in the residuals of the regression. Thus the so-called reduced-form suffers from potential endogeneity problems.[197]

Fourth, the practitioner is never certain that all relevant variables affecting price movements that are also correlated with z_{it} are included in the right hand side of the regression equation. This might be less of a concern when a fixed-effects estimator is employed on a panel dataset – this estimator controls for time-invariant omitted variables. However, when the time series of the panel dataset is sufficiently long, omitted time-varying variables may become a concern and impact the estimate. One method to alleviate such a concern is to apply the difference-in-differences estimator that we discuss below.

[197] This calls for an instrumental variable estimator. For an introduction to these types of estimator see, for example, Chapter 15 of *Introductory Econometrics: a modern approach* by Jeffrey Woolridge.

A.2 Difference-in-differences approach

Some studies have employed a difference-in-differences estimator. This approach can be used when two conditions are met:

- there is a clear change in input cost (or the "experiment") that affects a well identified group of firms ("treated firms"); and

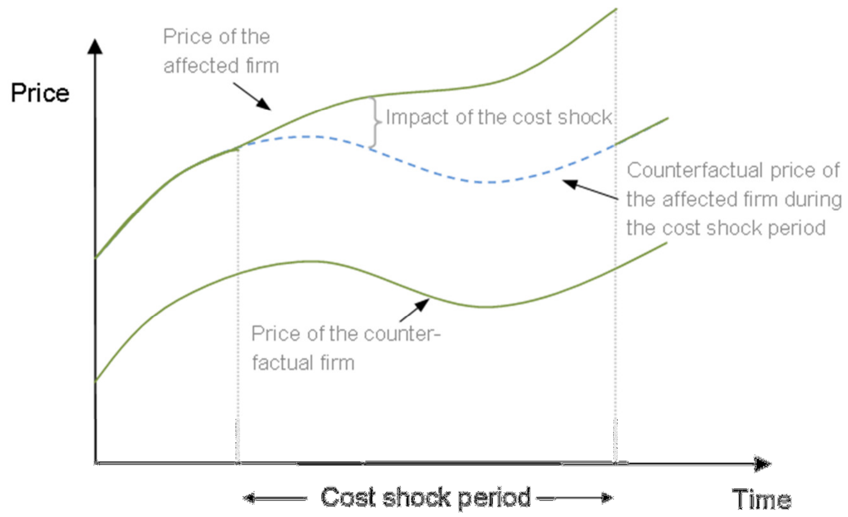
- the input cost change (the "experiment") does not affect a separate group of firms ("control group") that is sufficiently similar to the "treated firms".

The practitioner compares prices for the treated group before and after the change in input cost (the first difference) with the difference in prices for the control group before and after the cost change (the second difference). This gives the difference-in-differences estimator for the change in price "caused by" a change in cost. This estimator is valid if the following key assumption holds: in the absence of the cost change, the treated firms' price would have evolved in the same way as that of the control group.[198]

Figure 21 below provides a stylised example to illustrate the logic of the difference-in-differences approach to quantifying the impact of a cost shock. In the figure we present prices for two firms (green lines). The top green line represents the price of a firm that experiences a cost shock (affected firm), while the bottom green line represents the price of the firm that is not affected by the cost shock (counterfactual firm). The figure shows that the affected firm's price, relative to the counterfactual firm's price, increases due to the cost shock.

[198] The difference-in-differences estimator may also be used to estimate cartel damages in the situation where there are relevant comparator firms that are not affected by the cartel. See European Commission, Commission Staff Working Document 'Quantifying harm in actions for damages based on breaches of article 101 or 102 of the Treaty on the Functioning of the European Union', 11 June 2013, for a practical guide to applying the difference –in-differences approach.

Figure 21: A cost shock that only affects one firm in an industry



We can use the difference-in-differences approach to obtain an estimate of the price that the affected firm would have earned had it not been affected by the cost shock. The difference between the observed price and the counterfactual price is attributed to the cost shock.

Note that the choice of the control group is a critical issue. In principle, firms in the control group should be similar to firms in the treated group. This is because the key assumption is that the price of the treated firm would have moved in the same way as that of the control group. To this end, the practitioner might be tempted to use firms that have not been impacted by the cost change but are in the same market as the treated firms. Such a choice might not be wise after all. Indeed, even if some firms were not directly impacted by a cost shock, because they are in the same market as firm that experience a cost shock, the firms in the control group have also adjusted prices. In other words, other firms in the market may not constitute as good a benchmark as firms in similar but unrelated markets.

By way of illustration, we present the study by Doyle and Samphantharak (2006), which employs the difference-in-difference approach to quantify the effect of the repeal and reinstatement of sales tax on the retail price of unleaded gasoline in two US states, Illinois and Indiana. It considers three distinct tax reforms:

- on 1st July 2000, the 5% sales tax on gasoline was repealed in both Illinois and Indiana;
- on 28th September 2000, the 5% sales tax was reinstated in Indiana; and
- on 1st January 2001, the 5% sales tax was reinstated in Illinois.

To assess the pass-through, the difference-in-differences approach compares retail prices of unleaded gasoline in Illinois and Indiana with prices of unleaded gasoline in neighbouring states in which there was no change in sales tax before and after the relevant tax reform. In each case the authors employ daily data two days before the tax reform and two days after the reform.[199]

As price movements may be affected by factors other than the change in the tax regime, Doyle and Samphantharak (2006) sets up a price regression to control for fluctuations in wholesale prices as well as difference in local demand factors. The regression on the log of retail prices is presented below:

$$\ln(Retail\ Price_{sbt}) =$$
$$\gamma_0 + \gamma_1 l(Illinois\ or\ Indiana)_s + \gamma_2 Post\ Reform_t + \gamma_3 l(Illinois\ or\ Indiana)_s * Post\ Reform_t +$$
$$\gamma_4 \ln(Wholesale\ Price)_{st} + \gamma_5 X_s + \delta_b + \varepsilon_{sbt},$$

where $l(Illinois\ or\ Indiana)_s$ and $Post\ Reform_t$ are indicator variables for whether the petrol station s is in the state of Illinois or Indiana and whether time t is before or after the tax reform. In each case the difference-in-differences estimator is given by γ_3.

X_s is a vector of local features for each ZIP code in which the petrol station is located. These local characteristics include the size of the population, number of gas stations and income levels as well as other demographics. Brand fixed effects are also included to take into account potential decisions made at a brand level. The variable $\ln(Wholesale\ Price)_{st}$ is also included in some model specifications as a control for different changes in costs between the stations at the time of the reform.

The authors estimate a difference-in-difference regression for each tax reform. The effect of the tax repeal gives an average estimate of the pass-through rates for both Illinois and Indiana. Table 21 below presents the main regression results (the coefficients in bold represent the difference-in-difference estimates).

Table 21: Results of repeal and reinstatement of the 5% gasoline sales tax in Illinois and Indiana

	July Tax Repeal	October Tax Reinstatement (Indiana)	January Tax Reinstatement (Illinois)
$\mathbf{l(Illinois\ or\ Indiana)_s}$	-0.048 (0.038)	-0.056 (0.009)	0.019 (0.035)
$\mathbf{Post\ Reform_t}$	-0.052 (0.007)	-0.014 (0.006)	-0.000 (0.004)
$\mathbf{l(Illinois\ or\ Indiana)_s *}$ $\mathbf{Post\ Reform_t}$	**-0.035** **(0.007)**	**0.039** **(0.006)**	**0.027** **(0.004)**
Implied pass-through	70%	78%	54%

Source: Doyle and Samphantharak (2006), Table 2. Note: Clustered standard errors at the state level are reported in parentheses.

[199] The retail and wholesale price data were collected by Wright Express Financial Services Corporation using information from credit card receipts. For instance, in relation to the repeal of the sales tax on 1st July, the difference-in-differences approach compares prices on 27th and 28th June 2000 with prices after the repeal on 5th and 6th July 2000. Similarly for the reinstatement of the sales tax in Indiana, the sample includes prices before (26th and 27th October) and after (31st October and 1st November). For the reinstatement in Illinois, prices before were collected on 29th and 30th December 2000 and after on 2nd and 3rd January 2001.

The elimination of the 5% sales tax led to a reduction in retail prices of 3.5%, or a pass-through elasticity of 0.7.[200] Instead, the reinstatement of the sales tax (5%) led prices to increase by 3.9% in Indiana and 2.7% in Illinois, or a pass-through elasticity of 0.78 and 0.54 respectively.

This empirical study hinges on ad-hoc changes in tax reform. In principle, the difference-in-differences approach may also be used to estimate the impact of a cost change on a firm or a group of firms. However, this requires that the cost change impact only the "treated firms" and that data on a relevant control group is available.

A.3 Dynamic econometric models to estimate pass-through

When firms change price in response to cost shocks with delay, or only adjust prices in response to cumulative cost shocks, it might be more appropriate to use a dynamic model to estimate cost pass-through.[201] Otherwise, examining contemporaneous correlation between cost and price change may understate the pass-through. This is even more the case when the frequency of the data is high. For example, examining contemporaneous weekly data may reveal little about the extent to which firms pass on cost changes if firms change price less frequently. By the same token, the nature of the supply chain may condition the timing of the pass-through. When the cost shock takes place upstream, while the price examined is at the bottom of the supply chain, the cost change may filter down through several layers before affecting retail prices.

Using a dynamic model, the practitioner may be able to estimate short-run and long-run pass-through but also asymmetric pass-through. Below we present some of the most common dynamic specifications that have been used in the literature.

We initially focus on the simpler dynamic models. For example, Nakamura and Zerom (2010) estimates the pass-through of the commodity price of coffee to wholesale and retail prices. Specifically, it employs an index of coffee commodity prices for the US for the cost change. The model is specified as follows:

$$\Delta logp_{jmt}^{l} = a + \sum_{k=1}^{6} b_k \, \Delta logC_{t-k} + \sum_{k=1}^{4} d_k q_k + \epsilon$$

where $l = r, w$, stands for retail or wholesale. $\Delta logp_{jmt}^{r}$ is the log of retail price change for product j in market m at time t, $\Delta logp_{jmt}^{w}$ is the corresponding log of wholesale price change, $\Delta logC_{t-k}$ is the log of the commodity cost index at time $t-k$, q_t is a quarter of the year dummy, a, b_k and d_k are parameters and ϵ is a mean zero error term.

To account for the fact that a change in commodity price may be passed through with some delay, a lagged log commodity cost index is introduced in the specification. The long run pass-

[200] Because the dependent variable is expressed in logs, the percentage change is in fact given by exp(β-1). But for very small coefficient estimates the difference is minimal.

[201] For an introduction to dynamic econometric models see, for example, Walter Enders, 'Applied econometric time series', third edition, John Wiley & Sons, Inc., 2009.

through is given by the sum of the coefficients on the six lagged cost change variables: $\sum_{k=1}^{6} b_k$. This gives the cumulative effect on price for six consecutive quarters.

The authors selected the number of lags so that when adding another lagged change in the commodity price, the estimated long run pass-through would not be affected. In other words, their results suggest that the long run consists of six quarters, after that a change in commodity price has no impact on wholesale and retail prices.

The paper reports results for both log and level specifications for pass-through to retail and wholesale prices. These results are presented in the table below.

Table 22: Pass-through regression results

	Log specification		**Levels specification**	
	Retail	**Wholesale**	**Retail**	**Wholesale**
Short term pass-through	0.063 (0.013)	0.115 (0.018)	0.142 (0.040)	0.218 (0.061)
Long-run pass-through	0.252 (0.007)	0.262 (0.018)	0.916 (0.023)	0.852 (0.052)

Source: Nakamura and Zerom (2010), Table 2 and 3. Note: Standard errors (clustered by unique produce and market) are in parentheses.

Under the log specification, the short term pass-through elasticity is estimated at 0.063 for retail and 0.115 for wholesale, while the long run pass-through elasticity is higher in both cases at 0.252 and 0.262 respectively. The level specification gives similar results. The short term absolute pass-through rates are estimated at 0.142 and 0.218 for retail and wholesale and long term rates are 0.916 and 0.852.

The results show that the absolute pass-through rates and elasticities are much greater in the long-run compared to the short term. While this is not surprising, the magnitude of the difference showcases the importance of considering the potential dynamic effect. If the dynamic effect is not taken into account, the pass-through rate could be underestimated. The long run retail level pass-through rate is very similar to that of the wholesale level pass-through rate.

Similar to Nakamura and Zerom (2010), Leibtag et al. (2007) uses a similar dynamic specification to estimate long-run pass-through of commodity prices to retail and wholesale coffee prices in the US. However, in contrast to Nakamura and Zerom (2010), it makes use of micro data instead of a coffee commodity cost index to estimate the pass-through rates. It also considers the dynamic effect of a change in commodity price for six consecutive quarters. The results are very similar to those of Nakamura and Zerom (2010).

Other dynamic models have also been used to account for asymmetric pass-through. One popular time series technique is the error correction model (ECM).[202] In a nutshell, the model estimates the long-run relationship between price and cost, but also allows short-term deviations from this relationship. Below, we present two studies to illustrate the implementation of the asymmetric ECM, which also allows the practitioner to assess asymmetric pass-through.[203]

Chou et al. (2013) examines retail price adjustments in the gasoline and diesel markets of Taiwan, Japan, South Korea and Singapore using monthly data between January 2004 and June 2012. Using an asymmetric ECM, it estimates how retail gasoline and diesel prices adjust in these countries.

First, the authors assume that the long-term equilibrium relationship between gasoline (or diesel) prices and oil prices is given by:

$$r_t \ = \delta_0 + \delta_1 o_t + u_t$$

where r_t is the retail gasoline (or diesel) price, and o_t is the oil price in the domestic currency. r_t and o_t are expressed in natural logarithmic form. δ_1 is the long-term pass-through elasticity of oil to gasoline (diesel) prices. δ_0 represents additional retail costs, such as labour and rent.

They specify a model which allows for a wide variety of dynamic patterns in the data, and in particular, examine how the gasoline (or diesel) price and oil price diverge from the long run relationship. The standard ECM is given by:

$$\Delta r_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i \ \ \Delta r_{t-i} + + \sum_{i=0}^{n} \beta_i \ \ \Delta o_{t-i} + \theta \ \ z_{t-1} + \varepsilon_t$$

where the error correction term is given by $z_{t-1} = (r_{t-1} - \delta_0 - \delta_1 o_{t-i})$ and θ denotes the speed of adjustment coefficient. When $r_{t-1} < \delta_0 - \delta_1 o_{t-i}$, this means that the observed gasoline (or diesel) price was below its long run equilibrium value $(\delta_0 - \delta_1 o_{t-i})$ in the preceding period. This implies that it should increase toward equilibrium value, or $\Delta r_t > 0$, hence the adjustment coefficient θ should be negative.

In this model, β_0 measures the short-term effect of the oil price change, and $\sum_{i=0}^{n} \beta_i$ is the distributed lag effect of oil price changes; that is, this measures the cumulative effect of oil price changes. Δ denotes the first difference, and ε_t is the error term.

To allow for asymmetric price responses, the ECM can take the following form:

[202] For an introduction to ECM model see, for example, Walter Enders, "Applied Econometric Time Series", Third Edition, Wiley.

[203] There are a number of different ECM models that can be used. Grasso and Manera (2005) compares three of the most popular ECM models designed to describe asymmetric price behaviour. It investigates asymmetries in the movements of gasoline prices in France, Germany, Italy, Spain and the UK over the period 1985-2003. A detailed description of these models is outside the scope of this study and interested readers should refer to Grasso and Manera (2005) for further information on these models.

$$\Delta r_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i^+ \Delta r_{t-i}^+ + \sum_{i=1}^{m} \alpha_i^- \Delta r_{t-i}^- + \sum_{i=0}^{n} \beta_i^+ \Delta o_{t-i}^+ + \sum_{i=0}^{n} \beta_i^- \Delta o_{t-i}^- + \theta^+ z_{t-1}^+ + \theta^- z_{t-1}^- + \varepsilon_t$$

In this specification, the gasoline (diesel) price change, oil price change, and the error correction term are divided into positive and negative portions. The variables are defined as follows: $\Delta r_t^+ = \max\{\Delta r_t, 0\}$, $\Delta r_t^- = \min\{0, \Delta r_t\}$, $\Delta r_t^+ = \max\{\Delta r_t, 0\}$, $\Delta r_t^- = \min\{0, \Delta r_t\}$, $\Delta r_t^+ = \max\{\Delta r_t, 0\}$, and $\Delta r_t^- = \min\{0, \Delta r_t\}$.

This equation maintains the essence of the ECM but enables gasoline (diesel) prices to respond to impacts from oil prices in a more flexible manner. In particular, $\beta_0^+$and β_0^- are the immediate effects of positive and negative oil price impacts, respectively, and $\sum_{i=0}^{n} \beta_i^+$ and $\sum_{i=0}^{n} \beta_i^-$ respectively measure the cumulated impacts of positive and negative oil price effects. In addition, $\alpha_i^+$and α_i^- are the autoregressive distributed lag effects of Δr_t^+ and Δr_t^- respectively, and θ^+ and θ^+ measure the rates of convergence to equilibrium when prices are higher or lower than the equilibrium level.

The results of this asymmetric ECM model are presented in Table 23 below.

Table 23: Asymmetric error correction results

	Retail gasoline prices				Retail diesel prices			
	Taiwan	**Japan**	**South Korea**	**Singapore**	**Taiwan**	**Japan**	**South Korea**	**Singapore**
$\boldsymbol{\alpha_1^+}$	0.302** (0.121)	0.401*** (0.128)	-0.140 (0.121)	-0.087 (0.158)	-0.619** (0.263)	0.475*** (0.134)	0.272*** (0.100)	-0.133 (0.122)
$\boldsymbol{\alpha_1^+}$	0.071 (0.138)	-0.267 (0.184)	0.176 (0.191)	-0.068 (0.194)	0.026 (0.11)	-0.265 (0.17)	0.127 (0.186)	-0.489* (0.256)
$\boldsymbol{\alpha_2^+}$								-0.154** (0.075)
$\boldsymbol{\alpha_2^+}$								-0.139** (0.167)
$\boldsymbol{\beta_0^+}$	0.179** (0.072)	-0.099 (0.171)	0.076 (0.109)	0.314*** (0.113)	0.367* (0.189)	0.059 (0.135)	0.254*** (0.069)	0.435 ***(0.115)
$\boldsymbol{\beta_0^+}$	0.500*** (0.067)	0.035 (0.109)	0.690*** (0.11)	0.338*** (0.095)	0.482** (0.187)	-0.015 (0.078)	0.507 ***(0.11)	0.311 ***(0.081)
$\boldsymbol{\beta_1^+}$	0.095 (0.082)	-0.322 (0.227)	0.217* (0.117)	0.135 (0.118)	0.289** (0.117)	-0.211 (0.18)	0.237** (0.105)	
$\boldsymbol{\beta_1^+}$	0.131 (0.093)	0.559*** (0.138)	0.239* (0.127)	-0.084 (0.097)	0.306** (0.131)	0.362*** (0.113)	-0.033 (0.096)	
$\boldsymbol{\beta_2^+}$		0.123 (0.103)					0.043 (0.09)	
$\boldsymbol{\beta_2^+}$		0.175* (0.097)					-0.330*** (0.098)	
$\boldsymbol{\beta_3^+}$							-0.128 (0.09)	
$\boldsymbol{\beta_3^+}$							0.206* (0.117)	
$\boldsymbol{\theta^+}$	-0.161 (0.156)	-0.091 (0.206)	-0.269* (0.144)	-0.285* (0.164)	0.036 (0.258)	-0.329*** (0.098)	-0.641*** (0.234)	-0.241*** (0.047)
$\boldsymbol{\theta^-}$	-0.398*** (0.114)	-1.098*** (0.277)	-0.834*** (0.192)	-0.205 (0.165)	-0.262* (0.157)	-0.615*** (0.213)	-0.618* (0.319)	-0.378*** (0.084)

*Source: Chou et al. (2013), Table 3. Notes: Newey-West standard errors that are robust to heteroskedasticity and autocorrelation are shown in parentheses; and ***, **, and * indicate that the coefficients are significant at the 1%, 5%, and 10% levels.*

The authors then investigate whether long-term asymmetry exists by testing whether θ^+ and θ^- are equal. They find that there is only a significant difference between θ^+ and θ^- for two of the eight price variables (gasoline prices in Japan and South Korea).

Using a similar approach to that in Chou et al (2013), Borenstein, Gilbert and Cameron (1997) examines how retail gasoline prices respond to changes in crude oil prices in the US. The gasoline supply chain is made up of several arm's length transactions. As a result, any change in crude oil prices would have to trickle down the supply chain, affecting retail prices only after some delay.

As retail prices do not adjust to changes in crude oil prices instantaneously, Borenstein et al. adopt a dynamic model to estimate the short-run and long-run price adjustment.

The authors estimate:

$$\Delta R_t = -\theta_1\phi_1 + \textstyle\sum_{t=0}^{n}(\beta_t^{+}\Delta C_{t-1}^{+} + \beta_t^{-}\Delta C_{t-1}^{-}) + \sum_{t=1}^{n}(\gamma_t^{+}\Delta R_{t-1}^{+} + \gamma_t^{-}\Delta R_{t-1}^{-}) \text{-} \sum_{j=2}^{P}(\theta_1\eta_j SRVY_{j,t}) +$$
$$\theta_1 R_{t-1-} - \theta_1\phi_1 C_{t-1} - \theta_1\phi_2 Time + \varepsilon_t,$$

where ΔR_t is the change in retail gasoline price, and ΔC_t^{+} and ΔC_t^{-} represent the positive and negative changes in the crude oil price respectively. The model also includes signed lagged changes in the retail price ΔR_t to ensure that the error term is white noise. They also include a survey fixed effect, SRVY, to account for the fact that retail prices for different cities are surveyed at either the start or the end of the month. The regression includes a time trend as well.[204] In addition, and importantly, the model incorporates an error correction term, that is an assumed long-run relationship, between crude and retail prices, $R_t = \phi_0 + \phi_1 C_t + \varepsilon_t$.

Table 24 below reproduces the main regression results.[205] The first column presents the results for retail gasoline prices. The second column presents the results for spot gasoline prices, which is the price at which generic gasoline is sold by refiners.

[204] The model is estimated with a two-stage least squares estimator. This is because crude oil prices could be correlated with the error term. This is because local demand shocks could affect upstream prices in the short-run if transportation lags caused the local crude prices to disconnect temporarily with the world price for the upstream product. As instrumental variables, the authors use spot crude oil prices in England (Brent and Forties), which reflect world prices but are unconnected to local demand shocks and the six month ahead crude oil future price (New York delivery).

[205] The authors use the daily spot price for West Texas Intermediate (WTI) crude oil from January 1986 to December 1992. They also use spot gasoline prices for delivery to New York and the Gulf Coast for generic gasoline prices. They use averages for 33 cities east of the Rocky Mountains from weekly surveys to obtain branded city terminal prices (and omit cities from western US because spot markets are not as well established and the spot and futures commodity prices they have are for delivery to the East). For the retail gasoline price, they use the average unleaded regular self-service gasoline price for 33 US cities east of the Rocky Mountains that is collected twice monthly. For all cities except Atlanta, there is only one retail gasoline estimate per month, with each city appearing either in the first survey or the second survey.

Table 24: Key results of price adjustment equations

Downstream price:	**Retail**	**Spot gas**
Upstream price:	**Crude**	**Crude**
Periodicity:	Twice monthly	Weekly
Observations	164	351
ΔUpstream$_0^+$	0.549 (0.084)	0.888 (0.135)
ΔUpstream$_{-1}^+$	0.246 (0.087)	0.691 (0.14)
ΔUpstream$_{-2}^+$	0.022 (0.088)	-0.161 (0.136)
ΔUpstream$_{-3}^+$		
ΔUpstream$_0^-$	-0.181 (0.136)	1.088 (0.143)
ΔUpstream$_{-1}^-$	0.236 (0.098)	-0.239 (0.127)
ΔUpstream$_{-2}^-$	0.028 (0.100)	-0.286 (0.116)
ΔUpstream$_{-3}^-$		

Source: Borenstein, Gilbert and Cameron (1997), Table 1. Note: asymptotic standard errors are in parentheses.

As shown in Table 24 above, a 1 cent per gallon increase in the crude oil price leads to a 0.55 cent retail price increase in the first two weeks (coefficient estimate for ΔUpstream$_0^+$) whereas a 1 cent per gallon decrease *increases* the retail price by 0.18 cents per gallon (coefficient estimate for ΔUpstream$_0^-$). The adjustment from crude to spot gas is close to full. A 1 cent increase in the crude oil price leads to a 0.88 cent increase in the generic gasoline price while a 1 cent decline in the crude oil price is followed by a 1 cent decline in the generic gasoline price.

The authors use the parameter estimates to construct a cumulative adjustment function, which provides the effect of a 1 cent change in the crude oil price on the retail gasoline price at different intervals. This adjustment function also takes into account the long-run relationship (called "the error correction term"). According to the results, after ten weeks, a 1 cent change in the crude oil price causes the retail price to change by 0.81 cents (about 80% pass-through).

A.4 Structural models and simulation analysis

Studies using structural models examine cost pass-through using counterfactual simulations. That is, they simulate the impact of specific marginal cost changes on equilibrium prices. The advantage is that the price adjustment is a function of consumer behaviour as well as the competitive interaction between suppliers. The disadvantage is that the practitioner may have to work with functional forms that restrict consumer and firm behaviour unrealistically.

The structural approach to estimating cost pass-through involves estimating a demand system, calibrating marginal costs and then simulating the impact of marginal cost changes on prices. This section discusses:

- demand estimation using random coefficient logit models; and
- empirical applications of the structural approach to estimating cost pass-through.

A.5 Estimating demand curvature using random coefficient logit models

As indicated in the main body of this study, under imperfect competition the curvature of demand is a determinative factor of the pass-through rate. A structural model involves specifying a demand function. However, if the pass-through rate is determined by the functional form, the analysis is unlikely to provide reliable results. For example, if the model includes a linear demand function, the curvature of demand is assumed not estimated with the data.

One class of demand model, the random coefficient logit model developed by Berry, Levinsohn and Pakes (1995), allows the estimation of the curvature of demand. The random coefficient logit model allows consumers to have heterogeneous taste preferences for different products. We provide below a brief presentation, but for a more comprehensive introduction see Berry et al. (1995) and Nevo (2000).[206]

Let the indirect utility function of consumer i from consuming product j take the following form:

$$u_{ij} = x_j\beta_i - \alpha_i p_j + \xi_j + \varepsilon_{ij}, \qquad where\ \varepsilon_{ni} \sim iid.$$

The utility is a function of observed product characteristics, x_j, unobserved (by the econometrician) characteristics ξ_j and the price p_j. The taste parameters for price and product characteristics may vary with individual consumer characteristics so that the coefficient on product characteristics and price vary across consumers as follows:

$$\binom{\alpha_i}{\beta_i} = \binom{\alpha}{\beta} + \Pi D_i + \Sigma v_i,$$

where D_i is a vector of consumer characteristics; Π is a matrix of coefficient that determine how consumer tastes vary with demographics. v_i represents a vector of unobserved consumer characteristics and Σ is a matrix of coefficients that characterise how consumers tastes vary with these unobserved characteristics. Typically, v_i is assumed to be distributed multivariate normal and is independent of the distribution of D_i.

Indirect utility for consumer i can be represented by a mean component, δ_j, which is common to all consumers and a deviation from the mean component, μ_{ij}, as shown below:

$$u_{ij} = \delta_j + \mu_{ij} + \varepsilon_{ij} \quad \text{where } \delta_j = \beta x_j - \alpha p_j + \xi_j \text{ and } \mu_{ij} = (-p_j, x_j)(\Pi D_i + \Sigma v_i)$$

[206] In particular we refer to Berry et al (1995) and Nevo (2000) for a presentation on the estimation procedure of this model.

Finally, consumers have the option of selecting an outside good. Consumers may decide not to buy any of the products supplied on the market. Otherwise, if the price of all products on the market were to increase, so that relative price between each pair of products remains constant, aggregated quantity demanded would not fall.

Consumers are assumed to purchase one unit of the good that gives the highest utility. If ε_{ij} is assumed to follow a Type I extreme-value distribution, then the probability that consumer i purchases product j is given by:

$$s_{ij} = \frac{e^{\delta_j + \mu_{ij}}}{1 - \sum_{k-1}^{K} e^{\delta_k + \mu_{ik}}}$$

To compute market share, we need to aggregate the choice of all consumers. Let A_j be the set of consumer characteristics that induce the purchase of good j. The market share for good j is given by the probability that this product would be selected.

$$s_j = \int_{A_j} s_{ij} dP_v(v) d\hat{P}_D(D),$$

where $\hat{P}_D$ is the distribution of observed consumer characteristics and P_v is multivariate normal.

This model gives more flexible substitution patterns than the multinomial logit. In particular, the price elasticities depend on individual consumer price sensitivity. The own and cross price elasticities are given by:

$$n_{jk} = \begin{bmatrix} -\frac{p_j}{s_j} \int_{A_j} \alpha_i s_{ij}(1 - s_{ij}) dP_v(v) d\hat{P}_D(D) \\ \frac{p_k}{s_j} \int_{A_j} \alpha_i s_{ij} s_{ik} dP_v(v) d\hat{P}_D(D) \end{bmatrix}$$

For instance, the own price elasticity of a particular product will be high when the majority of its consumers have high price sensitivity. And because $\mu_{ij} + \varepsilon_{ij}$ is not independent of product and consumer characteristics, following a relative price change consumers would tend to switch to products with similar characteristics, and not to the most popular product as in the logit model.

Importantly, unlike the multinomial logit, the curvature of demand depends on consumer heterogeneity. As shown above, the price elasticity for product j is a weighted average of individual consumer price sensitivity. When the price of product j increases, some consumers stop purchasing it and select alternative products with similar characteristics, or opt for the outside option. Importantly, marginal consumers may be more sensitive to price change (high value α_i), hence they respond to a price increase by not purchasing the product or by dropping out of the market. Hence post price increase, the composition of consumers purchasing the product may include a greater proportion of consumers with low value α_i. This implies that the firm faces a less elastic demand after the price increase, and in turn this gives rise to a greater pass-through rate.

Using this type of demand model, it is possible to gauge the super elasticity of demand, which is the percentage change in the demand elasticity for a given percentage change in price, and is a common measure of demand curvature (see Klenow and Willis (2006)). For example, when the price elasticity is constant, the super-elasticity is zero, and firms do not adjust their mark-ups following marginal cost changes. However, when the super elasticity is positive (negative), this implies that a price increase gives rise to a more (less) elastic demand curve.

We identified a couple of studies that use the random coefficient logit model and present an estimate of the super elasticity of demand. In each case, the super elasticity is positive, indicating that as price is increased, the price-elasticity increases, which is consistent with concave, linear and less convex demand curves. Goldberg and Hellerstein (2013) reports a super elasticity of 0.8 to 1 for the demand for light beer in the US, and Nakamura and Zerom (2010) finds a range between 4.37 and 4.64 for demand for ground coffee in the US. In sum, for these widely available consumption goods, light beer and coffee, demand becomes more elastic as price increase. This in turn suggests that firms adjust mark-ups downwards when facing marginal cost increases.

These studies find that higher-income consumers are less price sensitive. As a result, one expects that following a price increase, the proportion of higher income consumers will increase, making demand less elastic, which is not consistent with a positive super elasticity.

However, the super elasticity is positive when, following a price rise, the proportion of price sensitive consumers increases. Although this may appear surprising at first, this may occur when high income consumers draw little utility from the product in question, so that they may be indifferent with the outside option. For example, high income consumers may be indifferent between purchasing ground coffee and drinking coffee at a café. In this case, a small price increase would induce high income consumers to prefer the outside option, and thus the proportion of high income consumers that purchase ground coffee is reduced. In turn, suppliers of ground coffee face a more elastic demand.

A.6 Empirical applications of the structural approach

A few studies, such as Kim and Cotterill (2008), Hellerstein (2008), Goldberg and Hellerstein (2013) and Bonnet et al. (2013), examine cost pass-through using structural models. All of them estimate a random coefficient logit model demand system to unearth consumers' substitution patterns. Then, using the demand parameter estimates, they calibrate the supply side.

On the supply side, typically firms (upstream and downstream) are assumed to compete à la Bertrand. Retailers have no bargaining power and take as given the offer from upstream manufacturers, which may consist of linear or non-linear tariffs. Note that the conduct assumption can be altered; in particular, it can be assumed that firms cooperate.

The system can be solved to yield each firm's marginal cost, which depends on observed prices, the parameters of the demand system, and also on whether firms behave competitively or collude. Following Kim and Cotterill (2008), when the supply side consists only of suppliers, the first-order conditions can be written in matrix notation as:

$$(p - mc)\Delta(p) + s(p) = 0,$$

where p is the vector of all prices, mc the vector of marginal costs and $s(p)$ the vector of market shares. Note that Δ is a *JxJ* matrix (with *J* products in the market) with the following elements:

$$\begin{cases} \dfrac{\partial s_k(p)}{\partial p_j}, & if\ brand\ k\ and\ j\ are\ produced\ by\ the\ same\ firm \\ 0 & otherwise \end{cases}$$

The first order condition is solved for marginal cost:

$$\widehat{mc} = p + \Delta(p)^{-1}s(p).$$

In a second step, the studies proceed to assess how changes in marginal costs of various sizes affect equilibrium prices. The ratio of the change in price to marginal cost gives the pass-through rate.

Analytically, pass-through can be derived from the first-order conditions by applying the implicit function theorem:

$$\frac{\partial p}{\partial mc} = -\frac{\Delta(p)}{\Delta(p) + (p - mc)\Delta'(p) + s'(p)}.$$

This shows that the pass-through hinges on the first and second-order derivatives of the demand function.

Annex B: An illustrative model of price and quality competition

This Annex sets out a Hotelling model of competition in which firms compete on price and quality. Quality is determined at stage 1; price is set at stage 2, taking quality as given. Quality is modelled to be such that higher quality does not increase unit production costs. Rather, at stage 1, firms make fixed cost investments in branding such that their perceived quality goes up. Other things equal, prices are strategic complements and quality strategic substitutes.

B.1 Assumptions

- Consumers are located uniformly on a unit: [0,1]
- Two firms ($i = 1,2$) are active in the market and are located at each end of the line:

  $$x_1 = 0$$
  $$x_2 = 1$$

- Firm i offers a product of quality V_i.
- A consumer located at z, purchasing V_i at price p_i, derives utility:

  $$u(V_i, p_i, z) = U + V_i - p_i - t\|x_i - z\|$$

  where U can be interpreted as the consumers' reservation value for the good and t is the distance disutility parameter.

- Marginal production costs are equal to c_i and are independent of quality. Investment in quality V_i is assumed to depend quadratically on V_i, and on parameter α. The resulting cost function is:

  $$C_i(\alpha, \beta_i, V_i) = c_i q_i + \frac{1}{2}\alpha V_i^2$$

- Each firm first simultaneously chooses quality; second, having observed the chosen qualities, each firm simultaneously chooses price.

B.2 Demand

The marginal consumer that is indifferent between the two offers is located at:

$$\hat{z} = \frac{1}{2} + \frac{(p_2 - p_1) + (V_1 - V_2)}{2t} \quad (1)$$

Hence, firm i's demand can be written as:

$$D_i(p_i, p_{-i}, V_i, V_{-i}) = \frac{1}{2} + \frac{(p_{-i} - p_i) + (V_i - V_{-i})}{2t}$$

B.3 Equilibrium

Second stage: Nash equilibrium in price

The problem facing firm i is

$$\begin{aligned} \max_{p_i \geqslant 0} \; \Pi_i &= (p_i - c_i) D_i(p_i, p_{-i}, V_i, V_{-i}) - \frac{1}{2}\alpha V_i^2 \\ &= (c_i - \beta_i)\left[\frac{1}{2} + \frac{(p_{-i} - p_i) + (V_i - V_{-i})}{2t} \right] - \frac{1}{2}\alpha V_i^2 \end{aligned} \quad (2)$$

If $p_i > 0$, the solution to (2) is given by the first-order condition:

$$FOC(p_i) : \frac{1}{2} + \frac{(p_{-i} - p_i) + (V_i - V_{-i})}{2t} + (p_i - c_i)\left(-\frac{1}{2t}\right) = 0$$

The resulting best response function for firm i is

$$p_i^{BR} = \frac{1}{2}\left[t + c_i + p_{-i} + (V_i - V_{-i})\right] \quad (3)$$

Firm i's best response function is upward sloping in p_{-i} (i.e. firms' decisions on prices are strategic complements). Using (3), we can now compute the Nash equilibrium in the second stage of the game, by solving the following system:

$$\begin{cases} p_i^{BR} = \frac{1}{2}[t + c_i + p_{-i} + (V_i - V_{-i})] \\ p_{-i}^{BR} = \frac{1}{2}[t + c_{-i} + p_i + (V_{-i} - V_i)] \end{cases}$$

Thus, equilibrium prices are given by:

$$\begin{pmatrix} p_i^* \\ p_{-i}^* \end{pmatrix} = \begin{pmatrix} t + \frac{2c_i + c_{-i}}{3} + \frac{V_i - V_{-i}}{3} \\ t + \frac{2c_{-i} + c_i}{3} + \frac{V_{-i} - V_i}{3} \end{pmatrix} \quad (4)$$

'Own' price firm-specific pass-through

Holding quality constant, 'own' price firm-specific cost pass-through is given by:

$$\frac{\partial p_i^*}{\partial c_i} = \frac{\partial}{\partial c_i}\left[t + \frac{2c_i + c_{-i}}{3} + \frac{V_i - V_{-i}}{3}\right] = \frac{2}{3} \tag{5}$$

'Cross' price firm-specific cost pass-through

Holding quality constant, 'cross' price firm-specific cost pass-through is:

$$\frac{\partial p_{-i}^*}{\partial c_i} = \frac{\partial}{\partial c_i}\left[t + \frac{2c_{-i} + c_i}{3} + \frac{V_{-i} - V_i}{3}\right] = \frac{1}{3} \tag{6}$$

Industry pass-through

Holding quality constant, industry-wide cost pass-through is:

$$\frac{\partial p_i^*}{\partial (c_i + c_{-i})} = \frac{\partial}{\partial (c_i + c_{-i})}\left[t + \frac{2c_i + c_{-i}}{3} + \frac{V_i - V_{-i}}{3}\right] = 1 \tag{7}$$

First stage: Nash equilibrium in quality

Knowing (4), the problem for firm i in the first stage can be written as:

$$\begin{aligned}\max_{V_i \geqslant 0} \Pi_i &= (p_i^* - c_i)\left[\frac{1}{2} + \frac{(p_{-i}^* - p_i^*) + (V_i - V_{-i})}{2t}\right] - \frac{1}{2}\alpha V_i^2 \\ &= \frac{1}{2t}\left(t + \frac{c_{-i} - c_i}{3} + \frac{V_i - V_{-i}}{3}\right)^2 - \frac{1}{2}\alpha V_i^2\end{aligned} \tag{8}$$

If $V_i > 0$, the solution for (8) is given by:

$$FOC(V_i) \Leftrightarrow \frac{1}{t}\left(t + \frac{c_{-i} - c_i}{3} + \frac{V_i - V_{-i}}{3}\right)\frac{1}{3} - \alpha V_i = 0$$

The resulting best response function for firm i is:

$$V_i^{BR} = \frac{3t + (c_{-i} - c_i) - V_{-i}}{9t\alpha - 1} \tag{9}$$

Second-order conditions for V_i are:

$$SOC(V_i) : \frac{1}{3t}\frac{1}{3} - \alpha < 0$$

It is easy to see that firm i's best reply function is downward sloping in V_{-i} (i.e. firms' decisions on quality are strategic substitutes). Using (9), we can now compute the Nash equilibrium of the first stage of the game, by solving the following system:

$$\begin{cases} V_i^{BR} = \frac{3t+(c_{-i}-c_i)-V_{-i}}{9t\alpha-1} \\ V_{-i}^{BR} = \frac{3t+(c_i-c_{-i})-V_i}{9t\alpha-1} \end{cases} \tag{10}$$

Thus, qualities chosen in equilibrium are:

$$\begin{pmatrix} V_i^* \\ V_{-i}^* \end{pmatrix} = \begin{pmatrix} \frac{1}{3\alpha} + \frac{c_{-i}-c_i}{9t\alpha-2} \\ \frac{1}{3\alpha} + \frac{c_i-c_{-i}}{9t\alpha-2} \end{pmatrix} \tag{11}$$

The equilibrium stability condition is satisfied when firm i's reaction function is less negatively sloped than the rival's reaction function. From (10), it is easy to derive the stability condition of the first-stage equilibrium. Specifically:

$$-\frac{1}{9t\alpha - 1} > -(9t\alpha - 1) \Leftrightarrow \alpha > \frac{2}{9t}$$

As a consequence, according to second-order and stability conditions, we conclude that:

- a unique, stable equilibrium exists when $\alpha > \frac{2}{9t}$;
- equilibrium is unstable when $\frac{1}{9t} < \alpha < \frac{2}{9t}$.

Equilibrium in the full game

Prices, profits and market shares

Knowing (11), it follows that, using (12), equilibrium prices can be written as:

$$\begin{aligned} p_i^* &= t + \frac{2c_i + c_{-i}}{3} + \frac{V_i^* - V_{-i}^*}{3} \\ &= t + \frac{2c_i + c_{-i}}{3} + \frac{2(c_{-i} - c_i)}{3(9t\alpha - 2)} \end{aligned} \tag{12}$$

With some algebra, we can demonstrate that the problem is well-defined (i.e. equilibrium prices are above 0) when

$$
\begin{aligned}
D_i &= \frac{1}{2} + \frac{(p^*_{-i} - p^*_i) + (V^*_i - V^*_{-i})}{2t} \\
&= \frac{1}{2} + \frac{c_{-i} - c_i}{6t} + \frac{c_{-i} - c_i}{3t(9t\alpha - 2)}
\end{aligned}
\qquad (13)
$$

Using (1), the market share of firm i can be written as:

$$
\begin{aligned}
D_i &= \frac{1}{2} + \frac{(p^*_{-i} - p^*_i) + (V^*_i - V^*_{-i})}{2t} \\
&= \frac{1}{2} + \frac{\beta_{-i} - \beta_i}{6t} + \frac{\beta_{-i} - \beta_i}{3t(9t\alpha - 2)}
\end{aligned}
\qquad (14)
$$

Using (8), profits for firm i can be written as:

$$
\begin{aligned}
\Pi^*_i &= \frac{1}{2t}\left(t + \frac{c_{-i} - c_i}{3} + \frac{V^*_i - V^*_{-i}}{3}\right)^2 - \frac{1}{2}\alpha(V^*_i)^2 \\
&= \frac{1}{2t}\left(t + \frac{c_{-i} - c_i}{3} + \frac{2(c_{-i} - c_i)}{3(9t\alpha - 2)}\right)^2 - \frac{1}{2}\alpha\left(\frac{1}{3\alpha} + \frac{c_{-i} - c_i}{9t\alpha - 2}\right)^2
\end{aligned}
\qquad (15)
$$

'Own' price firm-specific cost pass-through

'Own' price firm-specific cost pass-through for firm i in the full game is given by:

$$
\begin{aligned}
\frac{\partial p^*_i}{\partial c_i} &= \frac{\partial}{\partial c_i}\left\{t + \frac{2c_i + c_{-i}}{3} + \frac{2(c_{-i} - c_i)}{3(9t\alpha - 2)}\right\} \\
&= \frac{2}{3} - \frac{2}{3(9t\alpha - 2)}
\end{aligned}
\qquad (16)
$$

'Cross' price firm-specific cost pass-through

'Cross' price firm-specific cost pass-through in the full game is given by:

$$
\begin{aligned}
\frac{\partial p^*_{-i}}{\partial c_i} &= \frac{\partial}{\partial c_i}\left\{t + \frac{2c_{-i} + c_i}{3} + \frac{2(c_i - c_{-i})}{3(9t\alpha - 2)}\right\} \\
&= \frac{1}{3} + \frac{2}{3(9t\alpha - 2)}
\end{aligned}
\qquad (17)
$$

Industry-wide cost pass-through

Industry-wide cost pass-through in the full game is given by:

$$PT_3 = \frac{\partial}{\partial(c_i + c_{-i})}\left\{t + \frac{2c_i + c_{-i}}{3} + \frac{2(c_{-i} - c_i)}{3(9t\alpha - 2)}\right\} \tag{18}$$
$$= 1$$

B.4 Comparative statics for pass-through

Equations (16) and (17) show that, when firms can compete in quality and are asymmetric in production costs, the impact on prices of a change in production costs is not constant, and crucially depends on (i) the distance disutility parameter, t, and (ii) the cost of quality, α. The economic intuition behind this is related to the fact that firms do not compete only in prices, but also in qualities. Specifically, holding quality constant, an increase in firm i's production costs leads to an increase in prices of both firms and to a decrease in firm i's market share. Since firms' locations are exogenous, such effect is stronger the lower the value of t. Now, if we leave firms free to compete in quality, they will anticipate this effect and will incorporate it when choosing the optimal level of quality. Obviously, such optimal level will depend on the cost of quality, α.

In particular, with simple algebra, it can be shown that[207]:

- The model accounts for the possibility of negative own-price cost pass-through. As a matter of fact:

$$\frac{\partial p_i^*}{\partial c_i} < 0 \Leftrightarrow \frac{2}{9t} < \alpha < \frac{1}{3t}$$

  In other words, firms may respond, under certain conditions, to an increase in their own production costs by *reducing* their price.

  Intuitively, when competition is intense (i.e. t is small) *and* the cost of competing in quality is low (i.e. α is small), even a small cost shock will lead to a large decrease in the market share of the firm i (due to the low disutility of distance for consumers). Firm i will react with a substantial (since the denominator of the first-stage reaction function is low) reduction in quality, which affects the equilibrium price negatively. Such a negative effect more than offsets the positive effect on price due to the increase in production costs. Therefore, the net effect will be a decrease in equilibrium price (negative own cost pass-through).

---

[207] In the following, we will assume that that difference in production costs between firms is marginal, so that a (stable or unstable) equilibrium exists if $\frac{1}{9t} < \alpha < \frac{2}{9t}$ or $\alpha > \frac{2}{9t}$. In fact, for an interior solution to exists we need

$$\frac{1}{9t} < \alpha < \frac{2}{9t} - \frac{|c_i - c_{-i}|}{9t} \text{ or } \alpha > \frac{2}{9t} + \frac{|c_i - c_{-i}|}{9t}$$

This can be easily checked by looking at (4) and (11).

- 'Cross' price firm-specific cost pass-through can be higher than 'own' price firm-specific cost pass-through. Specifically:

$$\frac{\partial p_{-i}^*}{\partial c_i} > \frac{\partial p_i^*}{\partial c_i} \Leftrightarrow \frac{2}{9t} < \alpha < \frac{2}{3t}$$

  The intuition is as follows. Since quality choices are strategic substitutes, the rival will react to a reduction in quality by firm i by increasing its own quality. When competition is intense and quality is 'cheap', a change in firm i's production cost has a stronger *net* effect on the rival's price than on firm i's own price.

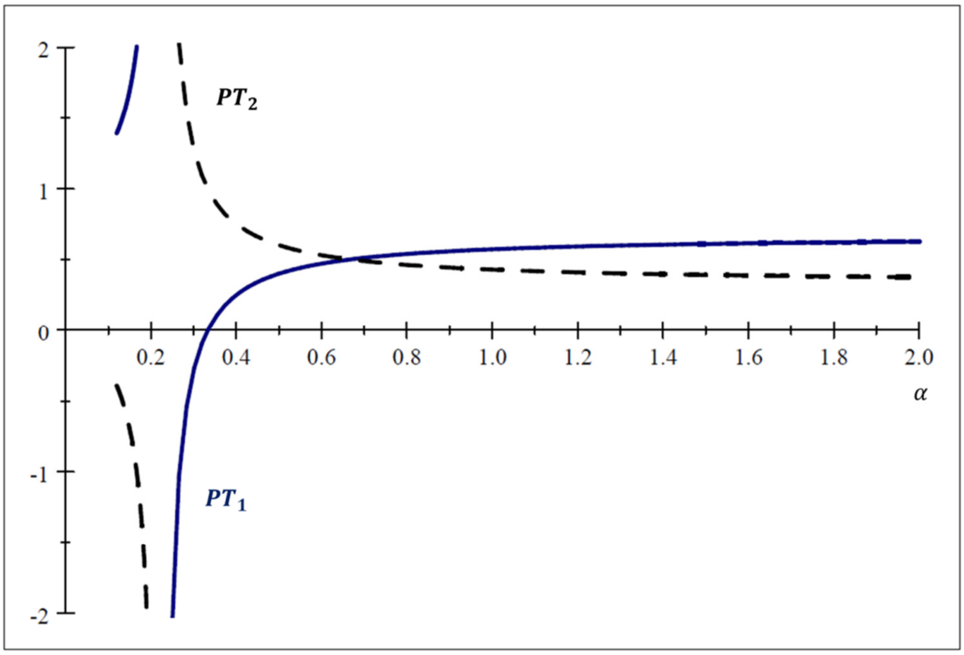
- There is a range of parameter values for which 'cross' price firm-specific cost pass-through can be very negative and 'own' price firm-specific cost pass-through very positive. Specifically, this happens when:

$$\frac{1}{9t} < \alpha < \frac{2}{9t}$$

  Here, firm i will react to an increase in its own production costs by *increasing*, rather than decreasing, quality. As a result, the increase (decrease) in the 'own' ('cross') pass-through will be higher (lower) than observed with exogenous quality.

  Moreover, around $\alpha = \frac{2}{9t}$ a sudden switch occurs – from a very positive (negative) to a very negative (positive) value for the 'own' (cross) price pass-through value. This can be clearly seen in Figure 22, which assumes $\mathrm{t} = 1$ and shows the behaviour of 'own' and 'cross' price firm-specific pass-through for different values of α.

Figure 22: Pass-through for $t = 1$ and different values of alpha[208]



Mathematically, this can be explained by the fact that, over this range of parameter values, the denominator of the first-stage reaction function becomes negative. Notice that when $\alpha = \frac{2}{9t}$, firm i's first-stage best response function switches from being more to being less negatively sloped than firm j's reaction function (see stability condition in previous section). As a consequence, in the range of values

$$\frac{1}{9t} < \alpha < \frac{2}{9t}$$

the equilibrium is unstable.

[208] Again, we assume here that difference in production costs between firms is marginal, so that a (stable or unstable) equilibrium exists if $\frac{1}{9t} < \alpha < \frac{2}{9t}$ or $\alpha > \frac{2}{9t}$.

Annex C: Details of the simulation exercise

In this Annex we provide details of the model specification used in the numerical study reported in Chapter 6 and the results obtained for each demand specification.

C.1 Linear demand

We consider first a differentiated Bertrand model with linear demand. Demand for product i, q_i, is given by:

$$q_i = a_i - b_{ii} p_i + \sum_{j \neq i} b_{ij} p_j$$

where p_i is the price of product i and p_j is the price of rival product j. We suppose a fundamentally symmetrical specification, such that the demand parameters are identical for each product: $a_i = a$, $b_{ii} = b_o$ and $b_{ij} = b_c$.

In our basic set up there are 5 single product firms. Each firm incurs the same, constant marginal cost c, set to 0.5. We select the values of the other parameters to be a=1, b_o =3.5 and b_c =0.5. The resulting equilibrium price is 0.55, implying a mark-up of 0.05. Each product's own price elasticity is 11.

We consider the effect on equilibrium prices of a 10% increase in marginal cost affecting (1) all firms in the market ("industry-wide cost increase"), and (2) only Firm 1 ("firm-specific cost increase").

C.2 Multinomial logit demand

In this case, consumers are assumed to select the product that yields the highest utility net of price. If the random utility component is distributed as independent extreme value, the choice probability (or market share) for product i is given by:

$$s_i(\boldsymbol{p}) = \frac{e^{a_i - b p_i}}{1 + \sum_k^K e^{a_k - b p_k}}$$

The utility of the outside good is normalised to 0, and its market share is simply $s_0 = 1 - \sum_k^K s_k(\boldsymbol{p})$.

For the case of *n* single product firms, the *n* first-order conditions are given by:

$$p_i - c_i = \frac{1}{b(1 - s_i(\boldsymbol{p}))}$$

or

$$\frac{p_i - c_i}{p_i} = \frac{1}{bp_i(1 - s_i(\boldsymbol{p}))} \equiv \frac{1}{\varepsilon_{ii}}$$

The elasticities are:

$\varepsilon_{ii} = -bp_i(1 - s_i(\boldsymbol{p}))$

$\varepsilon_{ik} = bp_k s_k(\boldsymbol{p})$

Again, for the numerical simulation we suppose five symmetric single product firms, each having the same marginal cost 0.5. We calibrate the market share of the outside good, and the utility parameters, *a* and *b,* so that the equilibrium price is the same as the model with linear demand.

The parameter *b* is determined by the first order condition *p-c=1/(b*(1-s(p)))* and *a* is determined by the market share formula:

$$s_i(\boldsymbol{p}) = \frac{e^{a-bp_i}}{1 + \sum_k^K e^{a-bp_k}}$$

With this method we obtain the parameters *a=66/5* and *b=24*. Note that the demand elasticity is 11, as in the linear demand case.

C.3 CES consumer preferences

Finally, we examine cost pass-through in a scenario in which demand is determined by consumer preferences that show a constant elasticity of substitution (CES). Constant elasticity of substation means, that in order to maintain the same level of utility, goods are substituted for one another at a constant rate - that is, independently of the initial consumption pattern. With *n* products, such a utility function is given by

$$U = \left(\sum_{i=1}^{n} q_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$$

Note that the measure $\sigma > 1$ defines the elasticity of substitution between two products. In order to derive demand functions, a standard household choice problem needs to be solved. Utility maximization under a budget constraint normalized to unity delivers demand for good j that is given by:

$$q_j = \frac{p_j^{-\sigma}}{\sum_{i=1}^{K} p_j^{1-\sigma}}$$

This demand is taken by the firms into their individual profit maximization decisions.[209] As one would intuitively expect, the quantity demanded decreases in a product's own price and

[209] CES preferences are often assumed in the analysis of monopolistic competition. It is important to note that this is not the same as a Bertrand game with product differentiation where demand is determined by CES preferences. In monopolistic competition, firms take

increases in the price of all other products. Profit maximization with constant and symmetric marginal cost, *c*, delivers the price

$$p_j = \frac{\sigma n - (\sigma - 1)}{(\sigma - 1)(n - 1)} c$$

The own-price elasticity of demand for product *j* is given by $\varepsilon_{jj} = \sigma \mp (1 - \sigma) p_j q_j$, and the cross-price elasticity is given by $\varepsilon_{ji} = -(1 - \sigma) p_j q_j$. Symmetry implies $p_j q_j = {}^{1}/_{n}$, which means that the own-price elasticity goes to σ when the number of products increases to infinity. In other words, with an infinite number of products, the own-price elasticity would be constant. Similarly, the cross-price elasticity goes to zero.

Again we simulate the impact on equilibrium prices of various marginal cost increases, using the linear case as a benchmark. We assume five symmetric single-product firms with constant marginal costs of 0.5. The only parameter we calibrate in the CES demand model is the elasticity of substitution parameter, σ, which is set at σ=13.5, to generate the same equilibrium price as the linear case. Note that the own price demand elasticity is 11 in equilibrium, as in the linear demand setting.

C.4 Results: Single-product firms

In the following table we summarise our pass-through results for the 5 single-product firm scenario for each demand specification.

Table 25: Pass-through of industry-wide and product-specific cost increases

		$\boldsymbol{p_1}$	$\Delta \boldsymbol{p_1}$	$\frac{\boldsymbol{\Delta p_1}}{\boldsymbol{\Delta c_1}}$	$\boldsymbol{p_{-1}}$	$\Delta \boldsymbol{p_{-1}}$	$\frac{\boldsymbol{\Delta p_{-1}}}{\boldsymbol{\Delta c_{-1}}}$	$\boldsymbol{\bar{p}}$	$\Delta \boldsymbol{\bar{p}}$	$\frac{\boldsymbol{\Delta \bar{p}}}{\boldsymbol{\Delta c_1}}$
	Benchmark	.5500			.5500			.5500		
Linear	**Product- specific**	.5757	.0257	**51.3%**	.5523	0.0023	**4.6%**	.5548	.0048	**9.6%**
	Industry-wide							.5850	.0350	**70.0%**
Logit	**Product- specific**	.5946	.0446	**89.2%**	.5512	0.0012	**2.4%**	.5547	.0047	**9.4%**
	Industry-wide							.5975	.0475	**95.0%**
CES	**Product- specific**	.5980	.0480	**96.0%**	.5519	0.0019	**3.8%**	.5555	.0055	**11.0%**
	Industry-wide							.5500	.0550	**110%**

Source: RBB analysis

the aggregate market price as given, that is, they do not consider that their price will influence the prices of competitors (similar as in a model with perfect competition). The monopolistic competition approach seems valid when individual firms have only a marginal impact on the market price index, i.e. when there are many firms active. We work in this section with five firms, such that the assumption that firms do not influence the aggregate price level does not seem valid. Hence is the Bertrand approach we follow more suitable.

C.5 Results: Multi-product firms

Industry constellation and HHI		p_1	p_2	p_3	p_4	p_5	$\bar{p}$	$\frac{\Delta p_1}{\Delta c_1}$	$\frac{\Delta \bar{p}}{\Delta c_1}$
1, 2, 3, 4, 5 **H=2000**	Benchmark	.5500	.5500	.5500	.5500	.5500	.5500		
	Firm-specific	.5946	.5512	.5512	.5512	.5512	.5547	89.2%	9.4%
	Industry-wide	.5975	.5975	.5975	.5975	.5975	.5975	95.0%	95%
1, 2, 3, {4, 5} **H=2645**	Benchmark	.5506	.5506	.5506	.5587	.5587	.5535		
	Firm-specific	.5949	.5521	.5521	.5613	.5613	.5597	88.6%	12.4%
	Industry-wide	.5977	.5977	.5977	.6035	.6035	.5999	94.2%	92.8%
{1, 2}, 3, 4, 5 **H=2645**	Benchmark	.5587	.5587	.5506	.5506	.5506	.5535		
	Firm-specific	.5985	.5985	.5528	.5528	.5528	.5611	79.6%	15.3%
	Industry-wide	.6035	.6035	.5977	.5977	.5977	.5999	89.6%	92.8%
1, {2, 3}, {4, 5} **H=3476**	Benchmark	.5514	.5601	.5601	.5601	.5601	.5579		
	Firm-specific	.5953	.5634	.5634	.5634	.5634	.5666	87.8%	17.4%
	Industry-wide	.5979	.6039	.6039	.6039	.6039	.6023	93.0%	88.8%

Industry constellation and HHI		p_1	p_2	p_3	p_4	p_5	$\bar{p}$	$\frac{\Delta p_1}{\Delta c_1}$	$\frac{\Delta \bar{p}}{\Delta c_1}$
{1, 2}, {3, 4}, 5	Benchmark	.5601	.5601	.5601	.5601	.5514	.5579		
H=3476	Firm-specific	.5994	.5994	.5649	.5649	.5542	.5688	78.6%	21.5%
	Industry-wide	.6039	.6039	.6039	.6039	.5979	.6023	87.6%	88.8%
1, 2, {3, 4, 5}	Benchmark	.5519	.5519	.5689	.5689	.5689	.5609		
H=3876	Firm-specific	.5955	.5540	.5734	.5734	.5734	.5699	87.2%	18.0%
	Industry-wide	.5981	.5981	.6099	.6099	.6099	.6044	92.4%	87.0%
{1, 2, 3}, 4, 5	Benchmark	.5689	.5689	.5689	.5519	.5519	.5609		
H=3876	Firm-specific	.6040	.6040	.6040	.5553	.5553	.5706	70.2%	20.8%
	Industry-wide	.6099	.6099	.6099	.5981	.5981	.6044	82.0%	87.0%
{1, 2}, {3, 4, 5}	Benchmark	.5634	.5634	.5719	.5719	.5719	.5680		
H=5050	Firm-specific	.6015	.6015	.5801	.5801	.5801	.5862	76.2%	36.3%
	Industry-wide	.6048	.6048	.6106	.6106	.6106	.6081	82.8%	80.2%
{1, 2, 3}, {4, 5}	Benchmark	.5719	.5719	.5719	.5634	.5634	.5680		
H=5050	Firm-specific	.6062	.6062	.6062	.5704	.5704	.5697	68.6%	32.4%
	Industry-wide	.6106	.6106	.6106	.6048	.6048	.6081	77.4%	80.2%

Industry constellation and HHI		p_1	p_2	p_3	p_4	p_5	$\bar{p}$	$\frac{\Delta p_1}{\Delta c_1}$	$\frac{\Delta \bar{p}}{\Delta c_1}$
1, {2, 3, 4, 5}	Benchmark	.5547	.5823	.5823	.5823	.5823	.5731		
	Firm-specific	.5969	.5899	.5899	.5899	.5899	.5912	84.4%	36.2%
H=5599	Industry-wide	.5988	.6171	.6171	.6171	.6171	.6120	88.2%	77.8%
{1, 2, 3, 4}, 5	Benchmark	.5823	.5823	.5823	.5823	.5547	.5731		
	Firm-specific	.6124	.6124	.6124	.6124	.5593	.5873	60.2%	28.0%
H=5599	Industry-wide	.6171	.6171	.6171	.6171	.5988	.6120	69.6%	77.8%
{1, 2, 3 4,5}	Benchmark	.6018	.6018	.6018	.6018	.6018	.6018		
	Firm-specific	.6256	.6256	.6256	.6256	.6256	.6256	47.6%	47.6%
H=10000	Industry-wide	.6256	.6256	.6256	.6256	.6256	.6256	47.6%	47.6%

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