‘Price Transmission in Vertically-Related Markets’

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Thesis submitted to the University of Nottingham
for the degree of Doctor of Philosophy, November 2004

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Abstract

The thesis aims to contribute to the literature on two fronts. Firstly, it aims to contribute to the literature by developing a conjectural variations model of price transmission in vertically related markets where the final product sector exercises both oligopoly power and oligopsony power. It finds that oligopoly and oligopsony power do not necessarily weaken the degree of price transmission relative to that under perfectly competitive markets although they can. The key to these outcomes is to be found in the functional forms for retail demand and farm supply.

Secondly, it attempts to draw inferences about the conditions under which the prices of the farm and retail prices cointegrate by themselves based on the predictions of the existing theoretical models of vertical price transmission. It then evaluates whether these conditions are borne out empirically. To this end, it tests for the existence of a co-integrating relation between the raw input and retail prices for a sample of 11 food and energy markets in the UK using the Johansen Full-information Maximum Likelihood Procedure. It finds that a co-integrating relation is identified for only 4 out of 11 price pairs; i.e., for potato, fresh fruits, milk and oil. For all other price pairs, it is not identified unless the cointegration regression allows for sector shocks. This result seems to support our theoretical prediction that, given information provided by a price pair alone, co-integration can be observed only for products for which the cost share of the farm input is unity; i.e., for products with a constant margin. And obviously, potatoes, fresh fruits and milk are products which are sold in supermarkets as they appear in their raw form with minimum processing involved suggesting that the share of processing cost for these products is minimal.

Acknowledgements

I would like to extend my heart-felt thanks to the School of Economics, University of Nottingham, UK for providing me with financial and infrastructural support.

I would also like to thank my supervisors, Dr Wyn Morgan and Dr Tim Lloyd not only for their valuable comments but also for their moral support. Dr Wyn Morgan's financial grant to me for three years has been particularly invaluable.

This is not to mention the support of family and friends. In this regard, I would like to acknowledge the special support given me by Elizabeth Ann Benamer whose boundless generosity and thoughtfulness has kept me in one piece for the best part of my PhD study.

Chapter 1

Introduction

In recent years the issue of price transmission from the farm to the retail sector in vertically related food markets, where the farm and marketing inputs are combined to produce the final product, has attracted a great deal of attention both in academic and policy circles. A plethora of theoretical and empirical studies in the price transmission literature and waves of government-commissioned inquiries into the behavior of supermarkets attest to the degree of attention the issue has attracted in these circles.

In the UK, the ascendancy of the issue owes much to public dissatisfaction with the pricing practices of retail (supermarket) multiples whose level of concentration has shown a dramatic increase in recent years. It is believed that they exercise market power in their relation with consumers such that in the event of any price reduction at the farm level consumers get little in benefit as the gains go to widen the supermarkets' margin. It is also believed that these retail multiples exercise buyer power over suppliers of the farm input such that not only do they force farm price down to a level lower than the perfectly competitive benchmark but they also place vertical restraints on suppliers of the farm input. In general there seems to be a belief on the public's behalf that retail concentration is bad for social welfare, as measured by consumers' and producers' surpluses.

The public's belief that retail concentration is bad for social welfare seems to have received support from economic theory. The works of Dobson et al. (1997, 2001 and 2003) and Clarke et al. (2002), for instance, show that under certain conditions, the increase in the level of retailer concentration can result in social welfare loss. Consider a market structure where the retail sector exercises market power in its relation with consumers and buyer power in its relation with producers who are perfectly competitive. Conventional wisdom holds that when retailers exercise seller power then relative to when the market is perfectly competitive, consumers pay a higher price for the product they purchase. Therefore, relative to the perfectly competitive benchmark, they suffer a welfare loss in proportion to the size of the price mark-up (the difference between retail price and marginal cost as a proportion of retail price). Again conventional wisdom holds us that, when retailers exercise buyer power over suppliers, then relative to when the market is perfectly competitive, producers receive a lower price for the product they sell. Therefore relative to a perfectly competitive benchmark, they suffer a welfare loss in proportion to the size of the price mark-down (the difference between the marginal revenue product and farm-gate price as a proportion of farm-gate price). On balance therefore, as this instance shows, the presence of a highly concentrated retail sector which is not only able to exercise seller power over consumers but also buyer power over producers results in a net social welfare loss such that a price discount which retailers secure from producers using their buyer power does not feed through to consumers as this discount only serves to widen the price mark-up.

As the existing body of economic theory shows, however, the loss to social welfare inflicted by the joint exercise of seller and buyer power is far worse than a model of pricing involving a mark-up and a mark-down can capture. This is because such simplistic price models cannot fully capture the welfare effects of practices commonly known in the literature as vertical restraints. These are conditions which retailers impose on suppliers by way of flexing their buyer power. They take different forms the most popular of which are slotting allowances, lump sum fees which suppliers have to pay retailers in order for their produce to find a space in supermarket shelves; listing charges whereby buyers require a fee payment before goods are purchased from the listed supplier; and unjustified high contribution by suppliers to promotional expenses by retailers, to name just a few. The effects of these practices on price transmission are less known. Potentially, however, there are enormous negative consequences on social welfare which derive from them. Firstly, they drive down farm prices to a level below the perfectly competitive benchmark. Secondly, by driving prices down in this way, they not only force small producers, who are not efficient, out of business in the long run but also threaten the viability of even efficient producers whose investments are undermined by their inability to recover fixed costs as they are forced to price at short run marginal cost. The knock-on effect of this in the long run is to drive out small retailers who cannot exercise market power over their suppliers and have as favorable a cost advantage as the retailers with buyer power, and thereby lead to higher prices and less choice for consumers.

Contrary to the public's perception that retail concentration is detrimental, however, the same economic theory also shows that under certain other conditions, the increase in the level of retail concentration can produce benign social welfare effects. Dobson and Waterson (1999) show that even though retail concentration leads to reduced competition at all stages of the marketing chain, it can generate productive efficiency benefits that enhance consumer welfare. Consider the vertical restraints which we made reference to earlier. They argue that, despite their potential harmful effects, such restraints can bring about efficient trading arrangements and lower prices for consumers by removing price distortions resulting from successive mark-ups, by allowing precommitments that facilitate optimal investment levels and by eliminating avoidable transaction costs such as search costs. In an earlier paper, Dobson and Waterson (1997), had also shown that, providing that retail concentration leads to little rise in selling power and that the services of competing retailers are very close substitutes for each other,.such concentration enables retailers to extract, from suppliers with seller power, discounts that can be passed on to consumers as lower prices.

Thus, as the above brief discussion clearly indicates, despite the public's negative perception of retail concentration, economic theory is ambiguous regarding its social welfare effects. Given this ambiguity, it is not surprising that theory cautions against making hasty policy recommendations regarding the regulation of retail concentration on consideration of only the negative social welfare effects of such concentration. Indeed, it advises that any such recommendations involve consideration of a series of welfare trade-offs. The first is a short-run trade-off between retailer buyer power and increased retailer seller power. If subsequent to concentration, retail buyer power is relatively greater than retail seller power, then discounts extracted from the suppliers can be passed on to consumers as lower prices for the final good. Obviously, this has a benign effect on consumer welfare. If, on the other hand, following concentration retail seller power is greater relative to buyer power, prices may rise to the detriment of consumers and economic welfare in general. The second is a trade-off between the short run benefits of lower prices and the long-run damage to supplier competition from weakened brands and greater own-label penetration and the distortion of retail competition in favor of large retailers. Indeed these potential trade-offs seem to have influenced the recommendations of a series of commissioned inquiries into the behavior of retail multiples in the UK. For instance, both the Monopolies and Mergers Commission report (MMC, 1981) and the Competition Commission Report (CC, 2000) identified many retail practices which stand to operate against the public interest. However, neither of these commissions made recommendations in favor of regulating the behavior of multiples.

Clearly, the ambiguity surrounding the welfare effects of retail concentration points to the difficulty of making prior judgements regarding the degree of price transmission, relative to the perfectly competitive benchmark, which obtains when the retail market is concentrated. *A priori,* there is no way of telling whether any deviation from this benchmark results from a concentrated retail sector or from a processing technology that is characterized by non-constant returns to scale. The popular perception is, however, that farm price changes do not fully reflect as retail price changes due mainly to retail concentration which increases firms' seller power.

It is against this background that theoretical work has focused on modelling vertical price transmission allowing for seller power (i.e., oligopoly power) in the retail market. (see, for instance, Holloway,1991; McCorriston et al., 1998). Results from this work suggest that the exercise of market power by supermarkets does not totally explain why farm price changes are not fully reflected as retail price changes. Indeed, they suggest that apart from the special case where the retail demand function is assumed to be linear, market power's impact on the degree of price transmission is ambiguous. This ambiguity arises largely because results are determined by the functional forms of the retail demand function. As will become evident in the main body of our thesis, however, there are also several other determinants of the degree of price transmission which interact with market power to make its impact ambiguous. A recent work by McCorriston et al. (2001) has shown that, even assuming a linear retail demand function, allowing for non-constant returns to scale in industry technology makes market power's impact on the degree of price transmission ambiguous. While decreasing returns to scale reinforce market power's impact on the degree of price transmission, increasing returns to scale weaken its impact.

As far as we are aware, market power's impact on the degree of price transmission has been modelled assuming that supermarkets exercise market power only in their relation with consumers and not in their relation with producers as buyers of the farm input. Indeed, there seems to have been no formal treatment of the impact of buyer power (i.e., oligopsony power) on the degree of price transmission. However, buyer power could be as important as seller power. In the UK food industry, for instance, the nature of the vertical relation between suppliers and grocery multiples has been a cause for concern both among academics and policy makers. Recent growth in retail concentration has been construed to mean that not only has the industry's selling power grown but its buying power might also have increased. This belief seems to have been borne out in the aforementioned Monopolies and Mergers Commission and the Competition Commission Reports which conclude that the grocery multiples had used their buying power to obtain discounts from suppliers. Dobson et al. (1999) also point to the potential for abuse of buying power in recent trends in the growth in concentration of UK retailing.

Owing to the absence of a formal model of oligopsony power's impact on the degree of price transmission, the issue of how supermarkets' exercise of market power in their dealings with both consumers and producers impacts on the degree of price transmission has not been addressed fully. Consequently, it remains an issue that is open-ended thus begging the development of a theoretical model of price transmission which takes account of the exercise of market power by supermarkets both in the retail and farm sectors.

Many theoretical works that have modelled the impact of market power on the degree of price transmission have operated within the framework of equilibrium displacement. So often, modelling within this framework has proceeded on the assumption that the readership knows the step-by-step technical rigors involved. This assumption might be valid for a readership which works within the theoretical field. But it might not be valid for a readership which works within the empirical field. Prior to embarking on any empirical work, however, the latter category has often to read into economic theory for inspiration. Even though there is a group within this category which is conversant with the rigors of the theory, there is likely to be another group which is not as conversant. And it is this group which will definitely demand exposition of the theory. As far as we are aware, there seems to be no synthesis of the models of vertical price transmission under different market structures. With an eye for this category of readership therefore there is a need to undertake an exposition of the major theoretical models of price transmission that have sprung up in the literature in the wake of the seminal article of Gardner (1975).

In tandem with the development of theoretical work, recent years have also witnessed a growing corpus of empirical literature whose focus has been to measure the degree of price transmission from the farm to the retail sector. In the literature two major strands of econometric approaches have sprung up. Whereas the first advocates a structural modelling approach the second advocates a long run equilibrium (i.e., co-integration) approach.

Estimation of the degree of price transmission conditional on the estimation of such structural parameters as market power, demand and supply elasticities and industry technology sits at the heart of the first modelling approach. While this approach has found acceptance, its limitation in not being able to dissect the price transmission path into its short- and long-run components has been well recognized. It is in this context that the second approach has found ascendancy. This approach is premised on the belief that if two prices are tied to each other in a long run economic relationship so that they are co-integrated, a change in one price leads to a proportional change in the other. The upshot is that even if in the short run the two prices diverge from each other, in the long run they revert back to equilibrium.

Whilst this suggests that in vertically related food markets, the prices of the farm and the retail product may cointegrate it does not in any way suggest that they cointegrate solely on the basis of information provided by the price pair and without the need for any other information. To date there has not been an attempt to draw any inferences about the conditions under which the prices of the farm and retail prices cointegrate based on the predictions of the theoretical models of vertical price transmission. Indeed, there seems to be a widespread perception that information provided by the prices of the farm and retail products alone are adequate for the analysis of the long run economic relationship between these prices. This partly emanates from the assumption that the food industry operates with a constant marketing cost, i.e., marketing costs are I(0). If marketing costs are not assumed to remain constant, however, there is no *a priori* reason to believe that a pair of price series relating to the farm and retail sectors would cointegrate by themselves. In fact, as we will show in the body of the thesis, existing theory suggests that price changes at different stages of a vertically related industry are spurred by industry-level shocks such that any test for cointegration between a price pair has to proceed taking account of these shocks. An interesting avenue of research would thus be to see whether the existing models of price transmission can be relied on to make inferences about cointegration given only information provided by a pair of prices.

Clearly, therefore, as things stand now, there seem to exist several contributions that can be made to the existing literature. In this thesis, we propose to make three contributions.

First, we seek to contribute to the analysis of market power's impact on the degree of price transmission. In this respect, we seek to examine the degree of price transmission assuming that the retail sector exercises oligopsony power in its relation with producers. We then analyze the degree of price transmission assuming that, further to exercising oligopsony power, the retail sector exercises oligopoly power in its relation with consumers. To this effect we develop a theoretical model of price transmission using a quantity-setting conjectural variations model of oligopoly and oligopsony.

Second, we seek to contribute to the literature by undertaking an exposition of the rigors involved in the major theoretical models of vertical price transmission. In this respect, we undertake a detailed exposition of the models of price transmission which obtain under the assumptions of different market structures and of industry technologies.

Third, we seek to contribute to the literature by deducing inferences about a cointegrating relation between the farm and retail prices based on the predictions of the theoretical models of price transmission that we will develop. To this effect, we derive price transmission elasticities assuming exogenous shocks originating in several sectors of the food industry and identify the conditions under which a cointegrating relation between the farm and retail prices can be inferred to exist.

Having stated our proposed contributions, we now offer a brief tour map of the thesis. In chapter 2, we present a diagrammatic analysis of changes in the price spread and the resultant degree of price transmission in vertically related markets taking the food market as our focus of analysis. In this chapter we offer an intuitive explanation of the mechanism through which the marketing margin is determined assuming that the input and output markets of the food industry are perfectly competitive and that input and output demand and supply functions are linear. We offer this explanation for both variable and fixed input proportions. We then show briefly the link between the marketing margin and the degree of price transmission as the latter is not independent of changes in the marketing margin. In fact, it is directly affected by movements in the marketing margin. This chapter is designed to prepare the ground work for a more rigorous explanation that is yet to come in the subsequent chapters.

In chapter 3, we make an exposition of the theoretical model of price transmission whereby all the markets in the food industry are assumed perfectly competitive, that industry technology is characterized by constant returns to scale, and that inputs are combined in variable proportions. Our exposition focuses on the model by Gardner (1975) whose framework has been looked upon as a benchmark in subsequent models of price transmission accounting for market power and non-constant returns to scale. In chapter 4 we undertake an exposition of the models of price transmission that have extended Gardner by allowing for market power in the retail market and for non-constant returns to scale in industry technology. Specifically, we undertake an exposition of the models by Holloway (1991) and McCorriston et al. (1998, 2001).

In chapter 5, we extend the model by Gardner not only allowing for market power in the retail sector but also for oligopsony power in the farm sector. To this effect, we first develop the model of oligopsony power and evaluate its impact on the degree of price transmission and see whether the outcome is any different from when only oligopoly power is assumed. We then further develop the model allowing for an interaction between oligopoly and oligopsony power and then evaluate the outcomes for the degree of price transmission.

In chapter 6, we carry out a set of experiments whereby the impact of market power at different stages of the industry is evaluated conditional on the values of other determining factors of the degree of price transmission. Specifically, we allow each of the determining variables to vary within a certain range, ceteris paribus, given a possible band of values for certain other key parameters of our interest, particularly market power. We run three sets of experiments, one assuming the industry is oligopolistic, another assuming the industry is oligopsonistic, and a final experiment assuming the industry is both oligopolistic and oligopsonistic.

In chapter 7, we present a review and evaluation of the existing empirical literature with a particular focus on cointegration.

In chapter 8, we derive several price transmission elasticities corresponding to exogenous shocks originating in the retail and farm sectors. Based on these elasticities, we then deduce inferences about the conditions under which a co-integrating relation arises between the prices of the farm and retail products. We then test the validity of our inferences from this exercise in chapter 9 using a series of 11 price pairs which belong to the UK food and energy markets. We finally conclude in chapter 10 where we present the major results of our thesis, identify its limitations and suggest potential avenues for future research.

Chapter 2

A diagrammatic representation of price transmission

2.1 Background

To date, several theoretical models have been developed to explain the degree of price transmission from the farm input to the retail product in vertically-related markets. In the chapters that follow, we will expound these models formally and extend them further. To set the groundwork for an understanding of these theoretical models, however, we deem it proper, at this early stage, to offer an intuition for the price transmission mechanism which these models set out to explain. We provide this intuition using a diagrammatic approach. This chapter presents such an approach and is intended to offer an insight into the same issues that will be highlighted in the forthcoming chapters.

Consider a perfectly competitive industry which combines farm and marketing inputs, a and b respectively, to produce a final product, x. To make matters clear, consider an industry which processes raw carcase beef using state of the art technology into a variety of retail products; e.g., packaged ground beef. In this particular case, whereas the carcase beef constitutes the raw input, the costs of processing, of packaging and of transporting the final product to supermarket shelves constitute the marketing input. We then want to analyze changes in the marketing margin which follow changes in an exogenous shock originating in each of the markets for a, b and x. In the manner of Tomek and Robinson (1990, Chapter 6), a marketing margin is defined as the difference between the final product price and the farm-gate price. All throughout the chapter, the marketing margin will be discussed in absolute terms and not in relative terms.

As will become clear in the course of the analysis, changes in the marketing margin depend as much on the proportions in which the two inputs are combined as on the source of the exogenous shock. For a given exogenous shock, marketing margin changes that obtain when fixed input proportions are assumed are different from changes that obtain when variable input proportions are assumed. Alternatively, for a given combination of inputs, marketing margin changes that obtain when a retail demand shock is assumed are different from those which obtain when a shock originating in the input supply stage is assumed. This means that for a given exogenous shock, changes in the marketing margin can be analyzed for different input combinations. Similarly, for a given input combination, changes in the marketing margin can be analyzed for different sources of an exogenous shock.

Against this background, we first illustrate the derived demand for the farm input and show its relation to the marketing margin assuming fixed input proportions. Given the assumption of fixed input proportions, we next present the incidence of changes in the marketing margin for different sources of the exogenous shock. We then finally show changes in the marketing margin assuming that inputs are combined in variable proportions and that the exogenous shock originates in the farm input supply sector.

2.2 Derived factor demand and the marketing margin: the case of fixed input proportions

Assume that, in a perfectly competitive industry, a and b are combined in a fixed proportion to produce x (i.e., the ratio, $\frac{a}{b}$ remains constant for all output levels and price

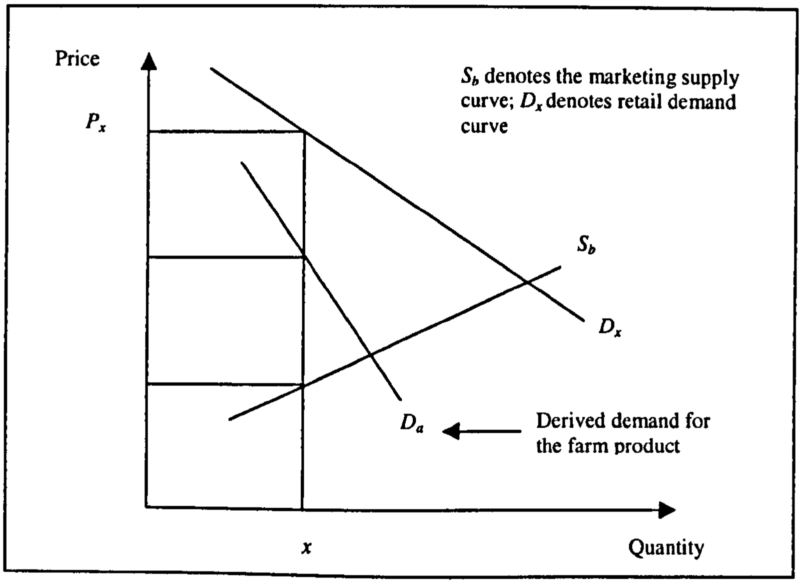

Figure 2-1: Derived demand for the farm product

ratios). Given this assumption, the demand for either input, which is indirect, can be derived from the demand for x which is direct. This is done, for any one input, by subtracting from the retail price of each separate amount of the final product the supply price of the corresponding amount of the other input. Consider the demand for the farm product, a. It is derived as shown in Figure *2.1*.

Given the assumption regarding industry technology, it is reasonable to suppose that in equilibrium both the markets for a and x clear the same quantity of a. In other words, for every unit of x there corresponds an equivalent unit of a which combines with b. The horizontal axis in Figure *2.1* therefore measures quantity of a and of x while the vertical axis measures input and output prices. The maximum price that can be paid for one unit of x for any level of quantity produced is given by the demand curve for x, D_x, while the minimum price paid for a unit of b for any quantity produced of this input is given by the supply curve for b, S_b.

The difference between the maximum price per unit of x and the minimum price per unit of b is the maximum price required to pay for a unit of a (i.e., $P_a = P_x - P_b$).

Graphically, this is shown as the vertical difference between the demand curve for x and the supply curve for b.

The derived demand curve for b ($D_b = D_x - S_a$) can be derived in like manner by subtracting from the maximum price per unit of x, the minimum price per unit of a. But for the purposes at hand, it suffices to illustrate only the derived demand curve for a.

Now refer back to Figure 2.1. For given supply conditions for b and demand conditions for x, the equilibrium price of a, P_a, is determined at a point where the supply curve for a, S_a, intersects the derived demand curve for the same, D_a. Similarly, for given equilibrium prices of a and b, the equilibrium price of the retail product, P_x, is determined at the intersection of the supply curve for x, S_x, and the demand curve for the same, D_x.

Marshall (op. cit., p. 385-386) identifies four conditions which render the derived demand curve for a factor inelastic. These are: (1) that the factor in question is essential; (2) that the demand curve for the final product is inelastic; (3) that the fraction of total cost that goes to the factor in question is very small; and (4) that the supply curve for the other factor is more inelastic.

The first condition follows directly from the assumption of fixed input proportions. Its inclusion as a condition therefore serves to make generalizations about situations where factors are not combined in a fixed proportion.

The second condition follows from the fact that demand for the input in question is derived from the final good's demand so that the more inelastic demand for the latter is the more inelastic demand for the input is and *vice versa*.

The third condition states that in so much as the cost share of the factor in question is too small to have a significant impact on the price of the final product (and, consequently, on retail demand), retailers are willing to pay a high price for its acquisition when such is required.

The fourth condition states that the curvature of the supply curve for one input influences the derived demand for the other (Ritson, 1990; Tomek and Robinson, *op. cit.*). If, for instance, the supply curve for marketing services, S_b is perfectly elastic, then, the derived demand curve for the farm product, D_a is parallel to the demand curve for the retail product, D_x as any change in the price of the retail product, P_x is matched by a proportional change in the price of the farm product. If, on the other hand, the supply curve for marketing services is less perfectly elastic, then, the derived demand curve for the farm product is inelastic too. Given the assumption of fixed input proportions, this is because a higher (lower) cost of acquiring these services means a lower (higher) price paid for the farm product.

2.3 The incidence of changes in the marketing margin: the case of fixed input proportions

Now that the notion of derived demand under the assumption of fixed input proportions has been introduced, the next task will be to analyze changes in the marketing margin subsequent to a shift in *(i)* the demand curve for the retail product; *(ii)* the supply curve for the farm product; and *(iii)* the supply curve for marketing services.

As a starting point, it is worth emphasizing the point that given the assumption of fixed input proportions and given the conditions of demand for the farm and retail products, the nature of the supply curve for marketing services determines the direction of change in the marketing margin. As will become clear as the analysis progresses, if the supply curve for marketing services is perfectly elastic, shifts in the supply curve for the farm product and the demand curve for the final product have no effect on the marketing margin as absolute changes in the prices of the final and farm products are equal. In other words, the demand curve for the farm product is parallel to that for the retail product (i.e., both have the same slope) such that the marketing margin remains unchanged. If, on the other hand, the supply curve for marketing services is less perfectly elastic, the marketing margin widens (narrows) in absolute terms as retail price increases (falls) when such shifts occur, because the derived demand curve for the farm product is more inelastic than the demand curve for the final product.

In the following, the supply curve for marketing services will be assumed upward sloping so that the derived demand curve for the farm product is more inelastic than the demand curve for the final product.

2.3.1 Effects of a retail demand shift and movements in the marketing margin

Consider, *ceteris paribus*, that following changes in consumer income or population size, demand for the final product increases. Obviously, the effect of an increase in demand for the final product is to increase the derived demand for both inputs, and, consequently, the prices at which they can be purchased. In Figure *2.2*, this is shown as a rightward shift in the retail demand curve from D_x to D'_x. Given the new retail demand curve, demand curves for the farm product and marketing services may then be derived as D'_a and D'_b respectively.

With reference to Figure *2.2*, the explanation as to why the derived demand curves have to shift in response to a shift in the demand curve for the final product proceeds as follows. *Ceteris paribus*, a rightward shift in the retail demand curve is reflected in an increase in the quantity demanded of the retail product from x_0 to x_1 and in a retail price increase from P_x to P'_x. For a given supply function of marketing services, this translates into an increase in demand for the farm product from x_0 to x_1, and, consequently, into an increase in the supply price charged by producers from P_a to P'_a. This shows as a rightward shift in the derived demand curve for the farm product from D_a to D'_a. As the production technology requires that inputs be combined in a fixed proportion, the increase in the quantity demanded of the farm product is matched by a proportionate increase in the quantity demanded of marketing services. This induces a rightward shift in the demand curve for these services from D_b to D'_b, and, consequently, an increase in the price of marketing services from P_b to P'_b.

As Figure 2.2 makes evident, given that the supply curve for marketing services is upward sloping so that the derived demand curve for the raw input is more inelastic

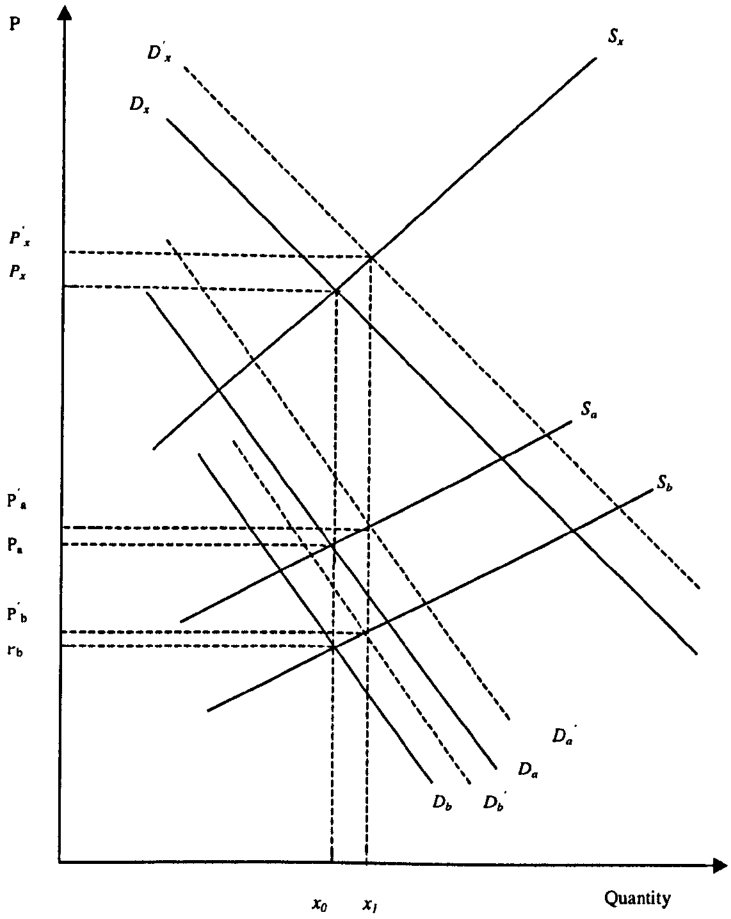

Figure 2-2: Effect of a rightward retail demand shift on the marketing margin: the case of fixed input proportions

than the demand curve for the retail product, the marketing margin would widen from $(P_x - P_a)$ to $(P_x' - P_a')$ consequent upon a rightward shift in the retail demand curve. This is because relative to the increase in farm-gate price, the increase in retail price is greater. It follows therefore that given the assumption of fixed input proportions, the marketing margin moves in the same direction as output and retail price following a rightward shift in the retail demand curve

2.3.2 A farm supply shift and movements in the marketing margin

Next consider the impact of changes in raw input supply on the marketing margin. Imagine, for instance, that due to an unfavorable weather condition or to a sudden increase in input prices, the supply of the farm product falls. Given that the demand curve for the final product and the supply curve for marketing services remain unchanged, this implies retailers have to pay a higher price for each unit of the farm product. Therefore the price of the farm product increases. Given that inputs are combined in a fixed proportion and that the supply function for marketing services remains fixed, a fall in the quantity supplied of the farm product and consequently, an increase in its price, leads to a proportionate fall in the demand for marketing services. For a given supply function for marketing services, the fall in demand for these services results in a fall in their price, so that at the original price for the final product, retailers get enough in margin to pay for the increase in farm price. However, an increase in the price of the farm product makes the retail product more expensive thus reducing its supply.

Therefore, intuitively, a fall in the supply of the farm product results in a fall in demand for marketing services and, given the assumption of fixed input proportions, in a fall in the supply of the retail product and an increase in the prices of the farm and retail products and a fall in the price of marketing services. Since it is assumed that the derived demand curve for the farm product is more inelastic than the demand curve for the final product, the increase in farm-gate price is likely to be greater than that in retail price. Consequently, the marketing margin falls following a leftward shift in farm supply.

Figure 2.3 shows the adverse change in the supply condition for the farm product as a leftward shift in the supply curve for the farm product from S_a to S'_a. The effect of this is to reduce farm supply from x_0 to x_1. Given a stationary demand for the final product, this leads to an increase in the farm-gate price from P_a to P'_a. Because the farm product has become more expensive, retailers reduce their demand for marketing services from x_0 to x_1 and the price they pay these services from P_b to P'_b. In the diagram, this shows as a leftward shift in the demand curve for marketing services from D_b to D'_b. The effect of a fall in the farm product on retail output is reflected as a leftward shift in the supply of the latter from S_x to S'_x, which, for a given consumer demand function, leads to an increase in retail price from P_x to P'_x. Given the conditions of retail demand and marketing supply, the marketing margin falls from $(P_x - P_a)$ to $(P'_a - P'_a)$ [1]. It therefore follows that consequent upon a leftward shift in raw input supply and given the assumption of fixed input proportions, the marketing margin moves in the same direction as quantity and in the opposite direction as retail price.

2.3.3 Effects of a marketing supply shift on the marketing margin

Finally, suppose the cost of marketing services increases. At the original price, this leads to a fall in the supply of these services and to an increase in their price. This in turn leads to a fall in the demand for these services. Given that inputs are combined in a fixed proportion, the increase in the price of marketing services, and, consequently, the fall in the quantity demanded of these services leads to a fall in the quantity demanded of the farm product, and, consequently, to a decrease in its price. Although the price of marketing services increases and that of the farm product decreases, the net effect is to

[1]The sum of the changes in the prices of the farm product and marketing services constitutes the change in the price of the retail product. And this is definitely less than the change in the price of the farm product because, in absolute terms, the change in the price of the farm product is greater than that in the price of marketing services.

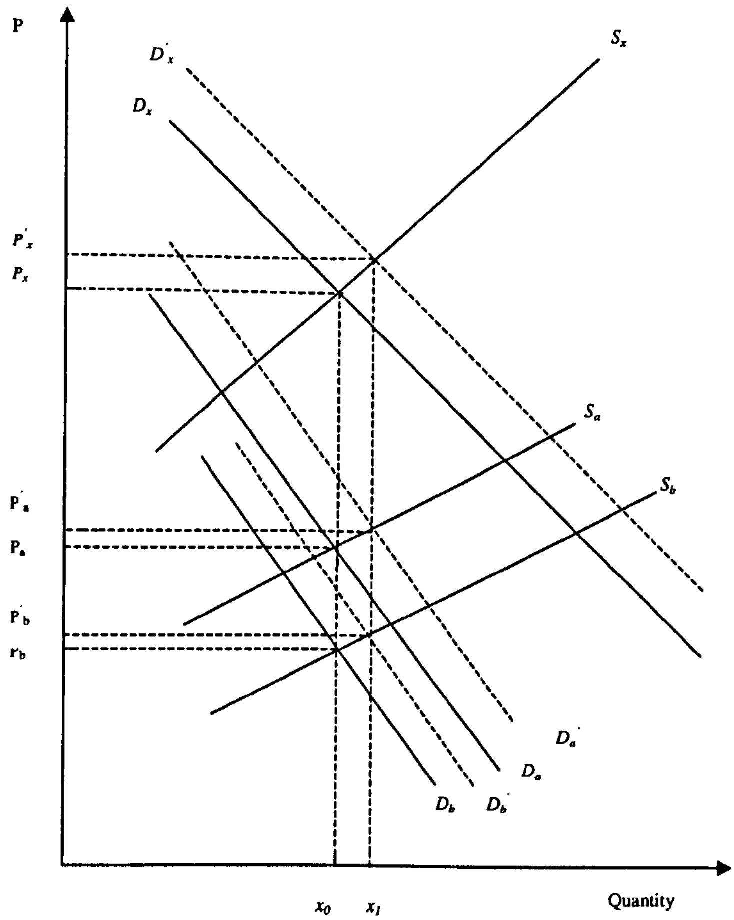

Figure 2-3: Effect of a leftward farm supply shift on the marketing margin: the case of fixed input proportions

increase retail price since a reduced demand for both inputs results in a reduced supply of the retail product. Assuming that the demand function for the final product remains unchanged, retail price must increase as retail supply falls albeit by less than the increase in the price of marketing services since the price of the farm product also falls. Under the given assumptions, therefore the increase in the price of marketing services leads to a widening of the marketing margin.

In Figure 2.4, the increase in the cost of marketing services shows as a leftward shift in the supply curve for these services from S_b to S'_b followed by an increase in their price from P_b to P'_b. To match the fall in the quantity demanded of marketing services, retailers reduce their original demand for the farm product to a level which is enough to produce x_1 quantity of the retail product. This induces a leftward shift in the demand curve for the farm product from D_a to D'_a. Consequently, the price of the farm product falls from P_a to P'_a. As a result of a fall in the quantity demanded of both inputs, the supply of retail output falls from x_0 to x_1 and, consequently, its price increases from P_x to P'_x. This is shown as a leftward shift in the retail supply curve from S_x to S'_x.

Obviously, the marketing margin widens because the price of the farm product decreases when the price of the retail product increases. Therefore, given the assumption of fixed input proportions, if there occurs a leftward shift in the supply curve for marketing services, then the marketing margin moves in the same direction as retail price and in the opposite direction as output.

2.3.4 Fixed input proportions and movements in the marketing margin: a summary

Given the assumption of fixed input proportions, the preceding analysis has generated important predictions about the behavior of changes in the marketing margin following changes in the conditions of retail demand and inputs supply when all markets are perfectly competitive. These predictions can be summarized as follows.

First, the margin widens when there is a rightward shift in retail demand. The

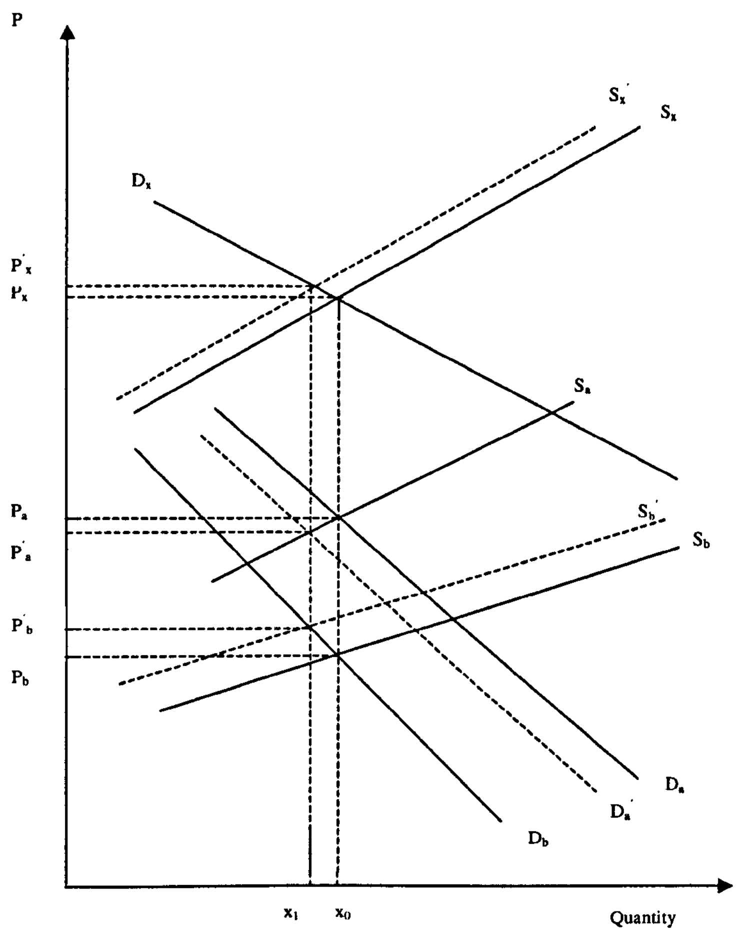

Figure 2-4: Effect of a leftward marketing supply shift on the marketing margin: the case of fixed input proportions.

implication is that following a rightward shift in the retail demand curve, the margin moves in the same direction as retail price and output, i.e., it widens. Second, the marketing margin narrows when there is a leftward farm supply shift. The implication is that following a shift in the supply of the raw (farm) input, the margin moves in the opposite direction as retail price and in the same direction as retail output. Finally, the marketing margin widens following a leftward shift in the supply of marketing services. The implication is that following a shift in the supply of marketing services, the margin moves in the same direction as retail price and in the opposite direction of output.

These predictions strictly hinge on the assumption that inputs are combined in a fixed proportion and the marketing supply curve is less perfectly elastic. Intuitively, on relaxing either assumption, one should expect the predictions made about margin behavior to change. For instance, if the supply curve for marketing services is perfectly elastic, then in absolute terms the marketing margin remains unchanged in the face of retail demand and input supply shocks. In the following section, we relax the assumption of fixed input proportions, *ceteris paribus*, and instead assume variable input proportions and see whether doing so impacts on margin change behavior.

2.4 The incidence of changes in the marketing margin: the case of variable input proportions

2.4.1 Background

As can be recalled from the analysis in the earlier section, the conceptual framework of changes in the marketing margin is highly restrictive in its assumption regarding the proportion in which inputs are combined to produce a unit of the final product. It is restrictive in that it assumes that relative input price changes do not lead to input substitution in the industry. Even though this might be a plausible assumption to make in the short run when supply of inputs is rigid such that the industry is not in a position to vary input proportion in response to relative price changes, in the long run this might not be the case as suppliers adjust their level of production with time in response to relative price changes. One should, however, beware of the fact that industry technology can be characterized by variable proportions even in the short run when individual firms combine their inputs in fixed proportion. This will become evident later, but first let us define variable input proportion.

When industry technology is characterized by variable input proportion, i.e., when the elasticity of substitution is greater than zero, then it follows that in response to relative input price changes (price ratios), the industry changes its original input combination with the result that it uses more of the relatively cheaper input and less of the relatively more expensive input to produce the same unit of output. In other words, it varies the proportion in which inputs are combined to produce a unit of output following changes in relative input prices.

In the food industry where the farm product and marketing services combine to produce the retail product, the degree of input substitution might be limited (see, for instance, Tomek and Robinson, *op. cit.*, and Gardner, 1975). But wherever the degree of input substitution is substantial, the following hypotheses are offered as possible explanations.

The most popular hypothesis holds that in response to a relative increase in the price of the farm product, the industry reacts by using less of this product and more of marketing services by reducing wastage and spoilage of the relatively more expensive product (Tomek and Robinson, *op. cit.*).

The second hypothesis postulates that following a relative increase in the price of the farm product, the food industry responds by changing the quality of marketing services and consequently of the retail product. This hypothesis subscribes to the idea of commodities being a bundle of characteristics and not objects of final consumption (Lancaster, 1971). Imagine there are two characteristic sets that are embedded in a typical food product; a first set which is linked to the farm product (nutrition, taste, etc.)

and a second set which is linked to marketing services (packaging, delivery, convenience, etc.). Then a relative increase in the price of the farm product can lead to a decrease in the production of characteristics of the first set and to an increase in those of the second set via a substitution of marketing services for the farm product. In other words, following an increase in the price of the farm product the industry invests more on packaging, advertising, etc. and less on the raw input. As Reed and Clark (2000) suggest this explanation may be valid in situations whereby packaging is a normal input such that consumers value the convenience associated with the packaging of food products and hence are willing to pay more for packaging through higher food prices.

The third hypothesis applies to situations where the industry's retail product is a composite of many individual commodities suggesting that production processes vary across firms (Wohlgenant and Haidacher, 1989; Wohlgenant, 1999). Consider, for example, an industry in which different beef products sold in supermarkets vary by the amount of processing involved in their production. Assume now that relative to the price of marketing services the price of the raw input increases. It is likely that firms in the industry which produce fresh meat products, i.e., firms which use a small proportion of marketing services and a large proportion of the farm input will reduce demand for fresh meat by much more than do firms which produce processed beef products, i.e., firms which use a large proportion of marketing services and a small proportion of the farm input. At the industry level, this implies that the ratio of farm inputs to marketing services falls following a relative price increase for the farm input. In other words, the proportion in which inputs are combined changes.

The fourth hypothesis holds that even though fixed input proportions might be the norm at the firm level, at the industry level, variable input proportions may hold the reason being that differences in size of firms lead to the use of different input proportions to produce the same unit of output (Wohlgenant and Haidacher, *op cit*).

Coming to the analysis of shifts in the demand curve for the retail product and in the supply curves for the farm and marketing inputs, the outcomes for the marketing margin which obtain when variable input proportions are assumed differ from those that obtain when fixed input proportions are assumed. To illustrate this point, we will not analyze all three shifts since the mechanism through which variable input proportions impact on changes in the marketing margin is the same for all three cases. The mechanism involves a counter-clockwise rotation of the new demand curve for the input which has become relatively more expensive, at the pivot of the original demand curve for the same input (Wohlgenant and Haidacher, *op. cit.*). To assist illumination of the point therefore the following will consider only a shift in the supply curve for the farm product. For a reason that will become clear later on, it will be assumed that the possibility for input substitution is very limited (i.e., the elasticity of substitution is small).

2.4.2 A farm supply shift and movements in the marketing margin: the case of variable input proportions

Suppose the supply of the farm product falls. Given the assumption of fixed input proportions, as might be recalled, this would have resulted in an increase in the farm-gate price. But the fall in farm supply would also have led to a fall in the demand for marketing services, and, consequently, to a fall in their price. The overall effect of a fall in the supply of the farm product would thus have been to reduce output of the retail product and, for a given retail demand function, to increase its price. But as the increase in retail price is not going to be as large as the increase in farm-gate price since derived demand for the farm product is more inelastic than retail demand, one would have expected the margin to narrow following a fall in farm supply.

Now consider how the assumption of variable input proportions impacts on this outcome. An increase in the farm-gate price relative to that in the price of marketing services makes the farm product relatively more expensive and marketing services relatively cheaper. This induces retailers to substitute inputs by employing more marketing services and fewer farm inputs per unit of the final output. But relative to a situation under fixed input proportions, use of more marketing services and fewer farm inputs per

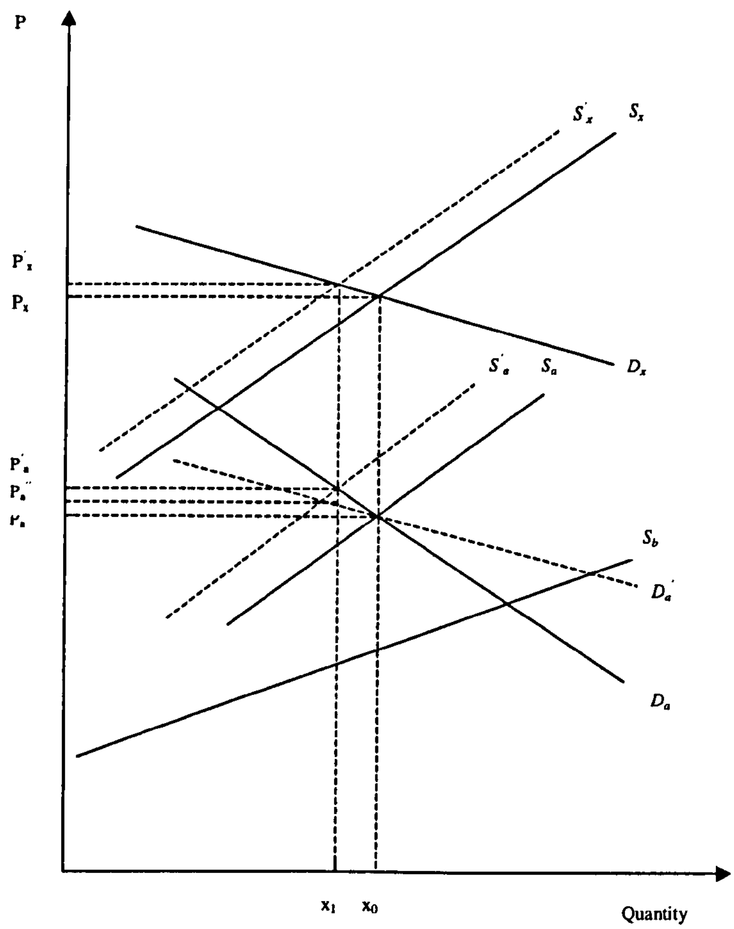

Figure 2-5: Effect of a leftward farm supply shift on the marketing margin: the case of variable input proportions.

unit of the retail output means that retailers have to expend, on average, more money on the former and less on the latter per unit of the retail output. Assuming that retail price remains at its fixed input proportions level, one would expect that, subsequent to a fall in the supply of the farm product, the margin widens relative to its fixed input proportions level but will still narrow relative to its level in initial equilibrium. So it appears that it is not that the assumption of variable input proportions reverses the direction of change in the marketing margin following a fall in the supply of the farm product but that it affects the magnitude by which the margin changes.

Figure 2.5 shows the impact on the margin of a leftward shift in the supply curve for the farm product from S_a to S'_a given the assumption of variable input proportions. Given the assumption of fixed input proportions, this would have led, for a given demand function for the farm product, to an increase in the farm-gate price from P_a to P'_a. It would also have led to a shift in the supply curve for the retail product from S_x to S'_x, and, consequently, to an increase in retail price from P_x to P'_x.

Now that input price ratios have changed so that the farm product becomes relatively more expensive than marketing services, retailers respond by employing a greater proportion of marketing services and a smaller proportion of the farm input per unit of the retail product. The fact that they demand less of the farm input to produce the same unit of output means that retailers reduce the maximum price they would have offered for the farm product under fixed input proportions from P'_a to P''_a. It is worth noting though that despite its fall from the fixed input proportions level[2], the price offered for the farm product still lies higher than the original equilibrium price, P_a. This shows as a counter-clockwise rotation of the new demand curve for the farm product, D'_a, at the pivot of the original derived demand curve, D_a (contrast this with a leftward parallel shift in the demand curve for the farm input under fixed proportions). In other words, the possibility for input substitution makes the derived demand curve for the farm product more elastic (Wohlgenant and Haidacher, *op. cit*, p. 7).

Under the given assumption of variable input proportions, therefore, the effect of a leftward shift in the supply curve for the farm product is to narrow the marketing margin from its original level but to widen it above the level that obtains under fixed input proportions. Relative to its position under the assumption of fixed input proportions, therefore, the marketing margin moves in the direction of retail price and in the opposite direction as output. The reason is that relative to when fixed input proportions are

[2]The magnitude by which the price level has to fall is proportional to the magnitude by which quantity demanded of the farm product falls. If, for instance, on introducing variable input proportions it takes only half a unit of the farm product to make the same one unit of the retail product, under fixed input proportions, then it follows that it costs only half the price under the latter to acquire this amount of the farm product per unit of the fainal product.

assumed, retailers use more of the marketing input, which has become relatively cheaper, and less of the farm input which has become relatively more expensive.

2.4.3 Changes in the marketing margin and the degree of price transmission: a note

Up till now, there hasn't been any discussion regarding the link between the marketing margin and the degree to which farm price changes translate into changes in retail price. Given linear demand and linear input supply functions, however, the degree to which farm input price changes translate into retail price changes are not independent of changes in the marketing margin. In fact, they are directly affected by movements in the marketing margin.

Consider a case where, given the assumptions of fixed input proportions and perfectly competitive input and output markets, the supply curve for marketing services is horizontal. Under the given assumptions, the marketing margin will remain unchanged regardless of an exogenous shock to the retail or input supply sectors. And, consequently, *ceteris paribus*, farm price changes will translate into equal retail price changes. This is because the demand curves for the farm and retail products are parallel.

Now consider a case where, given the assumptions of fixed input proportions and perfectly competitive input and output markets, the supply curve for marketing services is upward-sloping. Under these circumstances, for given changes in the conditions of retail demand and the supply of the farm and marketing inputs, the marketing margin will be changing at the same time that the farm input price is changing. Consequently, farm input price changes will not translate into proportional retail price changes. Therefore, given a rightward retail demand shift and a leftward marketing supply shift for which the marketing margin widens, one should expect changes in retail price to be greater than those in the farm price. On the other hand, given a leftward shift in farm supply for which the marketing margin narrows, one should expect retail price changes to be smaller than changes in farm prices.

As has been pointed out earlier, the assumption of variable input proportions does not affect the qualitative impact of changes in the conditions of supply and retail demand on the marketing margin. Consequently, on introducing the assumption of variable input proportions, one should expect the above predictions regarding the degree to which farm price changes translate into changes in retail price to remain valid.

In the subsequent chapters, the link between the marketing margin and the degree of price transmission will be elaborated in detail. Prior to doing that, however, it is important to emphasize the point that the degree to which changes in farm price translate into changes in retail price depends on whether the marketing margin is changing at the same time that farm-gate price is changing.

2.5 Summary

This chapter has presented a diagrammatic approach to the analysis of the effects of changes in the conditions of retail demand and inputs supply on the marketing margin. Based on the assumptions of fixed input proportions and of perfectly competitive input and output markets, the major results of the diagrammatic approach can be summarized as follows.

Firstly, the effect on the marketing margin depends on the source of the shock. Thus, given a retail demand shift, the margin moves in the same direction as retail price and retail output suggesting that it widens following a rightward retail demand shift and narrows following a leftward retail demand shift. Given a farm supply shift, the marketing margin moves in the opposite direction of retail price and in the same direction as retail output suggesting that it narrows for a leftward shift in supply and widens for a rightward shift in supply. Finally, given a marketing supply shift, the margin moves in the same direction as retail price and in the opposite direction of retail output suggesting that it narrows for a rightward shift in supply and widens for a leftward shift in supply.

Secondly, the effects of changes in the conditions of input supply and retail demand on the marketing margin depend on the curvature of the supply curve for marketing services. If the supply curve for these services is horizontal, the marketing margin remains unchanged in the face of changes in retail demand and in the supply of inputs. As such, the above results are valid for a marketing supply curve that is upward-sloping

The introduction of variable input proportions into the analysis, *ceteris paribus*, seems to have no qualitative impact on the above results. It only bears on the magnitude by which the margin changes following changes in the conditions of retail demand and supply of inputs. For instance, for a leftward farm supply shift, the marketing margin widens when variable input proportions are assumed relative to its level under fixed input proportions but it still narrows relative to its level in original equilibrium.

Changes in the marketing margin and the degree of price transmission which follow an exogenous shock will be discussed in more detail in the forthcoming chapters. But it is important to emphasize that the diagrammatic approach appears to be a useful aid in helping to understand the direction of changes in the marketing margin and the likely impact of these changes on the degree of price transmission.

However, as might have become clear by now, this approach cannot measure accurately marketing margin changes. This accuracy can only be achieved when an algebraic equilibrium framework of the relationship between retail and input prices is established as in the manner of Gardner (1975). This equilibrium framework does not only quantify changes in the margin following disturbances in the different markets but also incorporate fixed and variable input proportions into one framework treating the former as a special case where the elasticity of substitution is zero. In the following chapter therefore we review the theoretical literature to highlight the basic features of this framework. The specific models which attract a particular focus of our review will be Gardner (1975), Wohlgenant (1989) and Wohlgenant and Haidacher (1989).

Chapter 3

The degree of price transmission under perfectly competitive markets: an exposition

3.1 Background

In this chapter, we undertake a detailed exposition of the model of price transmission in perfectly competitive vertically-related markets. We start this exposition with the Gardner model (Gardner, 1975), a model which assumes perfectly competitive input and output markets, identical firms, constant returns to scale and variable input proportions in industry technology. Our exposition of this model is warranted because it is looked upon as a bench-mark in theoretical models of price transmission assuming different market structures. We then present an alternative approach to modelling price transmission that has been provided by Wohlgenant (1989), and Wohlgenant and Haidacher (1989). Whilst it still assumes perfectly competitive output and input markets and variable input proportions, this alternative approach differs from the Gardner model in that it accounts for diverse firms and non-constant returns to scale. Within the framework of this approach, the Gardner model is treated as a special case.

Now consider a vertically-related industry where the upstream market is represented by the suppliers of raw materials, the intermediate market by processors, distributors, packaging agents, etc., and the downstream market by retailers who sell the final product to the consumer. In its simplest form, the production function for this type of industry can be specified using a one-product-two-input model, $x = f(a, b)$, where x denotes the output of the retail sector, a denotes the raw (primary) input, and b denotes the input of intermediaries (i.e., the marketing input).

The underlying notion behind this specification is that of joint demand, where the demand for the final product is considered as a joint demand for all the factors of production (Marshall, *op cit*; Friedman, 1962, chapter 7; Tomek and Robinson, *op. cit*).

In a market structure where all firms involved in the three sectors are perfectly competitive (i.e., there are too many identical firms producing a homogeneous good for any one of them to have the power to set price, there is free entry and exit, and all firms have equal access to information), the price of the final product reflects the cost of the raw input, the cost of marketing inputs and the cost associated with retailing the product (i.e., the marketing margin).

Given this market structure, recalling from the earlier chapter, the marketing margin is defined as the difference between the price of the final product and the price of the raw input. Given this definition of a marketing margin, then, for a given input combination, the degree of price transmission from the raw input to the retail sector is determined by whether the marketing margin is changing at the same time that the price of the raw input is changing. On the other hand, in a market structure where either the retail stage or the raw input supply stage or both are not competitive (could be characterized by monopoly, oligopoly, monopsony or oligopsony), then the marketing margin also contains, apart from the aforementioned, a component which reflects market power (i.e., a mark-up or a mark-down or both). Under these circumstances, the degree of price transmission is determined not only by changes in the marketing margin but also by changes in the mark-up and (or) in the mark-down.

However, regardless of the market structure, the assumptions regarding the production function, i.e., whether the two inputs are combined in fixed or variable proportions and whether the technology exhibits constant, increasing or decreasing returns to scale have a significant effect on the magnitude of changes in the marketing margin and the resultant degree of price transmission.

All these will become clear in the course of our exposition of the various market structures. The most natural way to start this exposition is to consider a perfectly competitive multi-stage model of an industry where the separability of demand for the final product from the derived demand for the raw input makes it possible to analyze the price spread and the elasticity of price transmission. In this respect, the model developed by Gardner (1975), which, for our purposes, will be referred to as the basic model, is the appropriate point of departure.

3.2 The model (Gardner, 1975)

This model describes a perfectly competitive industry which produces a final product (x), using purchased raw input *(a)* and a marketing input *(b)*. For our purposes, we denote a to be a farm input and b to be marketing services. Industry equilibrium is described by the following six equations.

The first equation describes the marketing industry's production (supply) function as:

$$x = f(a, b) \tag{3.1a}$$

The major assumption regarding the production function is that the technology exhibits constant returns to scale such that a scaling of both inputs by an amount $\lambda \geq 0$ results in output changing λ times. The assumption of constant returns to scale derives from the property of homogeneous functions that is well established in microeconomics theory (see for instance, Varian, 1992, chapter 1).

Given a production function with two variable inputs, $f(a, b)$, and a scalar k, we say the function is homogeneous of degree k, if $\forall\ a,b$ and $\lambda > 0$, $f(\lambda a, \lambda b) = \lambda^k f(a, b)$. The function exhibits constant returns to scale when $k = 1$, increasing returns to scale when $k > 1$, and decreasing returns to scale when $k < 1$. The production function which is being considered thus belongs to a class of homogeneous functions with $k = 1$. Given that all firms in the industry are identical and that input prices are kept constant, the assumption of constant returns to scale implies that the industry total cost function is linear in output. This in turn implies that the industry's marginal cost, which is the same for all firms in the industry, is also linear. Given a linear marginal cost, economic theory states that the price of output which the industry faces equals minimum average cost which also equals marginal cost. From this it therefore follows that, given the assumption of constant returns to scale, the industry's supply curve for the final product is horizontal with equilibrium output being determined at the point of intersection between the supply curve and the final output demand curve.

The second assumption concerning the production function is that inputs are combined in variable proportions. This means that the proportion in which the two factors are combined to produce output varies as relative input prices change. Consequently, firms are in a position to substitute the relatively expensive input for the relatively cheap one whenever relative prices change.

The second equation describes the demand function for the retail product as:

$$x = D(P_x, N) \tag{3.1b}$$

where P_x is the retail price of the final product and N is an exogenous demand shifter. It can take many forms, such as population increase, change in income, for example.

Having specified demand and supply equations in the retail market, the model then specifies demand and supply equations in the input market. The demand equations for the two inputs are derived from the profit maximization problem of the firm which can be stated as:

$$\pi = \underset{x}{Max} P_x f(a,b) - P_a a - P_b b \qquad (3.1c)$$

Then the first-order conditions for a maximum are expressed as partial derivatives of the function, f, with respect to a and b respectively as:

$$P_a = P_x f_a \qquad (3.1d)$$

and

$$P_b = P_x f_a \qquad (3.1e)$$

where the subscripts f_a and f_b denote the partial derivatives of x with respect to a and b[1].

Equations $(3.1d)$ and $(3.1e)$ state that profits are maximized when each factor is paid a price equal to the value of its marginal product. Another way of putting this is to say that the price paid each factor is a proportion of the retail price, the proportion being the marginal product of the factor.

The last two equations capture, in inverse form, the input supply functions for a and b respectively as:

$$P_a = g(a,W) \qquad (3.1f)$$

[1]We assume the second order conditions for profit maximization are satisified

and

$$P_b = h(b, T) \tag{3.1g}$$

where W and T are exogenous shifters of the supply functions for a and b respectively. For convenience, W takes the form of weather and T a specific tax respectively.

The system thus contains six equations in six endogenous variables (i.e., x, a, b, P_x, P_a, P_b). For given equilibrium values of these variables, the price spread (i.e., the marketing margin) is measured, in absolute terms, as the difference between P_x and P_a (i.e., $P_x - P_a$).

Having described equilibrium in both input and retail markets, the model then introduces shocks originating in these markets. These shocks arise following changes in either of the exogenous variables, N, W or T. Their effect is to disturb (displace) initial equilibrium levels of output, inputs and prices in all markets. These equilibrium disturbances can be expressed as percentage changes (i.e., as dP_x/P_x, or da/a, for instance). Accordingly, the relative change in the price spread can be expressed as the difference between the percentage changes in P_x (*i.e.,* dP_x/P_x) and in P_a (i.e., dP_a/P_a). The effects of each exogenous shifter on equilibrium levels of output, inputs and prices are analyzed as follows.

3.2.1 Effects of a retail demand shift

First let the demand shifter, N, displace initial equilibrium (i.e., allow for a shift in the retail demand curve). The change in equation $(3.1a)$ can then be expressed, in total differential form, as:

$$dx = f_a da + f_b db \tag{3.2a}$$

For convenience and without loss of generality, multiply the first term on the right-hand side of (3.2a) by $\left(\frac{a}{x} \times \frac{x}{a}\right)$, and the second term by $\left(\frac{b}{x} \times \frac{x}{b}\right)$. Noting from equations (3.1d) and (3.1e) that $f_a = \frac{P_a}{P_x}$; and $f_b = \frac{P_b}{P_x}$, equation (3.2a) can then be re-written as:

$$dx = \frac{P_a}{P_x}\left(\frac{a}{x}\right)\left(\frac{x}{a}\right)da + \left(\frac{P_b}{P_x}\right)\left(\frac{b}{x}\right)\left(\frac{x}{b}\right)db \tag{3.2a'}$$

which, on rearranging, reduces to:

$$dx^* = S_a da^* + S_b db^* \tag{3.2a''}$$

where $dx^* = dx/x$; $da^* = da/a$; $db^* = db/b$. The expressions $S_a = \frac{P_a a}{P_x x}$ and $S_b = \frac{P_b b}{P_x x}$ represent cost shares of the farm input and marketing services respectively.

In a similar fashion, changes in equation (3.1b) can be expressed, in total differential form, as:

$$dx = \frac{\partial x}{\partial P_x} dP_x + \frac{\partial x}{\partial N}\frac{dN}{dN} \tag{3.2b}$$

Multiplying the first term on the right-hand side by $\left(\frac{P_x}{x} \times \frac{x}{P_x}\right)$, and the second term by $\left(\frac{N}{x} \times \frac{x}{N}\right)$, equation (3.2$b$) can be re-written as:

$$dx = \left(\frac{\partial x}{\partial P_x}\right)\left(\frac{P_x}{x}\right)\left(\frac{x}{P_x}\right)dP_x + \left(\frac{\partial x}{\partial N}\right)\left(\frac{N}{x}\right)\left(\frac{x}{N}\right)dN \tag{3.2b'}$$

which, on re-arranging, and on assuming a doubling of the exogenous demand shifter (i.e., $\frac{dN}{N} = 1$) can be written as[2]:

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[2]It is assumed that $\frac{dN}{\mathrm{N}} = dN^* = 1$ implying that the percentage changes in the endogenous

$$dx^* = \eta dP_x^* + \eta_N \tag{3.2b''}$$

where $\eta = \frac{\partial x}{\partial P_x} \times \frac{P_x}{x}$ is the own price elasticity of demand for x and is negative in all normal cases; $\eta_N = \frac{\partial x}{\partial N} \times \frac{N}{x}$ is the elasticity of x to a change in N, which assuming x is a normal good, is positive in all normal cases; and $dP_x^* = dP_x/P_x$.

Expressed in total differential form, the change in equation (3.1d) can be written as:

$$dP_a = dP_x f_a + df_a P_x \tag{3.2c}$$

where $f_a = \frac{P_a}{P_x}$ and $P_x = \frac{P_a}{f_a}$.

As one of the most fundamental postulates of economic theory, Euler's theorem states that given an homogenous production function of degree one, $x = f\,(a, b)$:

$$kx = af_a + bf_b \tag{3.3a}$$

where k=*1*. Given the condition for profit maximization, that firms pay each factor its marginal revenue product (as stated in equations 3.1d and 3.1e), it follows from (3.3a) that a firm with a constant returns to scale production function makes zero profit in the long-run as its revenue is totally exhausted in making payments to all factors[3].

Applying this theorem to $\partial f/\partial a$, therefore one obtains :

$$\frac{\partial}{\partial a}(x) = \frac{\partial}{\partial a}\left(a\frac{\partial f}{\partial a} + b\frac{\partial f}{\partial b}\right) \tag{3.3b}$$

variables are evaluted for a doubling of the demand shifter.

[3]It is worth noting that given that under perfectly competitive markets $f_a = \frac{P_a}{P_x}$ and $f_b = \frac{P_b}{P_x}$ then (3.3a) can be written as $P_x x = P_a a + P_b b$, which on dividing through out by $P_x x$ reduces to $1 = S_a + S_b$

which, on considering that the first partial of a constant returns to scale technology is homogeneous of degree zero (i.e., $k-1=0$ for $k=1$) so that the left-hand side reduces to zero, can be written as:

$$0 = af_{aa} + bf_{ab} \tag{3.3c}$$

or, alternatively, as:

$$f_{aa} = -\frac{b}{a} f_{ab} \tag{3.3d}$$

Equation (3.3d) might be interpreted as stating that the change in the marginal product of a with respect to a is equal to a proportion of the negative of this change with respect to b. Clearly, as more and more of b is employed, then for a given f_{ab}, the change in the marginal product of a with respect to a gets smaller and smaller. On the other hand, for given quantities of a and b, then the change in the marginal product of a with respect to a gets smaller as the change in the marginal product of a with respect to b increases.

On totally differentiating (3.3b), one obtains:

$$df_a = f_{aa}da + f_{ab}db \tag{3.3e}$$

Multiplying the first term of the right-hand side of equation (3.3e) by $\left(\frac{a}{f_a} \times \frac{f_a}{a}\right)$, and the second term by $(\frac{b}{f_a} \times \frac{f_a}{b})$, one then obtains:

$$df_a = f_{aa}\left(\frac{a}{f_a}\right)\left(\frac{f_a}{a}\right)da + f_{ab}\left(\frac{b}{f_a}\right)\left(\frac{f_a}{b}\right)db \tag{3.3f}$$

which, on rearranging, is written as:

$$df_a^* = a\frac{f_{aa}}{f_a}da^* + b\frac{f_{ab}}{f_a}db^* \tag{3.3g}$$

where $df_a^* = \frac{df_a}{f_a}$.

Hicks (1932) shows that the elasticity of substitution, σ, is inversely proportional to the cross second-order partial derivative of the production function exhibiting constant returns to scale and is written as:

$$\sigma = \frac{f_a f_b}{x f_{ab}} \tag{3.4}$$

The expression for σ in (3.4) can be interpreted as stating that as the quantity produced of the final product gets smaller, it gets easier to substitute one input for the other (or *vice versa*) such that the substitution elasticity gets larger.

Making use of equation (3.3d), (3.3g) can be re-written as:

$$df_a^* = -f_{ab}\left(\frac{a}{f_a}\right)\left(\frac{b}{a}\right)da^* + \left(\frac{bf_{ab}}{f_a}\right)db^* \tag{3.3h}$$

Multiplying both terms of the right-hand side of 3.3h by $\left(\frac{f_b}{x} \times \frac{x}{f_b}\right)$, and using (3.4) one can then obtain:

$$df_a^* = -\frac{S_b}{\sigma}da^* + \frac{S_b}{\sigma}db^* \tag{3.3i}$$

where $S_b = \frac{bf_b}{x}$ is the share of b in total output multiplied by f_b since $f_b = \frac{P_b}{P_x}$; and $\frac{1}{\sigma}$ is the inverse of equation (3.4). Now that df_a has been defined in terms of a relative change, equation (3.2c) can be re-written, in a relative change form, as:

$$dP_a^* = dP_x^* - \frac{S_b}{\sigma}da^* + \frac{S_b}{\sigma}db^* \qquad (3.2c')$$

where $dP_a^* = dP_a/P_a$.

Similarly, one can write equation (3.1e), in total differential form, as:

$$dP_b = dP_x f_b + df_b P_x \qquad (3.2d)$$

Using equation (3.3a), Euler's theorem can also be applied to $\partial x/\partial b$ to obtain:

$$\frac{\partial}{\partial b}(x) = \frac{\partial}{\partial b}\left(\frac{\partial f}{\partial a}a + \frac{\partial f}{\partial b}b\right) \qquad (3.5a)$$

which, on considering that the first differential of a constant returns to scale technology is homogeneous of degree zero, so that the left-hand side reduces to zero, can be re-written as:

$$f_{bb} = -\frac{a f_{ba}}{b} \qquad (3.5b)$$

Totally differentiating equation (3.5a), one can then obtain,

$$df_b = f_{ba}da + f_{bb}db \qquad (3.5c)$$

Multiplying the first term of the right-hand side of equation (3.5c) by $\left(\frac{a}{f_b} \times \frac{f_b}{a}\right)$, and the second term by $\left(\frac{b}{f_b} \times \frac{f_b}{b}\right)$, one obtains:

$$df_b = f_{ba}\left(\frac{a}{f_b}\right)\left(\frac{f_b}{a}\right)da + f_{bb}\left(\frac{b}{f_b}\right)\left(\frac{f_b}{b}\right)db \qquad (3.5d)$$

which, on re-arranging, reduces to:

$$df_b^* = f_{ba}\left(\frac{a}{f_b}\right)da^* + f_{bb}\left(\frac{b}{f_b}\right)db^* \qquad (3.5e)$$

Making use of (3.5b), equation (3.5e) can then be written as:

$$df_b^* = f_{ba}\left(\frac{a}{f_b}\right)da^* - f_{ba}\left(\frac{a}{b}\right)\left(\frac{b}{f_b}\right) \qquad (3.5f)$$

And multiplying both terms of the right-hand side of (3.5f) by $\left(\frac{f_a}{x} \times \frac{x}{f_a}\right)$, and using (3.4) one obtains:

$$df_b^* = \frac{S_a}{\sigma}da^* - \frac{S_a}{\sigma}db^* \qquad (3.5g)$$

Finally, adding to equation (3.5g) the relative change in P_x, the relative change in equation (3.2d) can be written as:

$$dP_b^* = dP_x^* + \frac{S_a}{\sigma}da^* - \frac{S_a}{\sigma}db^* \qquad (3.2d')$$

where $S_a = af_a/x$,which is the share of a in total output multiplied by f_a since $f_a = \frac{P_a}{P_x}$; and $dP_b^* = dP_b/P_b$ and da^* and db^*.

The change in equation (3.1f), can be written, in total differential form, as:

$$dP_a = \left(\frac{\partial P_a}{\partial a}\right) da + \left(\frac{\partial P_a}{\partial W}\right) dW \tag{3.2e}$$

Multiplying the first term of (3.2e) by $\left(\frac{P_a}{a} \times \frac{a}{P_a}\right)$ and noting that $dW = 0$ (since $dW = dT = 0$ when $dN > 0$), the relative change in (3.1f) can be written as:

$$dP_a^* = \frac{1}{e_a} da^* \tag{3.2e'}$$

where $e_a = \left(\frac{\partial a}{\partial P_a} \times \frac{P_a}{a}\right)$ is the supply elasticity for the raw input (i.e., for a).

In a similar vein, one can write the change in equation (3.1g), in total differential form, as:

$$dP_b = \left(\frac{\partial P_b}{\partial b}\right) db + \left(\frac{\partial P_b}{\partial T}\right) dT \tag{3.2f}$$

Multiplying the first term of the right-hand side of (3.2f) by $\left(\frac{P_b}{b} \times \frac{b}{P_b}\right)$, and noting that $dT = 0$, the relative change in P_b can be written as:

$$dP_b^* = \frac{1}{e_b} db^* \tag{3.2f}$$

where $e_b = \left(\frac{\partial b}{\partial P_b} \times \frac{P_b}{b}\right)$ is the supply elasticity for the marketing input.

Up to now only the relative changes in the six endogenous variables assuming a change in the demand shifter, N have been derived. Yet, however, the simultaneous changes in the endogenous variables have not been expressed in terms of the elasticity of x to a change in N, η_N. In the following section therefore the relative changes in the endogenous variables are solved for in terms of η_N.

Solving for relative changes in the endogenous variables in terms of η_N

It is quite evident from the above that, the system contains six equations in six endogenous variables $(dx^*, da^*, db^*, dP_x^*, dP_a^*, dP_b^*)$. As it stands now therefore the system is intractable. With the view to making it tractable, the number of equations in each market is reduced to only one and then solved for the endogenous variables in the three markets simultaneously in terms of η_N. To do this, equations ($3.2a''$) and ($2.9b''$) are equated to eliminate x in the product market, ($3.2c'$) and ($3.2e'$) to eliminate P_a from the raw input market, and ($3.2d'$) and ($3.2f'$) to eliminate P_b from the services market.

Doing this generates the following three-equation system:

$$-\eta dP_x^* + S_a da^* + S_b db^* = \eta_N \tag{3.6a}$$

$$dP_x^* - \left(\frac{S_b}{\sigma} + \frac{1}{e_a}\right) da^* + \frac{S_b}{\sigma} db^* = 0 \tag{3.6b}$$

$$dP_x^* + \frac{S_a}{\sigma} da^* - \left(\frac{S_a}{\sigma} + \frac{1}{e_b}\right) db^* = 0 \tag{3.6c}$$

where equation ($3.6a$) describes equilibrium adjustment in the market for x, ($3.6b$) in the market for a and ($3.6c$) in the market for b.

Solving the system of equations ($3.6a$)-($3.6c$) for da^*, db^* and dP_x^* using Cramer's rule, the following reduced-form equations for the relative changes in the six endogenous variables are obtained and expressed in terms of η_N[4]. For the purposes at hand, however,

[4] Muth (1964) has also solved this system of equations assuming simultaneous changes in the exogenous variables. See also Alston and Scobie (1983), who solve this system of equations when the shock comes from the marketing sector.

only relative changes for retail output and farm input prices are presented. They are given by:

$$dP_x^* = \frac{\eta_N \left(S_b e_a + S_a e_b + \sigma\right)}{D} \tag{3.7a'}$$

$$dP_a^* = \frac{\eta_N \left(e_b + \sigma\right)}{D} \tag{3.7b'}$$

where the denominator, $D = -\eta \left(S_b e_a + S_a e_b + \sigma\right) + e_a e_b + \sigma \left(S_a e_a + S_b e_b\right)$ is in all normal cases positive since $\eta < 0$ while all other parameters are non-negative. Equations $(3.7a')$ and $(3.7b')$ are identical to Gardner's equations A.1 and A.2 respectively.

A retail demand shift and movements in the price spread

In the preceding section, the system has been solved for dP_x^* and dP_a^*. The percentage change in the price spread can now be expressed as:

$$dP_x^* - dP_a^* \mid_{dN} = \frac{\eta_N S_b \left(e_a - e_b\right)}{D} \tag{3.8}$$

which is identical to Gardner's equation A.5.

As has been pointed out, the denominator D is positive in all normal cases. The sign of equation (3.8) is therefore determined by the numerator. In fact, as η_N and S_b are positive, the sign is solely determined by the relative sizes of the price elasticities e_a and e_b.

Based on equation (3.8), the predictions of the model regarding movements in the price spread in the face of a retail demand shift are thus that the spread remains unchanged when $e_a = e_b$; falls when $e_a < e_b$; and rises when $e_a > e_b$.

The fact that the spread remains unchanged when $e_a = e_b$ follows from the fact that the retail demand shift results in proportionate changes in P_a and P_b which in turn translate into an equally proportionate change in P_x.

Considering a rightward shift in retail demand, the intuition for the price spread falling given that $e_a < e_b$, can be explained with reference to an industry which produces food using a farm product, a and marketing services, b. Because the farm product, a, is land-intensive and a specific factor to the food industry while the components of the marketing input, b, are not, it follows that, in the short-run, the supply of a cannot be increased readily in response to a demand shift while that of b can. As a result, for a small σ, the increase in P_a is much more than that in P_b, i.e., $\frac{dP_a}{dP_b} > 1$. And since the cost share of b in total retail value is relatively smaller, the increase in P_x is smaller than that in P_a. Hence, the narrowing of the price spread in percentage terms.

Again, considering the case of the food industry, the intuitive explanation for the price spread rising in the face of a rightward shift in retail demand given that $e_a > e_b$ is as follows. If $e_a > e_b$, a given increase in retail demand pulls up P_b more than P_a, increasing the relative cost of b in the retail good. As the compounding effect is to increase P_x, by much more than the increase in P_a, the price spread increases.

It is worthy of note here that these outcomes clearly depend on the magnitude of the elasticity of substitution, σ. To illustrate this point, let $e_a < e_b$. If the two inputs, a and b are assumed highly substitutable to each other, a relative increase in P_a owing to a rightward shift in demand will induce substitution of a for b thus moderating the initial price increase in P_a. Hence, the greater σ is, the less the price spread changes. In the extreme case where $\sigma \longrightarrow \infty$, which implies perfect substitutability of the two inputs, equation (3.8) approaches zero, such that the price spread remains unchanged as demand shifts. On the contrary, as $\sigma \longrightarrow 0$, which represents the case of fixed input proportions, the maximum change in price spread is achieved.

Having analyzed the effects of a retail demand shift on changes in the levels of final output, inputs, prices and the price spread, the model then analyses the effects of a raw (farm) input supply shift on changes in these variables in a similar way.

3.2.2 Effects of a farm supply shift

Analysis of the effects of a farm supply shift brought about by a change in W proceeds in the same way as that of the effects of a retail demand shift. The only modification needed here is to set equation (3.6b) to e_W and equations (3.6a) and (3.6c) to zero. This is done because N and T are assumed to remain constant when W changes. The term $e_W = \left(\frac{\partial P_a}{\partial W} \times \frac{W}{P_a}\right)$ denotes the percentage change in P_a in response to a percentage change in W, which, when evaluated for a shock is always positive. It is derived by multiplying the second term of the right-hand side of equation (3.2e) by $\left(\frac{P_a}{W} \times \frac{W}{P_a}\right)$.

With this modification, equations (3.6a)-(3.6c) are re-written as:

$$-\eta dP_x^* + S_a da^* + S_b db^* = 0 \tag{3.9a}$$

$$dP_x^* - \left(\frac{S_b}{\sigma} + \frac{1}{e_a}\right) da^* + \frac{S_b}{\sigma} db^* = e_W \tag{3.9b}$$

$$dP_x^* + \frac{S_a}{\sigma} da^* - \left(\frac{S_a}{\sigma} + \frac{1}{e_b}\right) db^* = 0 \tag{3.9c}$$

where equation (3.9a) describes equilibrium adjustment in the market for x,(3.9b) in the market for a and (3.9c) in the market for b.

Solving for relative changes in the endogenous variables in terms of e_W

Solving the system of equations (3.9a)-(3.9c) using Cramer's rule yields the reduced-form equations for relative changes in the six endogenous variables, expressed, in terms of e_W.

Again, for the purposes at hand, only reduced-form equations for prices of the retail product and the farm input are presented. These are given respectively by:

$$dP_x^* = \frac{e_W e_a S_a (e_b + \sigma)}{D} \tag{3.10a}$$

and

$$dP_a^* = \frac{e_W e_a (e_b + S_a \sigma - S_b \eta)}{D} \tag{3.10b}$$

They are identical to Gardner's identities A.6 and A.7 respectively.

A farm supply shift and movements in the price spread

For given values of dP_x^* and dP_a^*, the percentage change in the price spread following a shift in the inverse supply function for a are then expressed as:

$$dP_x^* - dP_a^* \mid_{dW} = \frac{e_W e_a S_b (\eta - e_b)}{D} \tag{3.11}$$

which is identical to Gardner's A.9.

As previously pointed out, the denominator, D, is positive in all normal cases. Therefore, equation (3.11) is negative in all normal cases because e_W is positive and η is negative, and e_a and e_b are non-negative. This means that the spread will narrow as P_a increases subsequent to a leftward shift in the supply of the raw input. The converse of this is that the price spread will widen when there is an exogenous shock that reduces P_a by increasing a.

The economic reasoning for this is that despite both P_x and P_a falling as a increases, for a large σ, the increase in x requires that additional marketing inputs be employed.

Assuming a less perfectly elastic e_b (*i.e*, $0 \leq e_b \leq \infty$) this leads, in the short-run, to an increase in P_b, and, consequently, for a given b, to an increase in S_b. Thus, the initial fall in P_x is made up for by the increase in P_b. This therefore leads to the widening of the price spread. Here too, the outcome for equation (3.11) hinges on the value of σ with a larger magnitude dampening the effect of the shift on the price spread and *vice versa.*

3.2.3 Effects of a marketing supply shift

Finally, the model analyses the effects of a shift in the inverse supply function for b by setting equations (3.9a) and (3.9b) to zero while setting equation (3.9c) to e_T where $e_T = \left(\frac{\partial P_b}{\partial T} \times \frac{T}{b}\right)$ denotes the percentage change in P_b in response to a percentage change in the exogenous variable, T. This follows from the assumption that $dN = dW = 0$ when T changes. It is derived by multiplying the second term of the right-hand side of equation (3.2f) by $\left(\frac{P_b}{T} \times \frac{T}{P_b}\right)$.

Modifying equations (3.9a)-(3.9c) thus, the following three-equation system is obtained.

$$-\eta dP_x^* + S_a da^* + S_b db^* = 0 \tag{3.12a}$$

$$dP_x^* - \left(\frac{S_b}{\sigma} + \frac{1}{e_a}\right) da^* + \frac{S_b}{\sigma} db^* = 0 \tag{3.12b}$$

$$dP_x^* + \frac{S_a}{\sigma} da^* - \left(\frac{S_a}{\sigma} + \frac{1}{e_b}\right) db^* = e_T \tag{3.12c}$$

where equations (3.12a)-(3.12c) describe equilibrium adjustment in the markets for x, for a and for b respectively.

Solving for relative changes in the endogenous variables in terms of $\mathbf{e_T}$

Solving the system using Cramer's rule, the reduced-form equations for the six endogenous variables are derived and expressed in terms of e_T. But only reduced-form equations for the prices of the retail product and for the marketing input are presented here. These are given by:

$$dP_x^* = \frac{e_T S_b e_b (\sigma + e_a)}{D} \tag{3.13a}$$

and

$$dP_a^* = \frac{e_T S_b e_b (\eta + \sigma)}{D} \tag{3.13b}$$

A marketing supply shift and movements in the price spread

With values of dP_x^* and dP_a^* determined, the percentage change in the price spread following a percentage change in the exogenous variable, T, is expressed as:

$$dP_x^* - dP_a^* \mid_{dT} = \frac{e_T S_b e_b (e_a - \eta)}{D} \tag{3.14}$$

Given that D is positive, and so are all terms in the numerator except for η which is negative, the price spread in equation (3.14) is positive in all normal cases. This implies that a marketing shock, T , which leads to an increase in P_b, results in a widening of the price spread. This result follows because the increase in P_b is reflected partly by an increase in P_x , and, partly by a decrease in P_a. For a small σ, the intuition is that as P_b increases the demand for marketing services falls, and, so does the demand for the primary input. The latter results in a decrease in P_a.

Due to the aggregation problem, however, it is likely that the change in the exogenous shock, T will affect some marketing components more strongly than others. This means that the relative prices of these particular types will increase more substantially than those of others. This points to the need for disaggregating the marketing components into those whose relative prices change more substantially and into those whose relative prices change little following changes in T. As this complicates the analysis, however, the model is kept to its simplest form with all marketing inputs aggregated.

3.2.4 The elasticity of price transmission

The elasticity of price transmission, τ, is defined, in this particular context, as the percentage change in P_x which results from a percentage change in the price of the farm input, P_a[5]. Algebraically, it is defined as:

$$\tau^{PC} = \frac{dP_x^*}{dP_a^*} \tag{3.15}$$

where the superscript, PC, denotes perfect competition.

Just as dP_x^* and dP_a^* take on different values for each of the exogenous shifts so far considered, so does τ assume different values for each of such shifts. The elasticities of price transmission from the farm input to the retail sector in the face of exogenous shifts originating in the retail, farm and marketing sectors respectively are therefore expressed as:

$$\tau^{PC} \mid_{dN} = \frac{S_b e_a + S_a e_b + \sigma}{e_b + \sigma} \tag{3.16a}$$

[5]Please note this definition does not necessarily hold in the face of a retail demand shift whereby one talks in terms of a pass back elasticity (McCorriston, et al., 1999). However, this notion is not present in Gardner.

$$\tau^{PC}\mid_{dW} = \frac{S_a\left(\sigma + e_b\right)}{e_b + S_a\sigma - S_b\eta} \tag{3.16b}$$

and

$$\tau^{PC}\mid_{dT} = \frac{\left(\sigma + e_a\right)}{\left(\eta + \sigma\right)} \tag{3.16c}$$

where *3.16a* and *3.16b* are identical to Gardner's A.10 and A.11.

As equation (3.16a) clearly shows, when the exogenous shock originates in the retail sector, the elasticity of price transmission is determined by the relative cost shares, by the elasticities of farm and marketing inputs and by the elasticity of substitution. Assuming all other parameters are kept constant, the elasticity of price transmission takes on the value of unity for $e_a = e_b$. This is because the increase in retail demand increases the demand for the two inputs. And, since they are equally elastic to shifts in demand, their prices increase proportionately. This being the case, a percentage increase in P_a is fully reflected as a percentage increase in P_x. Another special case of the elasticity becoming unity arises when $S_a = 1$. When this holds, the marketing margin remains unchanged as P_a increases.

For $e_a < e_b$, a percentage increase in P_a is less than fully reflected in the change in P_x because P_b doesn't increase by as much as P_a does because the supply of b can be more readily increased with a modest increase in its price. As a result, P_x increases by an amount which is less than the increase in P_a. This implies that the marketing margin narrows as P_a changes.

For $e_a > e_b$, a price transmission elasticity of more than unity obtains. This is because P_b increases by much more than P_a does because supply of b is relatively less flexible. Therefore, the initial increase in P_a is reinforced by that in P_b. In other words, the marketing margin widens at the same time that P_a increases. Hence, a case of $dP_x^*/dP_a^* > 1$. But this scenario is very unlikely to occur in an industry where the farm input is assumed to be specific to the industry, and, consequently, more rigid in its response to a retail demand shift, and, hence less price elastic than the marketing input.

When the exogenous shock originates in the supply of the farm input, τ is less than unity in all normal cases, as equation (3.16b) clearly indicates. For a given fall in the supply of the farm input, this means that the increase in P_a is less than fully reflected in the change in P_x. This also means that the marketing margin narrows as P_a increases. The intuition is that relative to the farm input, the marketing input becomes cheaper so that P_x cannot rise by as much as P_a does. The only special case for which τ in (3.16b) takes on the value of unity is when the cost share of the farm input, $S_a = 1$ in which case the marketing margin remains unchanged. This in itself is a special case of P_x increasing in proportion to the share of the farm input, S_a, i.e., $\tau = S_a$. This is called a long-run, non-specific factor case, and obtains when e_b is perfectly elastic..

When the exogenous shock originates in the marketing sector, the elasticity of price transmission is not well defined as it takes different values according to whether $\sigma < \eta$ or $\sigma > \eta$ or $\sigma = \eta$. As is clearly indicated in equation (3.16c), for $\sigma < \eta$, the elasticity of price transmission is less than zero. This outcome can be generalized to a case of fixed input proportions for which $\sigma = 0$. This can be interpreted as stating that a change in a marketing shock results in P_x and P_a moving in opposite directions. The economic reasoning goes as follows. The increase in P_b induces a fall in demand for marketing services and assuming a relatively less elastic e_a and a very small σ, a fall in demand for the farm input, that reflects a fall in demand for marketing services, induces a fall in P_a. Yet P_x rises to make up for the rise in P_b. The upshot of this is that the marketing margin widens at the same time that P_a decreases.

For $\sigma > \eta$, the price transmission elasticity is not only positive in the face of a marketing shock but also greater than unity. Intuitively, this means that as P_b increases following the marketing shock, any shift towards the use of more farm input leads to an increase in P_a assuming a large σ. Consequently, both P_a and P_b compound each other to lead to an increase in P_x. Consequently, the marketing margin widens.

As can be noted for $\sigma = \eta$, the elasticity of price transmission is not defined because the denominator in equation (3.16c) is zero. In this case, the marketing margin is not defined. But in no case can the transmission elasticity in (3.16c) take on the value of unity.

Thus far, a cursory look into equations (3.16a)-(3.16c) seems to hint at the importance of σ, η,e_a, S_a, and e_b in determining the sign and magnitude of the elasticity of price transmission for a given source of an exogenous shock. Let's now examine the role of each parameter in detail through comparative statics which we undertake in the following sub-section.

3.2.5 Comparative statics

To test for the sensitivity of the elasticity of price transmission to changes in any one of the determining parameters, comparative statics can be run by differentiating τ with respect to each determining parameter. In anticipation of a model of price transmission assuming market power in the retail sector, which we will expound in the next chapter, consider (3.16b) which describes the elasticity of price transmission assuming a supply shock originating in the raw input sector.

First consider the sensitivity of τ to S_a and one obtains:

$$\frac{\partial \tau}{\partial S_a} = \frac{(\sigma + e_b)(e_b - S_b\eta)}{(e_b + S_a\sigma - S_b\eta)^2} > 0 \qquad (3.17a)$$

Clearly, (3.17a) is in all circumstances positive since $\eta < 0$ which is to be expected. As S_a increases, so does the degree of price transmission. In fact, as has been shown with reference to equation (3.16b), for a perfectly elastic e_b, τ =S_a such that for $S_a = 1$, τ takes on the value of unity.

Next consider the sensitivity of τ to e_b; and one obtains:

$$\frac{\partial \tau}{\partial e_b} = \frac{-S_a S_b\,(\sigma + \eta)}{\left(e_b + S_a\sigma - S_b\eta\right)^2} >=< 0 \tag{3.17b}$$

It can be seen that the comparative static result for (3.17b) is not well defined as the value it takes depends on the relative magnitudes of σ and η such that for $\sigma = \eta$, $\partial\tau/\partial e_b = 0$; for $\sigma < \eta$, $\partial\tau/\partial e_b > 0$; and for $\sigma > \eta$, $\partial\tau/\partial e_b < 0$.

The following explanation is provided for the ambiguity of this result. Firstly, if, relative to e_a, e_b increases, then an increase in demand for marketing services, following an increase in P_a, can be accommodated with a fall in P_b if $\sigma > \eta$. This leads to a decrease in the degree of price transmission. Normally, this applies when economies of scale operate in the supply of marketing services. Secondly, if, relative to e_a, e_b increases, then an increase in demand for marketing services resulting from an increase in P_a can only be accommodated with an increase in P_b if $\sigma < \eta$. This compounds the initial increase in P_a and thereby leads to an increase in the degree of price transmission. Finally, if, e_b increases relative to e_a, then no price transmission occurs as P_a increases if $\sigma = \eta$.

Now consider the sensitivity of τ with respect to σ; one obtains,

$$\frac{\partial \tau^{PC}}{\partial \sigma} = \frac{S_a S_b(e_b - \eta)}{\left(e_b + S_a\sigma - S_b\eta\right)^2} > 0 \tag{3.17c}$$

As (3.17c) shows, the comparative static result is always positive since $\eta < 0$.

The intuition goes as follows. Assume P_a increases, then, for a large σ, processors use more marketing services which have become relatively cheaper. But in the long term, this will raise the price of marketing services and thereby compound the initial increase in P_a. Consequently, the degree of price transmission from the farm input market to the retail market will be greater than when a small σ is considered.

Finally, consider the sensitivity of τ to η; one obtains,

$$\frac{\partial \tau}{\partial \eta} = \frac{-S_a S_b (\sigma + e_b)}{(e_b + S_a\sigma - S_b\eta)^2} < 0. \tag{3.17d}$$

The intuition is that as retail demand becomes more elastic, retailers are limited in the extent to which they can increase P_x to match the increase in P_a and *vice versa.*

3.2.6 Perfect price transmission: a note

The concept of perfect price transmission has been in wide use since its coinage by Colman (1985) in relation to the transmission of policy prices. Perfect price transmission in this context is defined as a degree of price transmission "where a change in a policy regulated price, such as intervention or minimum import price, causes an equal change in the farm-gate price" (p.172).

In an empirical context of vertically related markets in seven countries in the European Union, Palaskas (1995) defines perfect price transmission as occurring when the long-run co-integrating coefficient is unity. In this context, a coefficient with a value of unity implies that a 1% increase in the price of the farm input leads to a 1% increase in retail price given that prices are expressed in logarithms. Asche et al. (2001) take a similar view of perfect price transmission and defines it as occurring when the cost share of the farm input, S_a in total industry output value is unity. As shown above, when $S_a = 1$, $\tau = 1$.

In a theoretical context of vertically-related markets and assuming a farm input supply shock, McCorriston *et al.*. (1998) define perfect price transmission as occurring when the transmission elasticity, τ, equals the share of the farm input (S_a). Thus, their definition generalizes to different values of S_a of which a unit value is a special case. In their context, perfect price transmission implies that a 1% increase in the price of the farm input increases retail price S_a times.

It is now worth asking whether the theoretical model of price transmission under perfectly competitive markets, as expounded in the foregoing, always predicts perfect price transmission as defined in a vertical market context.

It appears that the definition given by Palaskas is admitted by the model in very few special cases which arise under highly restrictive assumptions. The first case arises when the supply elasticities for marketing and farm inputs are equal given a retail demand shock. The second case supporting a unit transmission elasticity arises when, for a retail demand or farm input supply shock, the cost share of the farm input is unity.

It also appears that the definition given by McCorriston *et al.*. is supported by the model in a very special case. For a given farm supply shock, or a retail demand shock, this arises when an industry faces a perfectly elastic marketing supply. This obtains when an industry operates in the very long-run whereby a long-run non-specific factor case arises.

For a given exogenous shock arising in the marketing sector, however, under no circumstances does perfect price transmission of any sort arise. Referring back to equation $(3.16c)$, this is because, in all normal cases, η is negative whereas σ and e_a are non-negative.

To re-cap, in price transmission discourses in vertically related markets, there seem to exist two major contexts in which perfect price transmission is believed to occur. Both consider the cost share of the farm input central to this occurrence. While Asche defines perfect price transmission as occurring when $S_a = 1$, which is another way of saying $\tau = 1$, McCorriston *et al.*. define perfect transmission as occurring when the transmission elasticity is equal to S_a, i.e., $\tau = S_a$. As such, the former definition can be considered as a special case of the latter. Evaluating the definition given by Palaskas on counts of the definition given by McCorriston *et al.*., there seems to be no ground for believing that a long-run co-integrating coefficient of unity always signifies perfect price transmission. To take an example, for a given raw input supply shock, let $S_a = 0.1$. In this case, $\tau = 1$ doesn't mean anything special while $\tau = 0.1$ does.

The theoretical model as presented in the foregoing admits perfect price transmission as a special case arising under highly restrictive assumptions rather than as a general case. In fact, for a given exogenous shock that originates in the marketing sector, perfect price transmission does not occur under any conditions.

Given the different definitions that are in use in the literature, a meaningful approach will be to define perfect price transmission as the degree of price transmission which occurs under perfectly competitive markets against which degrees of price transmission that obtain in all other markets are then compared.

3.3 An alternative approach

As has been made clear at the beginning of the chapter, the predictions of the Gardner model rest on the assumption that the industry operates with constant returns to scale implying that the industry supply curve is horizontal. This derives from the assumption that each firm in the industry is identical in size to every other and is too small to have any impact on industry price. In other words, all firms in the industry are assumed to be marginal.

Wohlgenant and Haidacher (WH, 1989) and Wohlgenant (W, 1989) show that, given a perfectly competitive market where inputs are combined in variable proportions, relaxing the assumption of identical (marginal) firms makes the assumptions of constant returns to scale and horizontal industry supply curve redundant. They show this by assuming that firms in the industry have diverse production functions such that some are infra-marginal and others are marginal. Obviously, the assumption of firm diversity results in a less than perfectly elastic final product industry supply curve.

Implicit in the perfectly competitive model with identical firms is the assumption that the relationship between the price of an input and quantity demanded of it is negative implying that the input in question is normal, i.e. an increase in its price reduces its demand. If, however, the industry's firms are diverse, then an input is treated as normal by some firms and as inferior by others with the implication that whether an input is considered normal or inferior to industry production is determined by the weighted sums of demand elasticities for individual firms. Theory states that an increase in the price of an inferior input raises a firm's average costs, but reduces its marginal costs. Given the assumption of identical firms in industry, then it follows that higher long run average costs drive firms from the industry, reduce industry output and consequently put an upward pressure on market price of output. But given the assumption of diverse firms, an increase in long-run average cost does not necessarily lead to reduced output and to higher consumer price.

To see this clearly, take an example provided by Reed and Clarke (2000). Assume there are two groups of firms in a competitive industry. The first contains infra-marginal firms which enjoy a cost advantage so that they can remain in the industry even if the long run average cost of other firms lies above market price. The second group contains marginal firms which do not possess this cost advantage so that when the long run average cost lies above market price they exit the industry. Given this composition of firms, say the price of an input which is inferior to the infra-marginal firms increases. Because of their cost advantage, these firms increase the supply of their output in the long run despite the increase in the price of the inferior input. This puts a downward pressure on the price of the industry output. Now consider the price of an input which is inferior to marginal firms increases; then their long run average cost increases to a level above output price in which case they exit the industry thus reducing industry supply and putting an upward pressure on market price of output. .

To illustrate their point, WH and W first set up a structural model which is expressed in terms of a two-equation system as:

$$\sum S_r^i(P_r, P_f, W) - D_r(P_r, Z) = 0 \tag{3.18a}$$

$$Q_f - \sum D_f^i(P_r, P_f, W) = 0 \tag{3.18b}$$

where S_r^i is the supply of the ith firm in the industry; P_r, P_f, and W are prices of the retail, farm and marketing inputs respectively; D_r is the industry retail demand Z is the retail demand shifter whereas Q_f and D_f^i represent the quantity supplied of the farm input and the quantity demanded of the farm input by the ith firm respectively. This two-equation system derives from a far bigger system which contains endogenous retail demand, retail supply and farm-level demand equations, a predetermined farm-level supply equation, an exogenous (a perfectly elastic) marketing supply equation, and retail and farm level market clearing equations.

The assumptions underlying equations (3.18a) and (3.18b) are that consumer demand is homogeneous of degree zero in retail price and income and that output supply and input demand are homogeneous of degree zero in farm and non-farm inputs.

Assuming a consumer demand shift, they next totally differentiate (*3.18a*) and (3.18b) to obtain the following eight structural elasticities,

$$(\xi_{rr} - e)\,.d\ln P_r + \xi_{rf}.d\ln P_f = e_z.d\ln Z - \xi_{rw}.d\ln W \tag{3.19a}$$

$$\xi_{fr}.d\ln P_r - \xi_{ff}.d\ln P_f = \xi_{fw}.d\ln W - d\ln Q_f \tag{3.19b}$$

where ξ_{rr} is the elasticity of retail supply with respect to retail price, e is the elasticity of retail demand with respect to retail price, ξ_{rf} is the elasticity of retail supply with respect to farm price, e_z is the elasticity of retail demand with respect to Z, ξ_{rw} is the elasticity of retail supply with respect to W, ξ_{fr} is the elasticity of farm-level demand with respect to retail price, ξ_{ff} is the elasticity of farm-level demand with respect to farm price, and ξ_{fw} is the elasticity of farm-level demand with respect to W. It is important to note here that the elasticities of aggregate retail supply and aggregate farm-level demand are defined as quantity-share-weighted sums of the respective elasticities of supply and demand for individual firms.

The key to their model is the assumption that the symmetry restrictions at the firm level hold at the industry level as well. These restrictions are: (1) that the change in output supply resulting from a change in price of an input equals the negative of the effect of a change in output price on demand for the input in question; and (2) that the change in demand for one input resulting from a change in price of another input equals the change in demand for the other input resulting from a change in price of the first input.

At the firm level, the first symmetry restriction implies that

$$\frac{\partial x_r^i}{\partial P_f} = -\frac{\partial D_f^i}{\partial P_r} \tag{3.20}$$

which, when summed over all firms, and with further manipulation, can be expressed, in elasticity form, as:

$$\xi_{rf} = -S_f \xi_{fr} \tag{3.20a}$$

where $S_f = P_f Q_f / P_r Q_r$.

The next step in the model involves specifying the following reduced form equations

$$P_r = P_r(Z, W, Q_f) \tag{3.21a}$$

$$P_f = P_f(Z, W, Q_f) \tag{3.21b}$$

Equations (3.19a) and (3.19b) are then used to describe the comparative statics of (3.21a) and (3.21b), in elasticity form, as:

$$d \ln P_r = A_{rz}.d \ln Z + A_{rw}.d \ln W + A_{rf}.d \ln Q_f \tag{3.22a}$$

$$d \ln P_f = A_{fz}.d \ln Z + A_{fw}.d \ln W + A_{ff}.d \ln Q_f \tag{3.22b}$$

where A_{rz} is the long run own price elasticity of industry supply; A_{rw} is the long run elasticity of industry supply to the marketing input price; A_{rf} is the long run elasticity of industry supply to the farm input price; A_{fz} is the elasticity of industry demand for the farm input to shifts in consumer demand; A_{fw} is the elasticity of industry demand for farm input to the price of the marketing input; and, finally, A_{ff} is the own price elasticity of industry demand for the farm input. Theory suggests that in all normal cases, A_{rf} and A_{ff} are negatively signed whereas A_{rz} and A_{fz} are positively signed. On the other hand, A_{rw} and A_{fw} cannot be signed *a priori* for the aforementioned reasons.

They show that given the symmetry restriction in (3.20a)

$$A_{rf} = -S_f A_{fz} \tag{3.23}$$

This condition requires that firms take farm and consumer prices as given (i.e., they are competitive) and that when they do so the response of consumer and farm-level prices is symmetric.

Given the above specifications they then state the conditions under which the industry's production function exhibits constant returns to scale. They show that the production function of the industry exhibits constant returns to scale when the following conditions hold.

$$A_{rz} = -A_{rf} \tag{3.24a}$$

$$A_{fz} = -A_{ff} \tag{3.24b}$$

The most important prediction of their model is that, given diverse firms, constant returns to scale arises as a special case rather than in general. But when it obtains, the implication is that the industry gets zero profit in the long run. This is because, given constant returns to scale, changes in retail demand and quantity of the farm output are proportionate thus leaving both retail and farm input prices unchanged. The corollary is that constant returns to scale implies a horizontal retail supply curve.

It is thus clear that the Gardner model assuming identical firms is a special case of the model of a perfectly competitive industry with diverse firms which operates with constant returns to scale. The implication is that if the assumption of diverse firms results in non-constant returns to scale, then it follows that the predictions of the Gardner model do not hold. In the next chapter, we will review the relevant models which analyze the effects of non-constant returns to scale in production technology on the predictions of the Gardner model.

But before concluding our review of the model of perfectly competitive markets with diverse firms, it is important to discuss its predictions regarding the elasticity of price transmission. In the context of diverse firms, it is defined as:

$$n = A_{rf}/A_{ff} \tag{3.25}$$

If the assumptions of a perfectly competitive industry and constant returns to scale are held, then by virtue of (3.23) and (3.24*b*) and taking note of the assumption of perfectly elastic marketing supply, estimates of this elasticity reduce to the cost share of the farm input, S_a. In the absence of a constant returns to scale assumption, however, a different estimate of the elasticity is obtained. It is interesting to note that, for a given retail demand shock, the Gardner model yields a price transmission elasticity equal to S_a only when the long run supply of the marketing input is perfectly elastic. This is not surprising because while in the perfectly competitive model with diverse firms, a perfectly elastic marketing supply is assumed, in the Gardner model this is not assumed.

3.4 Summary and evaluation

This chapter has made an exposition and discussed the major predictions of the model of price transmission assuming all stages in a vertically related industry are perfectly competitive, that the industry operates with constant returns to scale, and that production inputs are combined in variable proportions. Three major predictions appear to come out from this analysis and are summarized as follows.

Firstly, the degree of price transmission from the farm to the retail sector, as measured by the elasticity of price transmission, is determined as much by where the exogenous shock originates as it is by such structural parameters as demand and input supply elasticities, input cost shares and the elasticity of substitution.

Given an exogenous shock originating in the retail sector, the elasticity of price transmission is equal to unity either when the supply elasticities for both inputs are equal or the share of the farm input is equal to unity implying that the marketing margin remains unchanged in the face of such an exogenous shock. Given such a shock, the elasticity of price transmission is less than unity when the farm input supply elasticity is less than the marketing supply elasticity implying the marketing margin narrows as the farm input price increases. When the farm input supply elasticity is greater than the marketing supply elasticity, the price transmission elasticity is greater than unity implying that the marketing margin widens at the same time that the farm input price increases.

Given an exogenous shock originating in the farm sector, the price transmission elasticity is less than unity in all normal circumstances implying that the marketing margin narrows at the same time that the farm input price increases. When the share of the farm input is unity, however, the price transmission elasticity is equal to unity given this shock.

Given an exogenous shock originating in the marketing sector, the price transmission elasticity is greater than unity when the substitution elasticity is greater than the retail demand elasticity. It is negative when the substitution elasticity is smaller than the retail demand elasticity. On the other hand, it is undefined for a substitution elasticity equal to the retail demand elasticity. This occurs despite the fact that the marketing margin always widens at the same time that the farm input price falls implying retail price increases following an increase in the price of the marketing input.

Secondly, the relative significance of each of the parameters which determine the degree of price transmission varies. For a given exogenous shock originating in the farm sector, the substitution elasticity and the farm input cost share impact on the degree of price transmission positively while the elasticity of market demand impacts negatively. However, for such a shock, the marketing elasticity's impact is ambiguous, dependent as it is on the relative magnitudes of σ and η.

Finally, perfect price transmission, defined as a percentage change in farm input price translating into a percentage change in retail price or into a percentage change in retail price which is equal to the share of the farm input, is an exception rather than a rule, arising as it is under highly restrictive assumptions.

The overriding implication of these conclusions is that, given a perfectly competitive industry, and for a given exogenous shock, one is unlikely to be able to make robust predictions regarding the marketing margin and the degree of price transmission unless there is information on many parameters (i.e., the supply elasticities for both inputs, the substitution elasticity, the retail demand elasticity, and the input cost shares). This implication follows because the outcomes for the marketing margin and the degree of price transmission are dependent on the interactions between these parameters.

In this review we have shown that the model of vertical price transmission assuming perfectly competitive markets, constant returns to scale and variable input proportions is a potent model in that it provides considerable insight into the movements of margin behavior and the degree of price transmission in these markets. Despite its potency to predict margin behavior and the degree of price transmission resulting from an exogenous shock, nevertheless, the model's predictions are limited in their generality. This is because the assumptions of perfectly competitive markets, constant returns to scale technology and identical firms on which the model rests are highly restrictive. On relaxing each of these assumptions, however, totally different predictions hold about movements in the price spread and the degree of price transmission. For instance, as has been shown towards the end of the chapter, assuming diverse firms in a perfectly competitive industry operating with variable input proportions can make the assumption of constant returns to scale redundant and thereby affect the predictions of the model of price transmission in a perfectly competitive market with identical firms. In the next chapter, we explore the effects, on the model's predictions regarding the degree of price transmission, of relaxing the assumptions of perfect competition in the retail sector and of constant returns to scale in technology while keeping the assumptions that all firms in the industry are identical and that the input markets are perfectly competitive.

Chapter 4

The degree of price transmission under the assumption of market power and non-constant returns to scale: an exposition

4.1 Background

In the preceding chapter, we have reviewed and evaluated the literature which analyses the degree of price transmission in vertically-related markets assuming that all the stages in the industry are perfectly competitive, that the industry in question is made up of infinite number of identical firms, and that the industry operates with constant returns to scale. Given these assumptions, the model has been shown to predict that the degree of price transmission from the farm to the retail sector is determined by where, in the vertical chain, the exogenous shock originates and by the relative magnitudes of parameters that determine the elasticity of price transmission. And finally, it has been shown to predict that perfect price transmission is a special case that arises under highly restrictive assumptions rather in general.

This chapter sets out to illustrate the implications of relaxing the assumption of perfect competition in all stages of the vertical market and of constant returns to scale in industry technology while still keeping the assumption of identical firms in the industry. To this end, it first reviews the relevant literature which analyses price transmission assuming market power in the retail sector with all the input markets kept still perfectly competitive. It then reviews the literature which analyses price transmission assuming not only market power in the retail sector but also non-constant returns to scale in industry technology. It finally evaluates whether the predictions of the perfectly competitive market with identical firms are borne out when the assumptions of market power in the retail stage and of non-constant returns to scale in industry technology are introduced.

4.2 Market power: a definition

Before embarking on the review of the literature relating to price transmission in the presence of market power in the retail sector, it is important to first define market power and show its derivation. Market power means that a firm can change market price in order to influence the quantity of output which it sells in a particular market (Tirole, 1992, p. 219). This stands in contrast with the assumption of perfect competition where a firm has no influence over market price. Traditionally, market power has been modelled in the context of a quantity-setting conjectural variations model of oligopoly.

The quantity-setting conjectural variations model of oligopoly has been criticized as applying such dynamic concepts as reactions and conjectures to an apparently static, simultaneous-move game (Friedman, 1983). Despite this criticism, however, Dixit (1986) and Quirmbach (1988) emphasize the practical appeals of the conjectural variations approach. Firstly, it offers a framework within which different models of oligopoly (e.g., Cournot, monopoly) can be treated. Secondly, it allows measurement of the degree of market power by parametrizing conjectural variations; with the parameterized conjectural variation treating perfect competition, perfect collusion and the Cournot outcomes as special cases. These practical appeals are in fact what explain its popularity in the applied industrial organization literature.

4.3 Conjectural Variations

Conjectural variations in a non-competitive industry, where there are many identical firms with the same marginal cost, is defined *as the change in output of all other firms in response to a change in output of a representative firm* (see, Iwata, 1974; Appelbaum, 1982; Dixit, 1986; and Quirmbach, 1988, *inter alia).*

Algebraically, and using the notation of the Gardner model which has just been reviewed in the preceding chapter, this is denoted by:

$$\frac{\partial x}{\partial x_i} = \frac{\partial x_i}{\partial x_i} + \frac{\partial \left(\sum\limits_{j \neq i} x_j \right)}{\partial x_i} = 1 + \lambda \tag{4.1}$$

where x is industry output; x_i is output of the representative firm; $\frac{\partial x}{\partial x_i}$ is the firm's conjecture about the change in industry output following a change in its own output and $\lambda = \frac{\partial \left(\sum\limits_{j \neq i} x_j \right)}{\partial x_i}$ is the firm's conjectural variation.

Multiplying both sides of equation (4.1) by $\frac{x_i}{x}$, one can obtain the elasticity of industry output conjectured by the ith firm which is denoted by:

$$\theta_i = (1 + \lambda) \frac{x_i}{x} = \left(\frac{\partial x}{\partial x_i} \right) \left(\frac{x_i}{x} \right) \tag{4.2}$$

As (4.2) clearly shows, the firm's conjectural elasticity, θ_i, is composed of both the firm's output share (x_i/x) and its conjectures about the change in industry output $(\partial x/\partial x_i)$. When the market is perfectly competitive, $\theta_i = 0$ applies because $\frac{\partial x}{\partial x_i} = 0 \Rightarrow$

$\lambda = -1$. When the market is monopolistic or collusive , $\theta_i = 1$ because $\frac{\partial x}{\partial x_i} = 1 \Longrightarrow \lambda = 0$ and $\frac{x_i}{x} = 1$. In the special case of Cournot behavior, where $\frac{\partial x}{\partial x_i} = 1 \Longrightarrow \lambda = 0$, θ_i becomes the share of output of the ith firm in total industry output, $\frac{x_i}{x}$[1].

4.4 Profit maximization in the presence of oligopoly power in the output market

Having defined a firm's conjectural variation, the next step is to show how to solve the profit maximization problem of the firm when the output market is assumed oligopolistic. A market is said to be oligopolistic when, unlike in the perfectly competitive market, there are a small number of large firms competing among themselves for a market share. Competition among firms might be on the basis of quantity, as in the case of the Cournot model, or on the basis of price, as in the case of the Bertrand model.

4.4.1 The Cournot model of oligopoly

In the Cournot model, it is assumed that, on setting the profit maximizing level of output, each firm makes a conjecture about changes in industry level output following changes in its own output by first making a conjecture about changes in output by all other firms. In the Bertrand model, on the other hand, a profit maximizing firm is assumed to set its own price by making a conjecture about the change in industry price, following a change in its own price, by first making a conjecture about the change in price by all other firms in the industry.

[1]If we are assuming industry output as being an aggregation of output produced by n identical firms; i.e., $Q \equiv nq$ (the symmetric case), then

$$\frac{\partial Q}{\partial q} = \frac{n\partial q}{\partial q} = n$$

This means that the level of industry output changes in proportion to the number of firms changing their level of output. In the case being considered, only one firm changes output. Hence, $\partial Q/\partial q = 1$ (Tirole, 1992, p. 220).

The classic model of oligopoly first developed by Cournot (1838) and as presented in Varian (1992) considers two firms producing an homogeneous product with output levels x_1 and x_2. Industry output is represented by $x=x_1+x_2$. The industry's inverse demand function is denoted by $P(x)=P(x_1+x_2)$. Finally, each firm's cost function is denoted by $c_i(x_i)$. Given these assumptions, each firm's profit maximization problem is then specified as:

$$\max_{x_i} \pi_i(x_i, x_2) = P(x_1 + x_2)x_i - c_i(x_i); \quad i = 1, 2. \tag{4.3}$$

Equation (4.3) states that one firm's profit depends on the other firm's choice of output. Hence, in order to maximize its profit, firm 1 should make a conjecture about firm 2's level of output and *vice versa*. When each firm's conjecture about the other firm's choice of output is actually correct, then both firms' choices of output are said to constitute a Nash equilibrium.

The following first-order conditions are necessary conditions for a Nash-Cournot equilibrium to hold.

$$\frac{\partial \pi_1(x_1, x_2)}{\partial x_1} = P(X) + \frac{\partial P}{\partial X}\left(\frac{\partial x_1}{\partial x_1} + \frac{\partial x_1}{\partial x_2}\right) x_1 - \frac{\partial c_1(x_1)}{\partial x_1} = 0 \tag{4.4a}$$

and

$$\frac{\partial \pi_1(x_1, x_2)}{\partial x_2} = P(X) + \frac{\partial P}{\partial X}\left(\frac{\partial x_2}{\partial x_2} + \frac{\partial x_1}{\partial x_2}\right) x_2 - \frac{\partial c(x_2)}{\partial x_2} = 0 \tag{4.4b}$$

The second-order condition for each firm is given by:

$$\frac{\partial^2 \pi_i}{\partial x_i^2} = 2P'(X) + P''(X)x_i - \frac{\partial^2 c_i}{\partial x_i^2}(x_i) \leq 0 \tag{4.5}$$

From the first-order conditions, x_1 and x_2 are solved for to obtain the reaction functions for firms 1 and 2 respectively as:

$$x_1 = f_1(x_2) = \frac{\frac{\partial c(x_1)}{\partial x_1} - P(X)}{\frac{\partial P}{\partial X}\left(1 + \frac{\partial x_1}{\partial x_2}\right)} \tag{4.6a}$$

and

$$x_2 = f_2(x_2) = \frac{\frac{\partial c_2(x_2)}{\partial x_2} - P(X)}{\frac{\partial P}{\partial X}\left(1 + \frac{\partial x 2}{\partial x_1}\right)} \tag{4.6b}$$

The slopes of the reaction functions are $\left(\frac{\partial x_1}{\partial x_2}\right)$ for firm 1 and $\left(\frac{\partial x_2}{\partial x_1}\right)$ for firm 2. In the original Cournot model both are assumed zero because each firm believes that the other firm's choice of output does not change in response to a change in its level of output because the strategic output choices are made simultaneously. This is what gives the model its static nature.

In the manner of Appelbaum (1982), the Cournot model can be generalized to n identical firms producing an homogeneous product, x, using multiple inputs. Assume marginal costs are constant and the same across all firms which implies that firms' costs are linear. Furthermore, let firms face the same industry linear demand curve. Let $C_i{=}C_i\,(x_{i,}w)$ be the cost function of the ith firm where x_i is output of that firm and w is the input price vector. For a given industry demand function for the final product, $X{=}D(P_x, N)$, where P_x is industry price and N is a demand shifter, the inverse demand function is specified as $P_x = P(x)$.

Assuming that the demand function is continuously differentiable and decreasing in market price (i.e., $P'(x) < 0$) and that the cost function is continuously differentiable and non-decreasing in output (i.e., $C'(x) > 0$), firm i chooses output to maximize profit, π_i as:

$$\max_{x_i} \pi_i = P_x(X)\, x_i - C_i(x_i, w) \quad i = 1, ..., n \tag{4.7}$$

The first-order condition for a maximum is then given by:

$$P_x(x) - C_i'(x_i, w) + \frac{\partial P}{\partial x}\left(\frac{\partial x}{\partial x_i}\right) x_i = 0 \tag{4.8}$$

where $C_i'(x_i)$ is marginal cost, MC_i of the ith firm. Assume that the second-order condition $\frac{\partial^2 \pi_i}{\partial x_i^2} < 0 \;\forall\; i$=1, 2, ..., n is satisfied.

Equation (4.8) can be interpreted as stating that once the level of output which maximizes profit is attained, the amount of profit an extra unit of output brings to the firm (price minus marginal cost) and the magnitude by which price has to fall in order for the extra unit of output to be sold must equal zero.

Algebraically, this can be written as:

$$P_x dX + dP\left(\frac{\partial x}{\partial x_i}\right) x_i = MC_i \tag{4.8a}$$

Factoring out P_x, multiplying the second term of the right-hand side by $\frac{X}{X}$, and then division by dx yields,

$$P_x(x)\left[1 + \frac{\theta_i}{\eta}\right] = MC_i \tag{4.8b}$$

where η is the price elasticity of industry demand $\left(\frac{\partial x}{P_x} \times \frac{P}{x}\right)$ which is in all circumstances negative.

Equation (4.8b) is used to derive industry 'Lerner Index' (LI) which measures the degree of oligopoly power (see Appelbaum *op. cit*; and Bhuyan and Lopez, 1997)[2]. This is written as:

$$\frac{P_x - MC_i}{P_x} = \frac{\theta_i}{\eta} \tag{4.8c}$$

In the manner of Bhuyan and Lopez, *op. cit.*, equation (4.8c) is weighted by the market share ($s_i = x_i/x$) to obtain:

$$s_i - \frac{s_i MC_i}{P_x} = s_i \frac{\theta_i}{\eta} \tag{4.9a}$$

Equation (4.9a) can then be summed over i firms to obtain the aggregate 'Lerner Index' for the industry as:

$$LI = \frac{P_x - MC}{P_x} = \frac{\theta}{\eta} \tag{4.9b}$$

[2]Cowling and Waterson (1976) define the 'Lerner Index' slightly differently as:

$$\frac{P_x - C'(x_i)}{P_x} = -\frac{1+\lambda}{N\eta}$$

where $\lambda = \sum x_i \lambda_i / \sum x_i$ with

$\lambda_i = \frac{\partial \sum_{j \neq i} X_j}{\partial X_i}$ and N is the number of firms in the industry. As the number of firms declines the price cost margin increases.

where MC and θ are the weighted marginal cost and weighted elasticity of conjectural variation. The fact that $MC \geq 0$ implies that $LI \leq 1$; and the fact that $|\eta| > 0$, and that $P_x - MC \geq 0$ implies that $LI \geq 0$. Thus, the degree of oligopoly power lies between zero and one.

As (4.9b) makes evident, the 'Lerner Index' is proportional to the conjectural elasticity, θ, and inversely proportional to the industry price elasticity of demand. Obviously, for a given demand elasticity, the higher θ, the larger the mark-up which is defined as the difference between price and marginal cost expressed as a proportion of price. And conversely, the lower θ, the smaller the mark-up taking the extreme value of zero for a perfectly competitive market where $P = MC$. On the other hand, the less elastic consumer demand, the larger the mark-up and the greater the price distortion[3] and *vice versa*.

4.4.2 The Bertrand model of oligopoly

In the preceding, it was shown that in the Cournot model, oligopoly power shows as the mark-up of retail price over marginal cost because firms compete over output quantities taking market price as given. In the Bertrand model of oligopoly, however, the price mark-up disappears when firms have to compete over market price.

In the manner of Varian (1992)[4], consider a two-firm industry where each firm faces a constant marginal cost and produces an homogeneous product. The market demand curve is defined in such a way that each firm believes that it can supply the whole market if it sets its own price below the other firm's price. Given these assumptions therefore each firm's profit maximization problem can be set as:

[3]Price distortion is defined as the deviation of market price from the socially optimal price, i.e., the marginal cost (Tirole, 1992, p. 66).

[4]See also Tirole (1992) for an exposition of the Bertrand Paradox.

$$\max_{p_i} \pi_i = x_i(P_x)p_i - c_i(x_i(P_x), w_i) \tag{4.10}$$

where the price set by the ith firm is given by p_i.

The first-order conditions for firms 1 and 2 are then written, respectively, as:

$$\frac{\partial \pi_1}{\partial p_1} = x_1 + \left(\frac{\partial x_1}{\partial P} \times \frac{\partial P_x}{\partial p_1}\right)\left(p_1 - \frac{\partial c_1}{\partial x_1}\right) = 0 \tag{4.11a}$$

and

$$\frac{\partial \pi_2}{\partial p_2} = \left(x_2 + \left(\frac{\partial x_2}{\partial P} \times \frac{\partial P}{\partial p_{x2}}\right)\right)\left(p_1 - \frac{\partial c_2}{\partial x_2}\right) = 0 \tag{4.11b}$$

where c_1 and c_2 are marginal costs for firms 1 and 2 respectively. Assume that the second-order condition, $\frac{\partial^2 \pi_i}{\partial p_i^2} \leq 0$ is satisfied for i=1, 2.

From the first-order conditions, it can be observed that, on maximizing profit, each firm makes a conjecture about the change in market price following a change in its price level, $\frac{\partial P}{\partial p_i}$. The fact that p=p_1 if $p_1 < p_2$; $p = p_2$ if $p_1 > p_2$; and $p = p_1 = p_2$ if $p_1 = p_2$ implies that when making a conjecture about the change in market price, following a change in its own price level, each firm is implicitly holding a belief about the change in the price of the rival firm in response to a change in its output price.

Rearranging equations (4.11a) and (4.11b), the reaction functions for firms 1 and 2 can then be obtained as:

$$p_1 = f_1(p_2) = \frac{\partial c_1}{\partial x_1} - \frac{x_1}{\left[\frac{\partial x_1}{\partial P}\frac{\partial P}{\partial p_1}\right]} \tag{4.12a}$$

and

$$p_2 = f_2(p_2) = \frac{\partial c_2}{\partial x_2} - \frac{x_2}{\left[\frac{\partial x_2}{\partial P}\frac{\partial P}{\partial p_2}\right]} \tag{4.12b}$$

In the Bertrand model, the Nash equilibrium holds when each firm maximizes profit given that the conjecture it makes about $\left(\frac{\partial P_x}{\partial p_i}\right)$ is actually correct. This means that once equilibrium is achieved, then no change in one firm's output price will induce a change in market price. In other words, in equilibrium, $\frac{\partial P_x}{\partial p_i} = 0$. The key conclusion that follows from the Bertrand model is therefore that in equilibrium each firm must set output price equal to its marginal cost, which is what actually holds in the perfectly competitive model. As a result, the price-cost margin vanishes in the Bertrand model.

Under the given assumptions of product homogeneity and identical firms, any discussion of the effects of oligopoly power on the degree of price transmission is therefore possible only when a model of oligopoly assumes a pricing system whereby each firm in the industry allows for a price-cost margin. And of course this is possible only when firms are considered as competing on the basis of quantity as in the Cournot model and not on the basis of price as in the Bertrand model.

Assume that firms are competing on the basis of quantity. We then want to review the theoretical literature to see if assuming market power in the output market produces outcomes for the price spread and the degree of price transmission that are any different from those obtained assuming perfect competition in this market. Two models that will form the focus of our review are Holloway (1991) and McCorriston *et al.* (1998).

4.5 The price spread in an oligopolistic market (Holloway, 1991)

As has been pointed out earlier, the assumption of firms producing an homogeneous product dictates one to model market power in the context of quantity-setting oligopoly. As might be recalled, implicit in this model of oligopoly is that price of industry output is set equal to marginal cost plus the price-cost margin (i.e., the price mark-up). This is clearly seen when (4.9b) is rearranged to appear as:

$$P_x = MC + \left(\frac{\theta}{\eta}\right) P_x \tag{4.13}$$

It can be readily observed from (4.13) that the introduction of market power at the retail stage of the industry makes for a radical departure in approach when modelling price transmission. This is because retail price no longer equals marginal cost as when the retail stage is assumed perfectly competitive. Instead, it contains two components; a marginal cost component and a mark-up component. Assume now that retail price changes in response to a change in the price of the farm input. Then the change in retail price will reflect part as a change in the marginal cost and part as a change in the mark-up.

In the literature, there have developed several theoretical models which extend the work of Gardner *op. cit.* to allow for oligopoly power at the retail stage of the food industry. An early such model is that by Holloway (1991). This model extends the Gardner model by employing the notion of conjectural variations in the context of the food industry while explicitly allowing for the entry of new firms into this industry. The model operates within a 10-equation system.

The first equation denotes the industry's retail demand function as in the Gardner model inclusive of a retail demand shifter while the second denotes aggregate output of the industry, $x=\sum_i x_i$, $\forall\ i \in \{1,2,...n\}$ where n is the number of firms. The third equation denotes the first-order condition for an oligopolistic firm which is as stated in (4.13) above. The fourth equation specifies a nonzero fixed cost, κ, which is defined as the difference between the value of the nth firm's output and its marginal cost, i.e., as $P_x x_n - MC_n x_n - \kappa = 0$. This equation is included in order to make the number of firms endogenous, and together with the first-order condition, to make the conduct parameter, θ be determined not only by the elasticity of demand but also by a fixed cost, κ. The fifth and sixth equations describe demand for the farm and marketing inputs as derived from Shephard's lemma[5] while the seventh and eighth equations describe aggregation conditions for the inputs market in symmetric equilibrium. The last two equations describe inverse supply relations for the farm and marketing inputs as specified in the Gardner model.

This system of ten equations is then allowed to be displaced, in the manner of the Gardner model, by simultaneous movements in the exogenous variables in the retail, farm and marketing sectors and then the equilibrating adjustments in each of the endogenous variables solved for. This is done by assuming that farm commodity supplies are exogenous in the manner of Wohlgenant, *op. cit.* and that the supply of nonfarm inputs to the food industry is perfectly elastic.

The model then analyses, using comparative statics and simulation, the elasticities of Gardner's farm-retail price spread with respect to the three exogenous variables. The major conclusions that derive from this model are that, relative to the perfectly competitive case with an infinite number of firms, Cournot competition among a small number of firms distorts the adjustment of the price spread to movements in the exogenous vari-

[5]Denoting the farm input of the nth firm by a_n and its marketing input by b_n and their respective prices by P_a and P_b, then, given the cost function $C(P_a,P_b,x)$ where x is industry output, then by Shephard's lemma, the nth firm's conditional factor demand functions are derived as:

$$\begin{aligned} a_n &= \partial C(.)x_n/\partial P_a \\ b_n &= \partial C(.)x_n/\partial P_b \end{aligned}$$

ables. Given an increase in retail demand, the model finds that the price spread falls by much more when the number of firms is small than when it is large. On the other hand, given an increase in the supply of the farm input, the price spread widens by much more when the number of firms in the industry is small than when this number is large. Finally, given an increase in the price of marketing services, the price spread increases by much less when the number of firms is small than when it is large.

Holloway's model assumes linearity in both the retail demand and input supply functions. Consequently, its predictions are model dependent. However, it is a potent model in that it predicts the distortionary effects of oligopoly power on movements in the price spread following changes in the conditions of input supply and retail demand. As such, it suggests that prior to estimating the degree of price transmission in the food industry the behavior of this industry be examined through a rigorous test for perfect competition in its retail sector. Following this suggestion, a number of studies have been conducted so far. For empirical literature in this regard, see, *inter alia*, Holloway, *op. cit.*; Bhuyan and Lopez, *op. cit.*; and Gohin and Guyomard (2000).

Even though the Holloway model analyses the distortionary effects of oligopoly power in the retail market on movements in the price spread relative to those in a perfectly competitive market, it does not analyze the degree of price transmission which results from the presence of market power. As a model of vertical price transmission therefore it is not complete.

Recently, McCorriston *et al.* (1998) extend the Gardner model to allow for market power in the retail sector of the industry and then evaluate the effects of market power on the degree of price transmission taking the Gardner model as a benchmark. Their approach to measuring market power is very much in the tradition of the Holloway model as they operate within the framework of a quantity-setting conjectural variations model of oligopoly. But there are several differences with the Holloway model. First, they do not assume number of firms to be endogenous, i.e., they do not assume entry into the industry to be determined by a non-negative fixed cost. Second, they conduct comparative statics assuming only a shift in the supply of the farm input Third, they assume a generalized form of retail demand function rather than a linear retail demand function as the Holloway model does. Fourth, their major interest in modelling is more to evaluate the magnitude of the price transmission elasticity in the presence of market power relative to that in the Gardner model than to evaluate movements in the price spread under different market structures as the Holloway model does.

The model by McCorriston *et al.* operates within a system containing seven equations. Using the notation of the Gardner model, this system of equations is described and discussed at length.

4.6 The degree of price transmission in the presence of oligopoly power in the output market (McCorriston *et al.*., 1998)

The first equation describes the production function of the industry as:

$$x = f\left(a, b\right) \tag{4.14a}$$

The second equation describes the demand function for the retail product as:

$$x = D\left(P_x\right) \tag{4.14b}$$

The third and fourth equations describe the inverse demand functions for the farm and marketing inputs as:

$$P_a = Cf_a \tag{4.14c}$$

and

$$P_b = Cf_b \tag{4.14d}$$

respectively where C denotes industry marginal cost. They are derived from the firm's cost minimization problem. Finally, the fifth and sixth equations describe the inverse supply functions for these two inputs as:

$$P_a = g\,(a, W) \tag{4.14e}$$

and

$$P_b = h\,(b, T) \tag{4.14f}$$

The first-order condition for a profit maximum assuming market power in the retail sector is expressed in terms of the firm's mark-up over industry marginal cost, C as:

$$P_x \left(1 + \frac{\theta}{\eta}\right) = C \tag{4.14g}$$

which is then used to describe the price equation

$$P_x = \lambda C \tag{4.14h}$$

where the reciprocal of the bracketed term in (4.14g) is denoted by $\lambda = \frac{\eta}{\eta+\theta}$.

It is worth noting that except for the inverse demand functions for the farm and marketing inputs in (4.14c) and (4.14d) and for the retail price equation in (4.14h), the system's specification is similar to that of Gardner's. The system contains seven equations in seven endogenous variables (i.e., a, b, x, P_x, P_a, P_b).

4.6.1 The effects of a farm input supply shift

Having defined the system's equilibrium, the effects of disturbances in initial equilibrium originating in the farm input supply sector are analyzed in the same manner as in the Gardner model. As before, the procedure involves expressing changes in each of the seven equations as total differential changes. And not surprisingly, these changes are identical to those for the Gardner model except for changes in the inverse demand functions for the farm and marketing services which are now specified as:

$$dP_a = dC^* - \frac{\beta}{\sigma}\left(da^* - db^*\right) \tag{4.15a}$$

and

$$dP_b = dC^* + \frac{\alpha}{\sigma}\left(da^* - db^*\right) \tag{4.15b}$$

where

$$dP_x^* \left(1 - \mu\right) = dC^* \tag{4.15c}$$

where

$$\mu = -\frac{\omega\theta}{(\theta - \eta)} \text{ and} \tag{4.15d}$$

$$\omega = \partial\eta / \partial P_x$$

The terms α and β represent the factor cost shares, $\left(\frac{S_a}{(1+\theta/\eta)}\right)$ and $\left(\frac{S_b}{(1+\theta/\eta)}\right)$ respectively in the presence of oligopoly power[6]. The term μ represents the negative of the change in the price-cost margin and represents a fall (rise) in the price-cost margin as retail price rises conditional on whether ω is positive (negative). For instance, if an increase in P_x results in the demand elasticity becoming more elastic, i.e., η, which is negative gets larger in absolute terms as well, then the price-cost margin will narrow, implying that price falls in response to demand becoming more elastic.

4.6.2 The functional forms of retail demand and the price-cost margin: a digression

As has been hinted at from (4.15d), the direction of change in the price-cost margin following changes in P_x, critically depends on the demand elasticity's response to P_x. The functional form of demand is thus the key determinant of the change in the price-cost margin following changes in the conditions of supply in the farm input. To appreciate the importance of this crucial point, it is important that we make a digression in order to explain the sensitivity of the demand elasticity to a change in retail price given different functional forms.

Consider a generalized demand function of the form:

[6] Recall from (3.3a) the Euler equation, x = $f_a a + f_b b$. By virtue of (4.14c) and (4.14d), $f_a = P_a/c$ and $f_b = P_b/C\ \ a$. Also by virtue of (4.1g), C = $P_x(1+\theta/\eta)$. Then the Euler equation can be written as: x $= \frac{P_a a}{P_x(1+\theta/\eta)} + \frac{P_b b}{P_x(1+\theta/\eta)}$ which on dividing through out by x can be re-written as :
$1 = \frac{P_a a}{P_x x(1+\theta/\eta)} + \frac{P_b b}{P_x x(1+\theta/\eta)}$. Denoting $\alpha = \frac{P_a a}{P_x x(1+\theta/\eta)}$ and $\beta = \frac{P_b b}{P_x x(1+\theta/\eta)}$, the Euler equation can be written as:
1= $\alpha + \beta$ which is as shown in this model.

$$x = f(p) \tag{4.16}$$

from which the elasticity of demand is calculated as:

$$\eta = \left(\frac{\partial x}{\partial p} \times \frac{p}{x}\right) \tag{4.17}$$

To analyze the direction of change in the elasticity of demand, when P_x changes, differentiate η with respect to P_x to obtain:

$$\frac{\partial \eta}{\partial p} = \left[\left(\frac{\partial\left(\frac{\partial x}{\partial p}\right)}{\partial p}\frac{p}{x}\right) + \left(\frac{\partial x}{\partial p}\right)\frac{1}{x} - \left(\frac{\partial x}{\partial p}\frac{\partial x}{\partial p}\frac{p}{x^2}\right)\right] \tag{4.18}$$

which, on simplification, reduces to:

$$\frac{\partial \eta}{\partial p} = \left[\frac{\partial^2 x}{\partial p^2}\frac{p}{x} + \frac{\partial x}{\partial p}\frac{1}{x} - \frac{\partial x}{\partial p}\frac{\partial x}{\partial p}\frac{p}{x^2}\right] \tag{4.18a}$$

To evaluate the sign and magnitude of $\frac{\partial \eta}{\partial p}$ for different functional forms of demand consider the linear and constant elasticity demand functions. First consider the linear demand function.

$$x = a - bp \tag{4.19}$$

where a and b are positive constants. The first and second-order derivatives of the linear demand function are given as follows:

$$\frac{\partial x}{\partial p} = -b < 0; \text{ and } \frac{\partial^2 x}{\partial p^2} = 0 \tag{4.20}$$

Using (4.20), (4.18a) can then be re-written as:

$$\frac{\partial \eta}{\partial p} = \frac{\partial x}{\partial p}\frac{1}{x} - \frac{\partial x}{\partial p}\frac{\partial x}{\partial p}\frac{p}{x^2} \tag{4.18b}$$

which, when divided throughout by $\left(\frac{\partial x}{\partial p} \times \frac{1}{x}\right)$, reduces to

$$\frac{\partial \eta}{\partial p} = 1 - \eta \tag{4.18c}$$

Since in all normal cases η is negative, (4.18c) is always positive, implying that, when a linear demand function is assumed, the elasticity of demand moves in the same direction as retail price with the result that when the latter increases so does demand elasticity and *vice versa.* The implication of this outcome for the price-cost margin is quite clear. As might be recalled from (4.9b), the price-cost margin is inversely proportional to the elasticity of demand so that when the latter increases the margin narrows and *vice versa.* Given a linear demand curve, therefore the demand elasticity moves in the same direction as retail price the implication being that the margin moves in the opposite direction as demand elasticity and hence retail price.

Intuitively, this can be interpreted as saying that when consumers and retailers are related in a linear demand function, then retailers are more likely to lose customers if they increase price substantially in response to an increase in farm input price as this drives consumers away who have now become more sensitive to price changes.

This being the case, in the event of a sudden increase in farm input price following an exogenous shock, retailers increase price by just a little so that their customers are not driven away. But a small retail price increase comes only at the expense of a squeeze in their margin. If, on the other hand, there occurs a sudden fall in farm input price following such an exogenous shock, then retailers do not have to reduce retail price substantially as consumers have now become insensitive to a retail price change (in other words, they have become 'captive customers'). Instead, retailers reduce their price by just a little and instead widen their margin.

Consider now a constant elasticity demand function of the form:

$$x = \frac{a}{p^{\varepsilon}} \tag{4.21}$$

where a and ε are constants. Its first and second-order derivatives are given as:

$$\frac{\partial x}{\partial p} = -\frac{a}{p^2}; \text{ and } \frac{\partial^2 x}{\partial p^2} = \frac{2a}{p^3} \tag{4.22}$$

which, when substituted into equation (4.18a) yield a value for $\frac{\partial \eta}{\partial p}$ given by,

$$\frac{\partial \eta}{\partial p} = 0. \tag{4.18d}$$

For a given constant elasticity demand function therefore, the elasticity of demand is insensitive to changes in retail price with the result that the former remains unchanged as retail price changes. Intuitively, this means that in response to a change in farm input price, retailers change their price in the same proportion as the change in marginal cost with the result that their margin remains unchanged.

The effects of different functional forms on the price-cost margin can be summarized by invoking equation (4.13) which partitions the industry output price into marginal cost and the price-cost margin. Now consider an increase in the price of industry output. Then when $\frac{\partial \eta}{\partial P_x} = 1 + \eta > 0$, as in a linear demand case, the change in retail price is less than that in marginal cost because the change in the price cost-margin is negative. When $\frac{\partial \eta}{\partial P_x} = 0$, as in a constant elasticity demand case, the change in retail price equals that in marginal cost so that the price-cost margin remains unchanged.

So much for the digression. Now going back to the model which is being considered, having analyzed the effects of shifts in the inverse supply function for the farm input on all endogenous variables, the percentage changes in these variables are then solved for in terms of the percentage change in the farm input price, e_W.

4.6.3 Solving for relative changes in the endogenous variables in terms of e_W.

Doing this results in the following three-equation system[7].

$$-\eta dP_x^* + \alpha da^* + \beta db^* = 0 \tag{4.23a}$$

$$(1-\mu)\, dP_x^* - \left(\frac{\beta}{\sigma} + \frac{1}{e_a}\right) da^* + \left(\frac{\beta}{\sigma}\right) db^* = e_W \tag{4.23b}$$

$$(1-\mu)\, dP_x^* + \frac{\alpha}{\sigma} da^* - \left(\frac{\alpha}{\sigma} + \frac{1}{e_b}\right) db^* = 0 \tag{4.23c}$$

This system of equations is solved using Cramer's rule. For the purposes of our review, only percentage changes in the prices of the retail product and the farm input are presented respectively as:

[7]Note when μ=0, this three-equation system reduces to that in the basic model assuming the exogenous shock originates in the farm input supply sector.

$$dP_x^* = \frac{e_W e_a \alpha \left(e_b + \sigma\right)}{D'} \qquad (4.24a)$$

$$dP_a^* = \frac{e_W e_a \left(1 - \mu\right) \left(e_b + \alpha\sigma\right) - \beta\eta)}{D'} \qquad (4.24b)$$

where $D' = -\eta\left(\beta e_a + \beta e_b + \sigma\right) + \left(1-\mu\right) e_a e_b + \left(1-\mu\right)\sigma\left(\alpha e_a + \beta e_b\right)$. It is positive in normal cases.

4.6.4 The elasticity of price transmission in an oligopolistic market

Having obtained the percentage changes in P_x and P_a, the model finally derives the elasticity of price transmission, τ^{IC} (where the superscript, *IC*, stands for an imperfectly competitive market), as follows.

$$\tau^{IC}\mid_{dW} = \frac{dP_x^*}{dP_a^*} = \frac{\alpha\left(e_b + \sigma\right)}{\left(1-\mu\right)\left(e_b + \alpha\sigma\right) - \beta\eta)} \qquad (4.25)$$

Judging from (4.25), the major finding of the model by McCorriston *et. al.*. is that under the assumption of market power, the relative magnitude of the price transmission elasticity cannot be determined *a priori*. As the above digression has made clear, this is because μ is signed differently for different functional forms.

For a linear demand function, the transmission elasticity in an imperfectly competitive market is less than that in a perfectly competitive market since $\mu < 0$. On the other hand, for a non-linear demand function (specifically, for a constant elasticity demand form), the transmission elasticity in an imperfectly competitive market is identical to that in a perfectly competitive model since $\mu = 0$. An important implication deriving from their finding is that in the absence of prior knowledge regarding the demand function with which a particular industry is operating, then one just is not in a position to evaluate the degree of price transmission in an oligopolistic market relative to that in a perfectly competitive market.

Their finding is consistent with those established in the international trade literature, where the pass-through of foreign exchange costs to import price has been assessed (see, for instance, Bernhofen and Xu, 1999; Feenstra, 1988), and in the tax incidence literature where the impact of tax shifts on retail price changes has been assessed (Seade, 1985).

It is worth noting that while Holloway's model shows that, taking the Gardner model as a benchmark, the assumption of oligopoly power leads to distortions in the movements of the price spread following changes in the exogenous variables originating in the retail, farm and marketing sectors, the model by McCorriston *et al.*. is inconclusive on this count. This is not surprising given that the former assumes a linear retail demand function while the latter assumes a generalized demand function.

4.6.5 Summary and evaluation

In the preceding, we have reviewed two important theoretical models which analyze the effects of oligopoly power in the retail market on movements in the price spread and on the degree of price transmission. These are the models by Holloway and that by McCorriston *et al.*. Methodologically, it has been shown that they operate within the framework of the quantity-setting conjectural variations model of oligopoly. Whereas both models use the Gardner model as a benchmark, the Holloway model aims to evaluate movements in the price spread in the presence of market power in the retail market assuming simultaneous shocks in the output and input markets while the model by McCorriston *et. al.*. aims to evaluate the magnitude of the elasticity of price transmission in such a market assuming only a raw input supply shock.

The major conclusion of the Holloway model is that, relative to the perfectly competitive case with an infinite number of firms, Cournot competition among a small number of oligopolistic firms distorts the adjustment of the price spread to movements in the exogenous variables. Thus, relative to the change in the price spread that obtains in the presence of competition among a large number of firms, the change in the price spread which obtains in the presence of Cournot competition among a small number of oligopolistic firms is much more for a retail demand and farm input supply increases and much less for a marketing price increase. This result derives directly from the assumption of linear retail demand and input supply functions. As such, this conclusion is model sensitive.

The major conclusion of the model by McCorriston *et al.,* on the other hand, is that the effects of oligopoly power at the retail stage of the industry on the elasticity of price transmission cannot be determined *a priori.* This derives directly from the assumption of a generalized retail demand function for the industry. Given a linear industry retail demand function, the price-cost margin changes in the opposite direction to retail price with the result that when the latter increases the price-cost margin falls so that the net increase in retail price is less than that in the marginal cost and *vice versa.* Consequently, the elasticity of price transmission assuming an oligopolistic industry is smaller than a price transmission elasticity in a perfectly competitive industry. On the other hand, given a constant elasticity retail demand function, the elasticity of price transmission is the same in both perfectly competitive and oligopolistic markets. This is because changes in retail price only reflect those in the marginal cost as the price-cost margin remains unchanged following changes in farm input price.

The major implication that derives from the model by McCorriston *et al.* is that in the absence of a prior knowledge regarding the demand function with which a particular industry is operating one just is not in a position to evaluate the degree of price transmission in an oligopolistic market taking the degree of price transmission in a perfectly competitive market as a benchmark.

4.7 The degree of price transmission in the presence of oligopoly power in the output market and of non-constant returns to scale in industry technology (McCorriston *et. al.*. 2001)

4.7.1 Background

The literature that we have reviewed in relation to price transmission in both the Gardner model and the models with market power (i.e., those by Holloway and McCorriston *et al.*) assumes industry technology is characterized by constant returns to scale.

The major critique of this assumption is that by focusing on market structure to explain firms' performance (i.e., the price-cost margin), it neglects the role of firms' cost structure in determining this very performance (Morrison Paul, 1999; and McCorriston *et al.*., 2001). For instance, a drop in unit cost which follows any technological improvement results in increased cost efficiency (i.e., unit cost falls for any output level) thus leading to lower costs and ultimately to a lower price for consumers (Morrison Paul, *op. cit.*).

In the empirical literature, only rarely has constant returns to scale been observed in production. Testing for oligopoly power and constant returns to scale in 40 food and tobacco industries in the US, for instance, Bhuyan and Lopez, *op.cit.* find that the null hypothesis of constant returns to scale is rejected in thirty-three industries of the sample with 20 industries exhibiting increasing returns to scale and 13 exhibiting decreasing returns to scale. Of the total sample, only 7 industries exhibit constant returns to scale.

The aforementioned theoretical critique and the rarity of empirical evidence supporting constant returns to scale in production points to the necessity of having to extend the model of imperfect competition reviewed previously to take account of non-constant returns to scale in technology. In the following, we review a recent model by McCorriston *et al.* (2001) which does just this. It does not only allow for oligopoly power in the retail market but also account for non-constant returns to scale in industry technology. This model works on the premise that there is a link between returns to scale and the price-cost margin. To see clearly the workings of the model therefore it is necessary to first establish a linkage between returns to scale and the price-cost margin which we do next.

4.7.2 The linkage between returns to scale and the price-cost margin: a digression

The linkage between returns to scale and the firm's price-cost margin is better appreciated if a relationship between the cost function and production technology is first established. In the manner of Simon and Blume (1994), and sticking to the notation of the Gardner model consider

$$x = ka^{\alpha}b^{\beta} \tag{4.26}$$

where $\alpha = S_a$ and $\beta = S_b$ are shares of input, a and b in total output, x, and k is a technology parameter.

For a given cost function,

$$C = P_a a + P_b b \tag{4.27}$$

where P_a and P_b are the respective prices of a and b, the first-order condition for a maximum of profit is given by[8]:

[8]This is done by first defining the profit function as:

$$\pi = ka^{\alpha}b^{\beta} - P_a a - P_b b$$

$$\frac{\partial \pi}{\partial a} = P_a = \alpha k x a^{\alpha-1} b^{\beta} \tag{4.28a}$$

and

$$\frac{\partial \pi}{\partial b} = P_b = \beta k a^{\alpha} b^{\beta-1} \tag{4.28b}$$

Division of P_a by P_b and using equation (4.28a) yields values of a and b as:

$$a = \left(\frac{\alpha P_b}{\beta P_a k^{1/\beta}} \right)^{\beta/\alpha+\beta} x^{1/\alpha+\beta} \tag{4.29a}$$

and

$$b = \left(\frac{\alpha P_b k^{1/\alpha}}{\beta P_a} \right)^{-\alpha/\alpha+\beta} x^{1/\alpha+\beta} \tag{4.29b}$$

Substituting a and b into (4.27), one obtains the cost function expressed as a function of input prices, input cost shares and output:

$$C = \begin{bmatrix} w_1 \left(\frac{\alpha w_2}{\beta w_1 k^{1/\beta}} \right)^{\beta/\alpha+\beta} + \\ w_2 \left(\frac{\alpha w_2 k^{1/\alpha}}{\beta w_1} \right)^{-\alpha/\alpha+\beta} \end{bmatrix} y^{1/\alpha+\beta} \tag{4.30a}$$

Re-writing, for convenience, (4.30a) as:

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and then differentiating π with respect to a and b to get the first-order conditions normalising the price of output to 1.

$$C = \phi y^{1/\alpha+\beta} \tag{4.30b}$$

where ϕ denotes the bracketed term in (4.30a), the average cost function (AC) can be written as:

$$AC = \phi y^{\left(\frac{1}{\alpha+\beta}\right)-1} \tag{4.31}$$

Denoting, for simplicity, $\alpha + \beta = \rho$, where ρ is a scale measure, then $\frac{1}{\alpha+\beta} - 1 = \frac{1-\rho}{\rho}$. We say there are constant returns to scale in technology when AC is constant at ϕ, for all levels of output; i.e., when $\left(\frac{1-\rho}{\rho}\right) = 0$; increasing returns to scale when AC is declining in output; i.e., when $\left(\frac{1-\rho}{\rho}\right) < 0$; and decreasing returns to scale when AC is increasing in output, i.e., when $\left(\frac{1-\rho}{\rho}\right) > 0$[9].

[9]The returns to scale measure for the Cobb-Douglas production function can, alternatively, be derived as in Varian (1992, p. 17). Considering a production function

$$y = x_1^\alpha x_2^\beta$$

then, by the homogeneity rule, scaling of the inputs by a scalar, t, yields

$$y^* = f(tx_1, tx_2) = (tx_1)^\alpha (tx_2)^\beta = t^{\alpha+\beta} x_1^\alpha x_2^\beta$$

from which,

$$y^* = t^{(\alpha+\beta)} y$$

To see how output reacts to a scaling of the inputs, differentiate y^* with respect to t to obtain,

$$\begin{aligned} \frac{\partial t^{\alpha+\beta} x_1^\alpha x_2^\beta}{\partial t} &= (\alpha+\beta)\, t^{(\alpha+\beta-1)} x_1^\alpha x_2^\beta \\ &= (\alpha+\beta)\, t^{\left(1-\frac{1}{\alpha+\beta}\right)} x_1^\alpha x_2^\beta \end{aligned}$$

Denoting, for simplicity, $\alpha+\beta = \rho$, then we have $1 - 1/\alpha+\beta = 1 - 1/\rho = \frac{\rho-1}{\rho}$. We say constant returns

From the behavior of the cost curves, it is a very well known fact that when the average cost curve is falling, the marginal cost curve is falling over a certain range of output and when the former is rising the latter is rising too. From this behavior of the cost curves therefore it can be predicted that, for a given price of the retail product, P_x, the price-cost margin widens as the average cost falls (because marginal cost also falls for a given price), when increasing returns to scale obtain in production, and falls as the latter rises (because marginal cost rises for a given price), when decreasing returns to scale operate in production. On the other hand, the price-cost margin remains unchanged when the average cost remains fixed which implies that marginal cost is also fixed.

It is with an eye for this linkage between the mark-up and marginal cost, which is normally lost to a model which assumes constant returns to scale in industry technology, that McCorriston *et al.* (2001) extend the model of price transmission under the assumption of market power allowing for non-constant returns to scale.

4.7.3 The model (McCorriston *et. al..*, 2001).

In many ways, this model is similar to that which allows for market power with constant returns to scale as in McCorriston *et al.* (1998) and is described by a system of equations as presented in (4.14a)-(4.14h). The innovation introduced into the model being reviewed concerns relative changes in the prices of the farm and marketing inputs which now have to account for the effects of returns to scale as follows.

$$dP_a^* = dC^* - \frac{\beta}{\rho\sigma}da^* + \frac{\beta}{\rho\sigma}db^* + \frac{\sigma(\rho-1)}{\sigma\rho}dx^* \qquad (4.32a)$$

and

to scale obtain when $\frac{\rho-1}{\rho} = 0$; (implying $\rho = 1$) increasing returns to scale when $\frac{\rho-1}{\rho} > 0$; (implying $\rho > 1$) and decreasing returns to scale when $\frac{\rho-1}{\rho} < 0$ (implying $\rho < 1$).

$$dP_b^* = dC^* + \frac{\alpha}{\rho\sigma}da^* - \frac{\alpha}{\rho\sigma}db^* + \frac{\sigma(\rho-1)}{\sigma\rho}dx^* \tag{4.32b}$$

Division of the input cost shares, α and β, by the scale measure, ρ, is done in order to take account of an increase in cost shares when technology exhibits decreasing returns to scale (because division of the cost shares by $\rho \mid_{\rho<1}$yields larger such shares) and a decrease in these shares when the latter exhibits increasing returns to scale (because division of the cost shares by $\rho \mid_{\rho>1}$ yields smaller such shares).

The fact that changes in the prices of the farm and marketing inputs are proportional to a change in the retail product when there are increasing returns to scale in production and inversely proportional to a change in the latter when technology exhibits decreasing returns to scale can be explained as follows.

As pointed out earlier, when there are increasing returns to scale, average cost falls as output increases. This means, for a given demand for the retail product, it pays for firms to expand output as average cost falls. But this in turn means they have to demand more of these inputs which they can only do by paying higher prices. Conversely, average cost rises with output when there are decreasing returns to scale. This creates an incentive for firms to cut back on their scale of production so that (by so doing) they can reduce average cost. This is reflected in less of the inputs being demanded, and, consequently, in lower prices being paid for these inputs.

4.7.4 Effects of a shift in farm input supply

Analysis of the disturbances in initial equilibrium that come about subsequent to a farm input supply shock proceeds in the same fashion as in the perfectly competitive and market power models. This involves the task of expressing changes in each of the endogenous variables as total differential changes and then solving for the reduced-form equations for the percentage changes in the endogenous variables following an exogenous shock to the farm input sector. In the model being reviewed, these are derived, using Cramer's rule, from a three-equation system which is described as:

$$-\eta dP_x^* + \alpha da^* + \beta db^* = 0 \tag{4.33a}$$

$$(1-\mu)\, dP_x^* - \left(\frac{e_a\beta - \rho\sigma + e_a\alpha\sigma\,(\rho-1)}{\sigma\rho}\right) da^* + \left(\frac{\beta + \beta\sigma\,(\rho-1)}{\sigma\rho}\right) db^* = e_W \tag{4.33b}$$

$$(1-\mu)\, dP_x^* + \left(\frac{\alpha + \sigma\alpha\,(\rho-1)}{\sigma\rho}\right) da^* - \left(\frac{e_b\alpha + \sigma\rho - \beta\sigma\,(\rho-1)}{\sigma\rho}\right) db^* = 0 \tag{4.33c}$$

Again for the purposes of our review we consider only changes in the prices of the farm input and the retail product respectively as:

$$dP_a^* = \frac{e_w e_a[(1-\mu)\rho(\rho e_b + \alpha\sigma) - \beta\eta + \eta(\rho-1) + \eta\,(\rho-1)\,(\rho e_b + \alpha\sigma)]}{D''} \tag{4.34a}$$

and

$$dP_x^* = \frac{e_W e_a \alpha\rho\,(e_b + \sigma)}{D''} \tag{4.34b}$$

where $D'' = -\eta\,(\alpha e_a + \alpha e_b + \sigma\rho - \beta e_b\sigma\,(\rho-1) - \alpha e_a\sigma\,(\rho-1) - (e_a e_b)\,\rho\,(\rho-1)) +$
$(1-\mu)\,\rho(e_a e_b\rho + \alpha e_a\sigma + \beta e_b\sigma)$.

4.7.5 The elasticity of price transmission assuming oligopoly power and non-constant returns to scale

Given dP_x^* and dP_a^*, the model finally derives the elasticity of price transmission assuming market power in the retail sector and non-constant returns to scale in industry technology, τ^{NCR}, as:

$$\tau^{NCR} = \frac{dP_x^*}{dP_a^*} = \frac{\alpha\rho\left(e_b + \sigma\right)}{\left[\left(\alpha\sigma + e_b\rho\right)\left(\left(1-\mu\right)\rho + \eta\left(\rho - 1\right)\right) - \beta\eta\right]} \tag{4.35}$$

To see how the introduction of non-constant returns to scale impacts on the degrees of price transmission in the Gardner model and the model by McCorriston *et al.*., 1998, the elasticity of price transmission in the Gardner model, τ^{PC}, is divided by τ^{NCR} and evaluated for a perfectly elastic marketing supply to obtain[10]

$$\frac{\tau^{PC}}{\tau^{NCR}} = 1 - \mu + \eta\left(\rho - 1\right)/\rho \tag{4.36}$$

where η and μ are normally negative.

Given (4.36), the model makes predictions about the magnitude of the elasticity of price transmission in a market structure with oligopoly power in the retail market and non-constant returns to scale in industry technology taking as a benchmark the elasticity of price transmission in perfectly competitive markets with constant returns. These predictions can be summarized as follows.

First, given constant returns to scale (i.e., for $\rho = 1$), a linear demand function, and market power in the retail sector, the elasticity of price transmission falls short of that obtained assuming a perfectly competitive industry by μ (i.e., for $\rho = 1$, $\mu < 0$). When

[10] For ease of comparison, recall that, for a given shock originating in the farm input sector, the elasticity of price transmission in the Gardner model is given by:
$\tau^{PC} = \frac{S_a(\sigma+e_b)}{e_b+S_a\sigma-S_b\eta}$.

such is the case, the transmission elasticity for an industry with market power is said to be 'under-shifting' relative to that for a competitive industry.

Second, given decreasing returns to scale, a linear demand function and market power in the retail sector (*i.e.*, for $\mu < 0$ and $\rho < 1$), 'under-shifting' gets even more pronounced because, algebraically speaking, the impact of market power is reinforced by an amount, $\eta\,(\rho - 1)\,/\rho$, which is positive since η is negative and $\rho < 1$.

Third, given increasing returns to scale, a linear demand function and market power in the retail sector (i.e. for $\mu < 0$ and $\rho > 1$), then, for a small η, 'under-shifting' becomes less pronounced; with the impact of market power on the elasticity of price transmission being undermined by the amount, $\eta\,(\rho - 1)\,/\rho$, which is negative since η is negative and $\rho > 1$. In fact, in the extreme case of $\mu = 0$, 'over-shifting' might obtain as τ^{PC}/τ^{NCR} is less than unity (i.e., for $\rho\,|_{\rho>1}$and $\mu = 0$) the implication being that the transmission elasticity for a perfectly competitive industry with increasing returns to scale is greater than that for a competitive industry with constant returns to scale.

Intuitively, the fact that, for a relatively low substitution elasticity, decreasing returns to scale work to the same effect as market power can be explained with reference to the inverse relationship between average costs and returns to scale already established earlier.

As might be recalled, it was said earlier that as firms expand (or contract) output, their average cost rises (or falls) if the technology exhibits decreasing returns to scale. This means that a downward adjustment in output resulting from a negative shock to the supply of the farm input leads to a fall in the industry's average unit cost. This in turn means that an increase in P_a which follows an exogenous supply shock does not translate into a proportional increase in P_x because at the same time that the former increases, average cost falls with the result that the increase in the latter is smaller than that in P_a. Consequently, the degree of price transmission from the farm to the retail sector is smaller.

In the converse case of a technology exhibiting increasing returns to scale, average cost falls (or rises) as output expands (or contracts). This means that a downward adjustment in output resulting from a shock originating in the farm supply sector leads to an increase in industry average cost, and, subsequently, to that in retail price.

The implication is that an increase in P_a which follows an exogenous shock in the farm input sector is exacerbated by an increase in industry average cost, and, subsequently, by an increase in P_x that comes as a result of a contraction in retail output. It thus follows that relative to when constant returns to scale are assumed, the degree of price transmission is greater when increasing returns to scale obtain. This seems to be congruent with findings in the international trade literature. For instance, Feenstra *op cit.* find that an increase in the expected exchange rate can be more than fully passed through when marginal costs are declining in output.

4.7.6 Summary and evaluation

This section has introduced and reviewed a recent model by McCorriston *et al.*. (2001) which analyses the interaction between market power in the retail market and non-constant returns to scale in industry technology. As the review has made evident, a price transmission elasticity which is derived allowing for non-constant returns to scale and market power is sensitive not only to changes in the structure of the market as measured by the demand elasticity and the market power parameters but also to cost changes as reflected by the nature of returns to scale.

For given values of these market structure parameters, and taking the elasticity of price transmission assuming market power and constant returns to scale as a bench mark, and keeping all other determining parameters constant, the model just reviewed shows that the degree of price transmission from the farm to the retail sector reflects the nature of returns to scale with which industry technology operates. This being the case, under the given assumptions, the degree of price transmission is greater when production technology is characterized by increasing returns to scale and smaller when this technology is characterized by decreasing returns to scale.

4.8 A brief summary of the theoretical literature review and possible directions for further research

4.8.1 A brief summary

To this stage we have presented a detailed review of the major theoretical models of price transmission in vertically-related markets whereby an industry is assumed to produce a finished product using two inputs. The key conclusion that comes out of this review is that the outcomes for the degree of price transmission are highly sensitive to the assumptions made regarding market structure and processing technology.

Given the assumptions of perfectly competitive markets in the input and output markets, of variable input proportions and constant returns to scale in industry technology, three major predictions emerge out of the review regarding the degree of price transmission. Firstly, the degree of price transmission from the farm to the retail sector hinges on the relative magnitudes of the retail demand and supply elasticities and cost shares of the two inputs. Secondly, *ceteris paribus*, the outcome for the degree of price transmission is determined by whether the exogenous shock originates in the inputs supply sector or in the retail sector. Finally, in all normal cases, price transmission is not perfect with perfect price transmission arising only as an exception under highly restrictive assumptions rather than as a generality.

Given the assumptions of constant returns to scale, of variable input proportions and of perfect competition in the markets for the two inputs, the review shows that the outcome for the degree of price transmission in the presence of oligopoly power in the final product market, hinges, *ceteris paribus*, on the assumption regarding the industry's retail demand function. Firstly, given a constant elasticity demand function, the review shows that the degree of price transmission in the presence of oligopoly power is identical to the degree of price transmission in a perfectly competitive market. Secondly, given a linear demand function, the review shows that the degree of price transmission in the presence of oligopoly power is smaller than that in the perfectly competitive model.

The review also shows that for a given degree of competition in the markets for inputs and for the final product, and assuming all other parameters remain constant, the degree of price transmission is sensitive to the nature of returns to scale characterizing industry technology. *Ceteris paribus,* relative to the degree of price transmission obtained assuming constant returns to scale in industry technology, the degree of price transmission is greater when industry technology exhibits increasing returns to scale and smaller when industry technology exhibits decreasing returns to scale.

4.8.2 Possible directions for further research

As our review has made evident, the theoretical models of price transmission are premised on restrictive assumptions. First, they assume that the degree of price transmission is insensitive to the direction of change in the conditions of input supply or in those of retail demand. In other words, they assume that the magnitude and speed of change in retail price is symmetric with respect to an increase as well as a decrease in the price of the farm input. Second, not only do they assume that in the process of exchange on the spot trading occurs between retailers and input suppliers with the result that there is no need for any explicit contractual agreement to be put in place but they also assume that the boundary between retailers and input suppliers is distinct. Finally, as our review has shown, in accounting for market power, the models of price transmission assume the existence of only selling power (i.e., oligopoly power) and not buying power (i.e., oligopsony power) despite the latter's significance in vertically-related markets.

As a review of the literature will show, however, not only is it possible for the magnitude and speed of change in retail price to be asymmetric with respect to an increase as well as a decrease in the price of the farm input but it is also possible for retail price adjustment to cost changes to be rigid (sticky). Furthermore, it is possible for the process of exchange between producers and retailers to be characterized by a contractual agreement and for the boundary between retailers and input suppliers to dissipate as much as it is possible for market power to reveal itself in farm supply. In the following, we present a brief review of the existing literature regarding each of these theoretical possibilities. Let's first examine the literature regarding price asymmetry.

Contracting

The models of price transmission that we have reviewed so far have implicitly assumed that, in the process of exchange, on the spot trading (arms-length pricing) occurs between retailers and producers with the need for any explicit contractual agreement being ruled out as the two sides of each transaction are involved in a take-it-or-leave-it exchange.

But in the real world, a contract (be it explicit or implicit) plays a very important role in mediating trade of a "quid pro quo" type. Such a role becomes more important when the trading partners are involved in a long-term relationship whereby the quo is effected long after the quid (Hart and Holmstrom, 1989). Of major interest in this regard is the kind of long-term relationship that involves asset-specificity (Williamson, 1985).

The notion of asset-specificity holds that a small number of parties make a huge investment in specific assets which are made with an eye for a particular transaction (physical asset specificity); or in locations that are linked in a 'cheek-by-jowl' manner so as to economize on inventory and transportation costs (site-specificity); in human capital, arising in a learning-by-doing manner (human asset specificity); and in a generalized production capacity that is built with a specific buyer in mind (dedicated assets).

In all these four cases, the opportunity cost of investment that has already been made is much lower in the best alternative uses. These asset-specific investments thus produce a 'lock-in effect' such that, potentially, either party to the transaction will have a monopoly power ex post (after the investment is made) despite the fact that there might have been free competition ex ante (prior to making the investment). To forestall the possibility of such ex post monopoly power, parties to the transaction enter into a long term contractual relationship and make arrangements for governing the relationship.

In the extant literature, it is rare to come by theoretical models which analyze the degree of price transmission taking account of the fact that the different stages of the vertical market are locked-in in a contractual agreement. However, some contributors to the literature have made the point that the existence of a contractual relationship between agents in different stages of a vertical market (i.e., agents at the farm and retail stages) opens up the way for vertical market practices that cannot be captured by models of price transmission that we have reviewed so far. Known in the literature as vertical market restraints, these practices emanate when the balance of negotiating power between the retail and supply stages in the vertical market is lopsided such that the stage which negotiates from a position of strength extracts rent from that stage which negotiates from a position of weakness. Potentially, this power can abide in either stage.

McCorriston and Sheldon (1997) identify several such practices both in the UK and US food markets ranging from *discounts*, *full-line forcing*, *exclusive distribution*, *exclusive territories*, and *slotting allowances.* Discounts are defined as concessions which the retailer gets for carrying the supplier's brands. *Full-line forcing* is defined as a practice which forces the retailer to carry the complete range of a supplier's goods whereas *exclusive distribution* and *exclusive territories* are defined as contractual provisions that restrict not only a retailer's carrying only the supplier's brand but also restrict the geographical area of sales of that brand. On the other hand, *slotting allowances* are defined as fees which suppliers pay to the retailer for shelf space. While the first four practices arise when the supplier has more negotiating power than the retailer, the last practice arises when the retailer has more negotiating power than the supplier. The emergence of own-label products in big supermarkets in recent years has been interpreted as an increase in retailer's exercise of leverage over suppliers.

Theoretically, the social impact of these practices has been shown to be ambiguous. Operating within the framework of manufacturer-retailer bargaining model whereby the supply stage exercises monopoly power while the retail stage exercises oligopoly power, Dobson and Waterson (1997), for instance, show that the impact of this bilateral bargaining on the level of price consumers get depends on whether retailers sell identical or differentiated goods. They find that consumer price is lower if the services of competing retailers are very close substitutes for one another. If the services of competing retailers are differentiated, on the other hand, the price level consumers get is higher because the bargaining leads not only to the increase in the price-cost margin of retailers but also to an increase in rent which the supplier extracts from the retailers.

Whatever the case, the existence of contractual relationships between the retail and supply stages in a vertical market will definitely have a substantial implication for models of price transmission which account for the impact of market power. Recalling from our review of the literature, the standard approach measures market power as an index of the gap between retail price and marginal cost. As such, it measures market power in terms of variables that are easy to measure but variables that are not adequate . However, McCorriston (2002) argues, that such variables lack adequacy to capture the full complexity of market power. He further argues that if existing models are to inform on the full impact of market power on the degree of price transmission, market power needs to be re-defined to take account of trading practices which come about when the relationship between the supply and retail stages in the vertical market is contractual rather than an 'arm's length pricing'.

Vertical integration

The models of 'arm's length pricing' that have been considered so far assume that the contracting parties (firms) in a vertically related industry have distinct boundaries; i.e., they are independent entities. They do not treat the special case where both might be vertically integrated such that any contractual relations or market exchanges are ruled out. But in the real world vertical integration assumes an important place as one of many forms of economic exchanges.

Perry (1989) describes a firm as vertically integrated

> if it encompasses two single-output production processes in which either (1) the entire output of the "upstream" process is employed as part or all of the quantity of one intermediate input into the "downstream" process or (2)

the entire quantity of one intermediate input into the "downstream" process is obtained from part or all of the output of the "upstream" process (p. 185).

As the above description evidently shows, the defining feature of vertical integration is that it eliminates contractual or market exchanges and replaces them with internal exchanges within the boundaries of the firm. Apart from guaranteeing internal exchanges within the boundaries of the firm, vertical integration offers the firm complete ownership and control over neighboring stages of production or distribution and thereby gives it complete flexibility to decide over matters of investment, employment, production, and distribution relevant to all stages within the firm.(p. 186).

The latter description of vertical integration, however seems to suggest that the nature of the firm's relationship with labor and capital cannot be predetermined. Grossman and Hart (1986), for instance, focus on ownership and complete control over assets in defining vertical integration For them, whether the workers are employees or independent contractors does not in anyway alter the extent of vertical integration. On the other hand, for Williamson (1975) all that matters for distinguishing vertical integration is that the firm switch from purchasing inputs to producing them by hiring labor. For him, capital can be either owned or leased without altering the extent of vertical integration.

Vertical integration is a generic concept that might incorporate vertical "formation" which describes integration at the time of the firm's creation ; vertical "expansion" which describes a firm's internal growth that translates into formation of new subsidiaries in neighboring stages; or vertical "merger" which describes vertical integration occurring through the acquisition by one firm of an existing firm in a neighboring stage. (Perry, op cit P. 187).

Perry, *op cit* summarizes three broad determinants of vertical integration: technological economies, transactional economies and imperfect competition in the market. Technological economies may give rise to vertical integration since a firm which has integrated the upstream processes requires less of the other intermediate inputs in order to obtain the same output in the downstream process. Vertical integration arising from technological economies is deemed more important in flow process operations (chemicals, metals, and so on), the most-oft cited example being the integration of iron and steel making where there is a substantial saving of energy from not having to reheat iron.

The way transactional economies might give rise to vertical integration is well explained by Williamson (1975, 1985). According to him, contractual exchanges between a buyer and a seller involve costs which arise, in the main, from investments in assets which are specific to the contract. These investments are considered specific; and, outside of the contract, their opportunity cost is low. Hence, the notion of asset specificity.

The presence of asset specificity in the contract gives rise to "bilateral monopoly" and the corresponding "quasi-rents" expressed as the difference between the asset's value under the contract and that outside of it. The existence of such rents in turn encourages "opportunistic" behavior on the side of either party with each trying to extract these rents using, as a stick, the threat of withdrawing from the contract absent any price concessions (so called "hold up" problem). When asset-specificity is substantial, and the environment complex and uncertain, the cost of governing "opportunistic" behavior under the contract becomes huge so much so that internal exchange through vertical integration might be the preferred mode of industrial governance.

Finally, imperfect competition in a market may give rise to vertical integration when such a market is characterized either by monopoly or monopsony. A typical example is when, in a vertically-related market, an upstream monopolist forward-integrates into the competitive downstream stage which employs, with other intermediate inputs, a monopolist's product upstream in variable proportions.

In such circumstances, owing to a very high product price set by the monopolist, the downstream firm may be compelled to substitute the monopolist's product for other inputs that are supplied competitively at a cheaper price. Consequently, the monopolist is forced to give up its profit from the sale of its product to the downstream firm. To recoup lost profit, therefore the monopolist might have an incentive to forward-integrate into the downstream stage. It should be noted that such an incentive to integrate would not have existed had the downstream firm applied fixed proportions technology because, in this case, the derived demand for the monopolist's output would move in proportion to consumer demand.

Yet another incentive for vertical integration arises when a monopsonist backward-integrates into an upstream stage that is competitive. Suppose a firm is the sole buyer of a raw material (monopsony case) supplied by competitive firms that are subject to a rising supply price. Because of the rising supply price, manufacturers in the upstream stage produce too little of the raw material. Consequently, they bid up its price and create monopsony inefficiency. To correct this inefficiency therefore the monopsonist backward- integrates into the upstream stage.

The list of determinants is too long to be summarized here. And, of course, the major interest of this survey is not to analyze the determinants of vertical integration (see Perry 1989, *op cit* for a comprehensive survey). It is rather to see whether the predictions of the price transmission models in a non-integrated market, reviewed in the preceding, are borne out to the same degree in a vertically-integrated market.

As far as we are aware, there seems to exist no theoretical model of price transmission which operates within the framework of a vertically-integrated market. Therefore a comparison of the predictions of the price transmission models for integrated and non-integrated market structures is not possible.

McCorriston and Sheldon (1996), however, come close to approaching this issue when they analyze the role of intermediate stages, in the production and distribution system of the EU banana regime, on the pass-through of tariff changes to final goods' prices. Using the predictions of a two-stage theoretical model of a market whereby both the wholesaling (which processes and distributes an imported intermediate good, in this case banana) and retailing stages exercise oligopoly power, they run policy simulations for the UK banana market both when the market is vertically integrated (i.e., when the market is thought of as a single stage) and when it is vertically related[11].

[11] In their case too, the issue of vertical integration is approached only indirectly. In fact, there is no

Table 4.1: The effects of policy changes on the degree of price transmission

Market structure	Degree of pass-through
One/Two stage-perfect competition	1.00 (1.00)
Single-stage monopoly	0.50 (0.50)
Two-stage monopoly	0.25 (0.25)
Single-stage Cournot oligopoly	0.71 (0.76)
Two-stage Cournot oligopoly	0.38 (0.43)

Using the UK banana market data for 1989, and assuming a 14 % fall in import tariff, they simulate the effects of policy changes on the degree of pass-through (price transmission from the wholesaling stage to the retailing stage) and on consumer welfare. As our interest, however, is to see how price transmission operates in vertically-related and vertically-integrated markets, we only present their simulation results for the effects of policy changes on the degree of tariff pass-through under different market structures and for two differentiated products.

The above simulation results clearly indicate that relative to the competitive case, a higher degree of tariff (cost) pass-through obtains when the industry is vertically integrated (as proxied by a single-stage production) rather than when it involves a multi-stage production process. This is true both for monopoly and oligopoly markets.

A disaggregated downstream sector

All the theoretical models of price transmission that we have reviewed thus far do not distinguish between processing and retailing stages. They rather treat them as a single stage. Obviously, doing this simplifies evaluation of the degree of price transmission from the farm to the final product sectors but it might not reflect reality on the ground. It is a well known fact that many vertically-related industries have the processing and retailing stages as separate entities. In theoretical modelling therefore it is necessary to treat them

reference to the single-stage banana market as being synonymous with a vertically-integrated industry. But from their analysis, it can easily be deduced that, when talking about a one-stage market, all they have in mind is a vertically-integrated banana market with the retailer processing and distributing the imported item by itself (partial integration, in this case, back-ward integration).

as such. And this implies that there be three stages in the market, i.e., farm, processing and retailing stages, rather than two, as is usually assumed in practice.

As McCorriston and Sheldon, *op cit.* have shown, modelling price transmission within the framework of a three-stage industry does not alter the qualitative predictions regarding the degree of price transmission which derive from a two-stage framework. But the quantitative implication of modelling along this line for the degree of price transmission (i.e., the magnitude of the price transmission elasticity) can be considerable when these stages are characterized by market power. Hence, a theoretical development of a price transmission model which accounts for more than two stages in the industry can make for an interesting research pursuit.

Oligopsony power

As can be recalled from the price transmission models that we have reviewed (see, for instance, McCorriston *et al.*, 1998), the impact of market power on the degree of price transmission is analyzed assuming that the retail stage exercises only selling power and not buying power over suppliers. However, buying power could be at least as important, if not, more so than seller power. From their investigation into the UK food chain, for instance, the Monopolies and Mergers Commission (MMC, 1981) and the Competition Commission (CC, 2000) report that the grocery multiples had used their buying power to obtain discounts from suppliers. Indeed, of the 52 practices that were identified by the CC as characterizing the vertical relation between retailers' and suppliers, 27 stood to operate against the public interest (i.e., against the suppliers and in some cases against the consumers). Dobson *et al.* (1999) also point to the potential for abuse of buying power in recent trends in the growth in concentration of UK retailing.

To date, there seems to have been no formal treatment of oligopsony power's impact on the degree of price transmission. All the relevant contributions made so far in connection with oligopsony power have focused either on measuring its degree as in, for instance, Schroeter (1988); Azzam and Pagoulatos (1990); Rogers and Sexton (1994);

or on comparative statics analysis of the effects of a farm product supply shift on retail price, output and profit as in Chen and Lent (1992); or on returns to research as in Alston et al. (1997).

Given that the food industry is potentially both oligopolistic and oligopsonistic, the absence of any formal treatment of oligopsony power's impact on the degree of price transmission has meant that the combined effects of oligopoly and oligopsony power on the degree of price transmission cannot be assessed. Thus, a theoretical development of a model of price transmission accounting for the effects of both oligopoly and oligopsony power is a possible avenue for further research.

Aggregation

As our review has shown, the issue of aggregation features a key element in studies which model price transmission allowing for oligopoly power in the retail sector of an industry composed of multiple firms that produce a homogeneous product. The aggregation issue arises because most often empirical work is conducted with the industry rather than the firm as a unit of analysis, as most variables of interest are available at the industry level. Different price transmission models deal with the issue of aggregation differently. One category of models (See, for instance, Bhuyan and Lopez, op cit) aggregates over firms to obtain industry level variables by applying the consistent aggregation conditions suggested by Iwata, op cit and Appelbaum, op cit. This category of studies achieves aggregation at the industry level with respect to the variables of interest, i.e., industry marginal cost and conjectural variations by normalizing firm-level variables by market shares and by assuming that firms face the same marginal cost, the same retail price and the same demand elasticity and that, in equilibrium, they have the same conjectural variations.

This mode of aggregation is criticized on several grounds. Firstly, the assumption of identical marginal costs that derives from the application of the Gorman polar cost function, which assumes that firms have different fixed costs but identical slopes because different firms' cost functions are parallel to each other, is unrealistic. In fact, as Bresnahan, op cit shows, in the presence of market power, the marginal costs of firms are likely to vary in equilibrium.

Secondly, the practice of normalizing firm-level variables by market share is open to criticism. This criticism is particularly directed at the implicit assumption that firms of similar market share have similar conjectural elasticities. This assumption is steeped in the belief that firms operate at the same level of physical capacity and have the same financial status in relation to the capital market. Haskel and Scaramozzino (1997) show that this might not be necessarily the case. Assume a quantity-setting conjectural variations model where two firms have the same market share but operate at different levels of physical capacity. Given this assumption, they argue, a rival without spare capacity cannot respond to changes in output levels by the other firm in the same way that a firm with a spare capacity can. Consequently, the two firms would not have similar conjectural elasticities. Now assume two firms have similar market shares but one has a better access to the capital market than the other. As a result, they would not have the same conjectural elasticities because a rival's response to quantity changes by the other firm would depend on the ease with which it can raise funds. Furthermore, as Deaton and Muellbauer (1980) and Allen (1998) point out, providing that firms' products are strict substitutes, the industry's demand system is not insensitive to the market shares of firms. This is because as the firm's market share rises, the elasticity of demand for its product becomes more inelastic. The implication is that two firms with different market shares cannot face the same demand elasticity for their products as often assumed in this kind of models.

Thirdly, this mode of aggregation is insensitive to whether the firm is a leader or a follower. However, a firm's reaction to changes in output by other firms certainly depends on whether that firm is a leader or a follower. In a quantity-setting conjectural variations model of oligopoly therefore it is reasonable to expect two firms to react differently in response to a quantity change by a particular firm depending on whether they are a leader or a follower.

Several studies have avoided the first two criticisms by normalizing firm-level variables by the number of firms rather than by market shares. See, for instance, McCorriston, et al. (2001). This is in keeping with the procedure suggested by Cowling and Waterson, op cit. who do not only allow for differences in firms' marginal costs but during aggregation normalize industry level variables using the number of firms thereby totally avoiding market shares. Despite this improvement, however, many a study in the price transmission literature seem to suffer from the third criticism. One fruitful avenue of research that can be pursued in the future is therefore to model price transmission allowing for market power in the context of a Stackelberg model whereby firms are categorized according to whether they are leaders or followers.

'Prices rise faster than they fall': price asymmetry

Recent years have seen the emergence of a vast literature on price asymmetry. This has been motivated by the widespread belief that in response to cost changes not only do prices rise faster than they fall (short-run price asymmetry) but they also rise by a greater magnitude than when they fall (long run price asymmetry). In this small section, we do not pretend to undertake an exhaustive review of studies that have been carried out with price asymmetry as their major theme. And of course, our major aim is to see whether there is any evidence of price asymmetry in the literature. To make our point therefore we will present the findings of only selected studies. As far as we are aware, there has not been any theoretical work which models price asymmetry in vertically-related markets. All the findings that we present will therefore be extracted from empirical studies.

Peltzman (2000) carries out a comprehensive study to test for the symmetric response of output price to changes in costs. He utilizes monthly economy-wide data on 77 consumer and 165 producer goods in the United States and finds that in over two-thirds of the sample, the null hypothesis of symmetry in price transmission is rejected. This applies both in the short- and long-run cases. Thus, his findings support the widespread belief that prices rise faster than they fall (i.e., price transmission is asymmetric) in response to cost changes. When he analyzes data for a specific supermarket chain, however, he doesn't find any systematic asymmetry. His findings thus appear to suggest that price asymmetry is a phenomenon that is unique to economy-wide data and not to firm level data. Given that he considers only a single cost component relating to a major input in each of the product categories, it is difficult to evaluate whether output prices respond asymmetrically to cost shocks in general and not just to changes in the price of a single input.

Analyzing fortnightly data for US retail and crude oil prices from March 1986 to December 1992, Borenstein *et al.* (1997) had previously shown that the change in retail gasoline price is greater for an increase than for a decrease in crude oil price. In a similar exercise, Kinnucan and Forker (1987) had shown, using monthly data for four major dairy products in the US spanning January 1971-December 1981, that the farm-retail price transmission in the dairy sector is asymmetric.

Using a monthly series for crude oil and retail petrol prices for the UK over the period January 1982 to June 1995, Reilly and Witt (1997) also reject the hypothesis of a symmetric response by petrol retailers to rises and falls in crude oil prices. Earlier, Bacon (1991), using fortnightly data from 1982 to 1989, and Manning (1991), analyzing monthly data from March 1981 to December 1989 for the UK had found evidence that pump prices in the UK show a faster and more concentrated response to cost increases than to cost decreases.

Analyzing producer and wholesale prices for pork in northern Germany from January 1990 to October 1993, von Cramon-Taubadel (1997) also finds that price transmission between the producer and wholesale levels of the pork market in northern Germany is asymmetric.

Meyer and von Cramon-Taubadel (2002, mimeo.) present an extensive survey of the literature on price asymmetry. Spanning the period, 1980-2002, their survey identifies 38 scientific studies that have tested the null hypothesis of symmetry in the degree of price transmission using different econometric applications. Of the 197 such tests run for a broad category of products, nearly one-half reject the null hypothesis of symmetry.

As this brief review of the literature shows, there seems to exist a huge body of empirical evidence to suggest that price transmission in vertically-related markets is asymmetric. Several contributors have invoked different explanations for the asymmetric response of retail price to input price changes.

Using a model in which firms take account of menu costs and inflation in their decisions to adjust their desired level of price, Ball and Mankiw (1994) show that shocks which increase a firm's desired price will trigger a greater response than shocks which reduce it. This is because firms will take advantage of positive shocks to correct for accumulated and anticipated inflation, while inflation will already have effected some of the adjustments made necessary by negative shocks by reducing real prices.

Market power at the retail stage of an industry has been cited as a possible explanation for price asymmetry (see, for instance, von Cramon-Taubadel, 1998; Borenstein *et al.*, 1997). This explanation proceeds by saying that in an attempt to hide market power, oligopolistic retailers will collude more quickly in response to shocks that squeeze their margin (i.e., shocks that raise raw input price) than to shocks which stretch this margin (i.e., shocks which lower raw input price). This, they propose, generates an asymmetry in the speed with which retail price responds to cost changes. Without having to allow for collusion among oligopolist firms, another view ascribes asymmetry to firms' conjecture in an industry that in response to cost increases rivals increase their retail prices by much more than they reduce them in response to a proportional fall in costs (Bailey and Brorsen, 1989).

The plethora of studies pointing to the existence of price asymmetry in the degree of price transmission seem to suggest that an empirical test for the sensitivity of the elasticity of price transmission both to market structure parameters and to processing technology should be supplemented with tests for its sensitivity to price asymmetry. At a theoretical level, however, this plethora is a pointer to a possible extension of the existing models of price transmission to account for the asymmetric response of retail price to changes in the price of the raw input.

4.9 Extensions

In the previous section, we have presented a summary and an evaluation of the existing models of price transmission. First, it has shown that these models assume the same degree of price transmission when the shock is positive as when it is negative. Second, it has shown that these models operate within the framework of a two-stage industry. Third, it has shown that any transactions among the different stages of the vertical market take place on the spot and not on a contractual basis. Finally, it has shown that market power applies to the retailer-consumer relation and not to the retailer-supplier relation.

By way of a critique, it has pointed out that; (1) price adjustment can be asymmetric depending on whether the shock is positive or negative; (2) there can be more than two-stages involved in the production process of vertically-related markets; (3) transactions among the different stages can take form in a contractual relation rather than in on-the-spot trading; (4) aggregation (5) the retailer-supplier relation can be characterized by market power (i.e., oligopsony power) as much as the retailer-consumer relation is characterized by oligopoly power.

The above critiques are pointers to the possible theoretical extensions that can be made in the future regarding research on price transmission. The first possible extension is to allow for asymmetry in retail price adjustment to changes in farm input price. The second possible extension is to allow for more than two stages in the vertical market. Another potential extension is to allow for contracting rather than on-the-spot trading among different stages of the vertical market. The last but not least theoretical extension is to allow for market power in the retailer-supplier relation and then evaluate its interaction with oligopoly power..

Obviously, incorporating all these extensions in a single framework is not going to be an easy task. However, an extension of the existing models of price transmission to account for either of these possibilities is quite feasible. In this thesis we set out to extend the existing theoretical models of price transmission allowing for market power in the retailer-supplier relation. Particularly, we allow for oligopsony power in the farm sector. We then allow for its interaction with oligopoly power in the retail sector and assess the impact of this interaction taking the degree of price transmission in a perfectly competitive market as a benchmark.

4.10 Plan for the rest of the thesis

Throughout the preceding chapters, we have attempted to offer the reader a reasonable inventory of the extant theoretical literatures on price transmission in vertical markets. To recap what we have done thus far, in chapter 2 we have provided an intuitive approach to understanding the mechanisms through which changes in the price of the farm input is transmitted to the price of the final product. Apart from being intuitive, this chapter has set the stage for a more rigorous analysis of the degree of price transmission in chapter 3 in which we have reviewed the degree of price transmission in vertically-related markets assuming that both the input and output markets are perfectly competitive, that inputs are combined in variable proportions and that industry technology is characterized by constant returns to scale. In chapter 4, we have introduced the reader to the major extensions that have been made to the model expounded in chapter three, namely the models of price transmission accounting for oligopoly power in the output market, and for non-constant returns to scale in industry technology.

As might be recalled, we have identified, wherever appropriate, the existing gaps in the theoretical literature and suggested several possible research avenues that can be pursued in the future. Such include: modelling price transmission allowing for oligopsony power in the retailer-supplier relation; modelling price transmission allowing for a contractual relation between retailers and input suppliers; modelling price transmission allowing for an asymmetric response of retail price to a rise as well as a fall in farm input price; and modelling price transmission allowing for a disaggregated downstream sector of the vertical market. Of all these contributions, the one we have picked out as being of major policy significance is modelling price transmission when, *ceteris paribus*, the retailer in the vertical market exercises oligopsony (buyer) power.

On this particular front, we categorize our specific contributions into two. Our first contribution involves extending the Gardner model (1975) of price transmission in vertical markets assuming that the retailer in the vertical chain exercises oligopsony power over the sellers of the farm input. We then further extend the model assuming that the retailer not only exercises oligopoly power in its relation with farm input suppliers but that it also exercises oligopoly power in its relation with consumers. This is presented in chapter 5. Our second contribution involves simulating the degree of price transmission when the retailer exercises market power both in its relation with consumers and suppliers of the farm input given our assumption regarding retail demand and farm supply functions, input proportions and the cost share of the farm input in total industry cost. We then evaluate the interaction between and the significance of each of these market structure parameters. This is presented in chapter 6.

Chapter 5

The degree of price transmission under the assumption of oligopoly and oligopsony power

5.1 Background

We have shown earlier, through a survey of the existing theoretical literature, that the effect, on the degree of price transmission, of allowing for oligopoly power at the retail end of a vertically-related industry is ambiguous. This is because the outcome for the degree of price transmission depends on the type of retail demand function faced by the industry.

To date, the impact of market power on the degree of price transmission has been analyzed exclusively in the context of oligopoly power. There seems to have been no formal treatment of the impact of market power when retailers exercise buying power (i.e., oligopsony power) over farm input suppliers. All the relevant contributions made so far in connection with oligopsony power have focused either on measuring its degree as in, for instance, Schroeter (1988); Azzam and Pagoulatos (1990); Rogers and Sexton (1994); or on comparative statics analysis of the effects of a farm product supply shift on price, output and profit as in Chen and Lent (1992); or on returns to research as in Alston *et al.* (1997).

This chapter therefore sets out to examine the impact of oligopsony power in the farm sector on the degree of price transmission assuming all other sectors are perfectly competitive. It then allows for the interaction between oligopoly power at the retail sector and oligopsony power in the farm sector. With these aims in mind, the chapter develops a model where both oligopoly and oligopsony co-exist. Using this model, it then analyses the effects of functional forms on the degree of price transmission.

It might be wondered as to why oligopsony power should be assumed to apply only in the supply of the farm input. Rogers and Sexton (1994) identify several reasons why oligopsony power is more likely to apply in this market than in the market for other inputs. Firstly, the bulky and perishable nature of this input makes the cost of shipping so high that producers are limited in their geographic mobility and thus are forced to supply their produce to buyers who are close to their outlets. Secondly, the specialized nature of processors' needs for the farm input renders it very difficult for them not only to substitute other farm inputs for the input they process but also to substitute the latter for other farm inputs in alternative processes of production. Thirdly, the extensive investments that farm input producers put in sunk assets in order to specialize in the production of particular farm commodities renders the supply of these commodities inelastic. In other words, such investments are potentially fraught with Williamson's 'hold-up problem'.

Buyer power can be defined, following Dobson et al. (2001), as the ability of leading retail firms to obtain from suppliers more favorable terms than those available to other buyers or to be expected under normal competitive conditions. In this context, buyer power can mean not only the ability of retail firms to extract discounts from suppliers, but also their ability to place contractual obligations, commonly known as vertical restraints, on suppliers. While the ability to extract discounts might manifest itself in the price mark-down which we will define later, the ability to place vertical restraints can take several forms. It can, for instance, take form in listing charges whereby buyers require a fee payment before goods are purchased from the listed supplier; in slotting allowances whereby the buyers require a fee for the allocation of shelf-space; and in unjustified high contribution by suppliers to promotional expenses by retailers, to name just a few.

In the presence of buyer power in a vertically-related market, it is difficult, *a priori*, to derive the implications for the degree of price transmission which would obtain under a perfectly competitive industry. As we will show later on in the chapter, this is because, in and of itself, buyer power has very little to do with price transmission. As far as the outcome for the degree of price transmission is concerned, buyer power in an industry matters only to the extent that retailers use this power either to extract discounts from or to impose vertical restraints on suppliers. Dobson et al. (2001) identify three conditions which have to be satisfied for retailers to be able to exercise their buying power over suppliers. These are that (i) they contribute to a substantial portion of purchases in the market; (ii) there are barriers to entry into the buyers' market; and (iii) the farm supply curve retailers face is less perfectly elastic; i.e., it is upward sloping.

Assume now the above three conditions for the exercise of buyer power are satisfied. When is the exercise of buyer power by retailers believed to be bad for price transmission taking, as a benchmark, the degree of price transmission which obtains in a perfectly competitive market? What are the welfare costs which result from the exercise of market power that warrant government intervention? Assuming such welfare costs exist, is it producers or consumers who lose out most? To answer these questions we need to consider some intuitively appealing theoretical insights from the literature regarding the effects of buyer power both when it exists in isolation, and when it interacts with seller power.

First, consider the case of an industry where retailers exercise buying power in their relation with farm input suppliers but not selling power in their relation with consumers. Further assume that the supply sector is characterized by perfect competition. This kind of market structure matches our description of buyer power that exists in isolation. As we will show later in the chapter, when buyer power prevails in the market, the price paid producers is less than that in a perfectly competitive input market. On price transmission considerations, Dobson et al.. (1997, 2001, 2003) argue that, in isolation, buyer power is not necessarily bad. In fact, if the competition among retailers is so intense, it is possible that lower price paid to farmers might feed through to lower retail prices and thereby enhance the degree of price transmission from the farm to the retail sector. The degree of price transmission thus achieved can be further enhanced if there are cost savings associated with the joint purchasing implied by buyer power. Thus, on price transmission considerations, the exercise of buyer power by retailers in such a market structure cannot be judged to be bad. On welfare considerations, however, there seems to be reason to believe that the exercise of such power is bad to the extent that it lowers the price producers get to levels below the perfectly competitive market. Yet, whether the prevalence of buyer power and its exercise by retailers is bad on considerations of overall social welfare is unclear. This is because the net social welfare effect depends on the relative importance of the welfare gain consumers enjoy by getting lower price for the final good they purchase and the welfare loss that producers suffer by receiving lower price for the good they sell to retailers.

Now consider the case of an industry where retailers exercise buyer power over suppliers at the same time that they exercise seller power over consumers. In this case, any lower price paid to farm input suppliers might not feed through to consumers as the discount extracted from the suppliers might increase retailers margin instead. In fact, depending on the elasticity of market demand, consumers might end up paying a higher price as a result of mark-up pricing. In this particular instance, the exercise of buyer power is bad both on price transmission and social welfare counts. It is bad on the first count because relative to that in the perfectly competitive case, the degree of price transmission which obtains in this type of market structure is smaller. It is bad on the second count because of a social welfare loss resulting from consumers paying a higher price than they would have paid if there were no seller power and from producers receiving a lower price than they would have if there were no buyer power. Much of the discourse, among policy and academic circles, on the effects of market power both on the degree price transmission and on social welfare seems to have been inspired by this theoretical insight.

Next consider the case of an industry where retailers exercise buyer power over producers at the same time that the latter exercise seller power over retailers. This is the case of what is commonly known in the literature as bilateral bargaining (see Dobson et al., 1997). *A priori*, one cannot evaluate the effect of bilateral bargaining on price transmission and on social welfare. This is because the observed outcomes for price transmission and social welfare reflect the relative bargaining power of sellers of the farm input and of its buyers. If, relative to buyer power, the seller power of suppliers is more significant, then the price paid to farmers might be higher than in a perfectly competitive market the implication to consumers being that they have to pay a higher price for the final product, and,.consequently, suffer a welfare loss. If, on the other hand, relative to the seller power of producers, buyer power is more significant, then it is more likely that producers get a price lower than that in the perfectly competitive case. It has to be noted, however, that owing to their bargaining position, producers are less likely to get a price as much lower as in the first case we considered, i.e., a case where seller's bargaining power is assumed away. Whether lower prices thus forced on producers will feed through to final good prices as in the first case we considered depends on whether retailers exercise seller power over consumers. Given this market structure therefore it is difficult to say which of the two market powers prevails on balance.

To this point, we have conceived of buyer power in the context of only discounts that retailers get from suppliers. As such, we have disregarded the impact that buyer power, in the form of vertical restraints, can have on the degree of price transmission and welfare be it in isolation or on interaction with seller power. However, as we have pointed out above, the retailer-supplier relation might be characterized by vertical restraints which not only drive farm prices down but also restrict producers' freedom to supply elsewhere. As Dobson et al. (2003) argue, on social welfare considerations, these practices are harmful to the farm input producers. Firstly, they drive down farm prices to a level below the perfectly competitive case. Secondly, by driving prices down in this way, they not only force small producers, who are not efficient, out of business but also threaten the viability of even efficient producers whose investments are undermined by their inability to recover fixed costs now that they are forced to price at short run marginal cost. The only category of suppliers who are more likely to resist buyer power in the form of vertical restraints remain those producers with a strong product identity that appeals to final consumers and those who exert market power to counter buyer power. Despite their harmful effects on producers' welfare nonetheless, the impact of vertical restraints on the degree of price transmission is less clear. In fact, as far as we are aware, there is not much done by way of research to analyze such an impact

Given the ability of buyer power both to extract discounts from and impose vertical restraints on producers, it comes as no surprise that the issue of price transmission and the social welfare implications that derive from it attracts a lot of attention in policy and academic circles. In this thesis, we do not intend to analyze the impacts, on the degree of price transmission, of both discounts and vertical restraints. For the purposes at hand, we will rather limit ourselves to the analysis of the effects of buyer power on price transmission only to the extent that such power manifests itself as the deviation of price producers receive from the perfectly competitive outcome. The first step in the analysis of the effects of buyer power on the degree of price transmission is to identify the existence of such power and measure its extent. Traditionally, the degree of buyer power has been measured using the elasticity of conjectural variations. And the derivation of this elasticity is the task we turn to next.

5.2 The elasticity of conjectural variations assuming oligopsony power

The major object in measuring oligopsony power is to see if firms in a particular industry are setters of price in the farm input market rather than price takers as in a perfectly competitive model. Whenever firms are behaving as price setters, it means that any changes they make regarding the quantity purchased of the farm input, through a price change, affect industry level purchase of the input. But industry-level changes in the quantity purchased of this input subsequent to a change in quantity purchased at the firm-level can arise because of a change in the quantity purchased by any one firm in the industry. This suggests that conjectural variations is the appropriate approach to measuring the degree of oligopsony power in the farm input market.

Recalling from our exposition of the model of oligopoly power, conjectural variation represents firms' beliefs about rivals' reactions to their choice of output assuming firms are competing in quantity. In other words, conjectural variation measures the rate of change in output of all other firms in response to a change in output of a representative firm.

Applying the notion of conjectural variations to the analysis of market power in the farm supply market is quite straightforward. We just simply measure the rate of change in the farm input purchased of all other firms in response to a change in the quantity of such input purchased by the representative firm. In this respect, conjectural variation measures firms' beliefs about rivals' reactions to their choice of farm input assuming firms compete in quantity purchased of the farm input. Competition among firms based on input price, as in the Bertrand model, is assumed away because, given the assumption that all firms purchase a homogeneous farm input, such a type of competition compels firms to set input price equal to the marginal revenue product thus making, superfluous, the notion of a mark-down which is central to the analysis of oligopsony power[1].

Sticking to the notation used in the basic model, and following in the footsteps of oligopoly models (see Iwata *op. cit.*; Cowling and Waterson, *op.cit.*; and Applbaum, *op.cit.*, among others), denote the quantity demanded of the farm input by the ith firm by a_i and that demanded by the industry as a whole by a. Assume that all firms in

[1] This conclusion derives from the application of the Bertrand model to an oligopsonistic competition of firms. The algebra is not presented here because it mimicks that for oligopolistic competition which we have presented in the literature review.

the industry are identical. Then the conjectural variation in the factor market where oligopsony power is present can be expressed as:

$$\frac{\partial a}{\partial a_i} = \frac{\partial a_i}{\partial a_i} + \frac{\partial\left(\sum_{j \neq i} a_j\right)}{\partial a_i} = 1 + s; \quad i{=}1,\ldots,\ n \tag{5.1}$$

where $\partial a/\partial a_i$ denotes the change in industry-level purchase of the farm input in response to a change in the quantity purchased of this input by the representative firm; The term $s = \frac{\partial\left(\sum_{j \neq i} a_j\right)}{\partial a_i}$ denotes the firm's conjectural variation.

Multiplying both sides of equation (5.1) by $\frac{a_i}{a}$, which denotes the firm's share in total industry purchase of the farm input, the elasticity of industry farm input conjectured by the ith firm, ϕ_i can be derived as:

$$\phi_i = (1+s)\,\frac{a_i}{a} = \left(\frac{\partial a}{\partial a_i}\right)\frac{a_i}{a} \tag{5.2}$$

The parameter, ϕ_i, measures the firm's conduct and is shown to be a function of both the firm's input conjectural variation, (s) and its input share (a_i/a). For a value of $\partial a/\partial a_i = 0 \Longrightarrow s = -1$, $\phi_i = 0$, indicating that the firm's decision to change the quantity of farm input purchased has no impact on industry level purchase which is exactly what obtains when the factor market under consideration is perfectly competitive. For a value of $\partial a/\partial a_i = 1 \Longrightarrow s = 0$ and $a_i = a$, $\phi_i = 1$, implying that there is either only one buyer in the market, in which case we say monopsony power exists in the farm input market, or all buyers have colluded. The intermediate case of $0 < \phi_i < 1$ obtains when the input market is characterized by oligopsony power with the special case of $\phi = \frac{a_i}{a} \Longrightarrow 1+s = 1$ and $s = 0$ representing Cournot competition.

5.3 Deriving the measure of oligopsony power: the price mark-down

In the presence of oligopsony power in the farm input market, the first-order conditions for a maximum profit for the representative firm strictly depend on the assumption made regarding the nature of production technology employed (Azzam and Pagoulatos, 1990).

If the production technology is such that the final product is related to the oligopsonistically purchased input in a fixed proportion, so that firms face a constant marginal cost for the marketing input, then the first-order condition requires that the marginal factor cost and the marginal revenue product net of the marginal cost of the marketing input be equal. This approach is evident in Schroeter (1988) and Rogers and Sexton (1994). Since this approach assumes fixed input proportions technology, it imposes identical conjectural elasticities in both the imperfectly competitive output and input markets because the final output and the oligopsonised input are represented by the same variable in the profit function.

If, on the other hand, the production technology allows for variable proportions between output and the farm input, then the first-order conditions reflect specific conjectural elasticities corresponding to the output and the oligopsonised input markets. This approach is followed by Azzam and Pagoulatos (1990), and Chen and Lent (1992) and recently by Kinnucan (2003).

In the manner of the latter approach, and in keeping with the assumption of variable input proportions which we have shown to be characteristic of the models of price transmission reviewed earlier, assume that an industry has n identical firms producing a homogeneous product (x) using two inputs, i.e., the farm input, a and marketing services, b.

Let the production function of the ith firm be denoted, by:

$$x_i = f\left(a_i, b_i\right) \tag{5.3}$$

where x_i represents quantity of the firm's final product; whereas a_i and b_i represent the quantities purchased of the farm and marketing inputs respectively. The production function, $f(.)$ is assumed to be smooth, concave and twice continuously differentiable. Technology is assumed to exhibit constant returns to scale and to combine inputs in variable proportions.

Given the assumption of variable factor proportions, the ith firm's cost function can be specified as separable in both inputs as:

$$C_i = P_a a_i + P_b b_i \tag{5.4}$$

where P_a and P_b denote prices of the farm and marketing inputs respectively.

Finally, let the industry's supply function of the farm input be specified, in inverse form, as:

$$P_a = g\left(a\right) \tag{5.5}$$

where

$$a = \sum a_i = a_1 + a_2 + ... + a_n \tag{5.6}$$

On the basis of the above specifications, the ith firm's profit function can then be specified as:

$$\pi_i = P_x x_i - P_a a_i - P_b b_i \qquad \text{for } i=1,\ldots,n \tag{5.7}$$

where P_x denotes the price of the final product.

Assuming that each firm's objective in the industry is to maximize profit, the problem of the firm is to choose a_i and b_i in order to maximize profit as in equation (5.7) subject to equations (5.3), (5.5) and (5.6).

The first-order conditions for a maximum of π_i are then derived as:

$$\frac{\partial \pi_i}{\partial a_i} = P_x f_{ai} - P_a - \left(\frac{\partial P_a}{\partial a} \frac{\partial a}{\partial a_i} \right) a_i = 0 \tag{5.8}$$

and

$$\frac{\partial \pi_i}{\partial b_i} = P_x f_{bi} - P_b = 0 \tag{5.9}$$

where f_{ai} and f_{bi} are the first-order derivatives of the profit function with respect to the farm and marketing inputs respectively. Assume that the second-order conditions for a profit maximum are satisfied so that,

$$\frac{\partial^2 \pi_i}{\partial a_i^2}, \frac{\partial^2 \pi_i}{\partial b_i^2} \leq 0 \tag{5.10}$$

Equation (5.8) can be interpreted as stating that the marginal value product of the ith firm obtained from employing an extra unit of the farm input, $P_x f_{ai}$, equals the perceived marginal factor cost of employing this extra unit, $P_a + \left(\frac{\partial P_a}{\partial a} \times \frac{\partial a}{\partial a_i} \right) a_i$. Alternatively, it can be interpreted as stating that once the level of farm input which maximizes profit is attained, the sum of the firm's profit that comes from employing an extra unit of the farm input (i.e., marginal value product minus price of the farm input) and the magnitude by which the price of the farm input has to increase in order for the extra unit of the farm input to be supplied to the industry equals zero. Algebraically, this can be expressed as:

$$P_x f_{ai} = P_a da + dP_a \frac{\partial a}{\partial a_i} a_i \tag{5.8a}$$

Factoring out P_a and multiplying the second term of the right-hand side of equation (5.8a) by $\frac{a}{a}$ and then division of the same by da and re-arranging we obtain:

$$P_x f_{ai} = P_a \left(1 + \frac{\phi_i}{e_a}\right) \tag{5.8b}$$

where ϕ_i is as defined in equation (5.2), and e_a is the price elasticity of supply for the farm input, $\left(\frac{\partial a}{\partial P_a} \times \frac{P_a}{a}\right)$.

Equation (5.8b) can be manipulated to appear as:

$$\frac{P_x f_{ai} - P_a}{P_a} = \frac{\phi_i}{e_a} \tag{5.8c}$$

In the manner of Bhuyan and Lopez (1997), the optimality condition in equation (5.8c) is weighted by the firm's share of farm input purchased in total industry farm input purchased, $\frac{a_i}{a}$ $= s_i$ to obtain:

$$\frac{s_i P_x f_{ai}}{P_a} - s_i = s_i \frac{\phi_i}{e_a} \tag{5.8d}$$

which, when aggregated over i yields the aggregate analog of optimality condition (5.8c)

for the industry as:

$$\frac{P_x f_a - P_a}{P_a} = \frac{\phi}{e_a} \tag{5.8e}$$

where $P_x f_a$ and ϕ are weighted marginal revenue product and weighted elasticity of conjectural variations in the farm input market respectively.

Aggregation over all firms to obtain the industry's measure of oligopsony power in (5.8e) is made possible by applying, in the reverse order, the necessary and sufficient consistent aggregation condition to derive the measure of oligopoly power at the industry level as presented in Applebaum (1982, p. 292).

This condition assumes that all firms have equal marginal costs which in turn requires that all firms' cost curves intersect at the same level of marginal cost without each firm having to have the same marginal cost curve. It also assumes that, in equilibrium, firms choose their level of output such that the conjectural elasticity, θ, is the same across all firms. But this does not require that all firms have identical conjectural elasticities. Finally, given an homogeneous product and the same industry price, it assumes that all firms face the same price elasticity of demand.

Applying the above condition for aggregation to derive an industry-level measure of oligopsony power, the requirement for the necessary and sufficient condition to hold is that all firms share the same marginal revenue product. This condition can only be satisfied when all firms face the same market price of output and the same marginal product. This also requires that all firms' marginal revenue product curves intersect at the same level of marginal revenue product without these marginal revenue product curves having to be identical. It also requires that all firms face the same input price, which together with the assumption of an homogeneous input, makes reasonable the assumption that all firms face the same elasticity of raw input supply. Finally, we assume that in equilibrium firms choose input quantities at which the conjectural elasticity, ϕ, is common to all firms. Again, this does not require firms to have the same conjectural elasticities.

In (5.8e), $\frac{\phi}{e_a}$ measures the farm input price distortion (input price mark-down) in the industry brought about by oligopsony power. It is measured as the percentage deviation of the marginal value product of the farm input ($P_x f_a$) from the marginal factor cost (P_a). It is clearly shown that the mark-down is proportional to the conjectural elasticity, ϕ, and inversely proportional to the elasticity of farm input supply, e_a.

For a given supply elasticity, this suggests that the more the market for the farm input gets oligopsonistic, the greater the price mark-down (the price distortion) becomes and *vice versa*. But this conclusion only holds for a price elasticity of farm input supply which is inelastic. When supply is perfectly elastic (i.e., when e_a approaches ∞), the implication is that no matter how oligopsonistic the market for the farm input is, the size of the mark-down becomes negligible approaching zero in the limit.

The measure of oligopsony power lies within the range of zero and $\frac{1}{e_a}$; taking the value of zero when $\phi = 0$, suggesting a factor market which is perfectly competitive, and a value of $\frac{1}{e_a}$ when $\phi = 1$ suggesting a factor market which is monopsonistic or collusive. The intermediate values of ϕ between zero and one, on the other hand, suggest a factor market which is oligopsonistic.

5.4 The oligopsonist firm's perceived marginal expenditure

In this section, we apply the procedure used to derive the oligopolist firm's perceived marginal revenue as in Quirmbach (1988) to the derivation of the oligopsonist firm's perceived marginal expenditure.

Let the expenditure of firm i on the farm input, E_i, be given by:

$$E_i = P_a(a)a_i \tag{5.11}$$

For a given E_i, the firm's marginal expenditure can then be calculated as:

$$\frac{\partial E_i}{\partial a_i} = \left(\frac{\partial P_a}{\partial a} \times \frac{\partial a}{\partial a_i} a_i \right) + P_a \tag{5.12}$$

For a firm which is the only buyer in the industry of the farm input, $\frac{\partial a}{\partial a_i} = 1$, and $a{=}a_i$. Taking note of these facts, the monopsonist's marginal expenditure, $\frac{\partial E_i}{\partial a_i}$, can then be written as:

$$\frac{\partial E}{\partial a} = \frac{\partial P_a}{\partial a} a + P_a \tag{5.13}$$

To derive the oligopsonist firm's perceived marginal expenditure, we first normalize the first term of the right-hand side of equation (5.13) by $\frac{a}{a}$, then add $\phi_i P_a - \phi_i P_a$, and rearrange to obtain:

$$\frac{\partial E_i}{\partial a_i} = \phi_i \left(\frac{\partial P_a}{\partial a} a + P_a \right) + (1 - \phi_i) P_a \tag{5.13a}$$

Noting that the first bracketed term of the right-hand side of (5.13a) represents the monopsonist firm's marginal expenditure and aggregating over all firms in the industry subject to the consistent aggregation conditions that we have discussed previously, the oligopsonist industry's marginal expenditure can be expressed as a convex combination of the monopsonist firm's marginal expenditure (MME) and average expenditure, P_a (AE), as:

$$\frac{\partial E}{\partial a} = \phi_i (MME) + (1 - \phi_i) P_a \tag{5.13b}$$

Equation (6.13b) is a generalized form of the pricing rules that apply to different

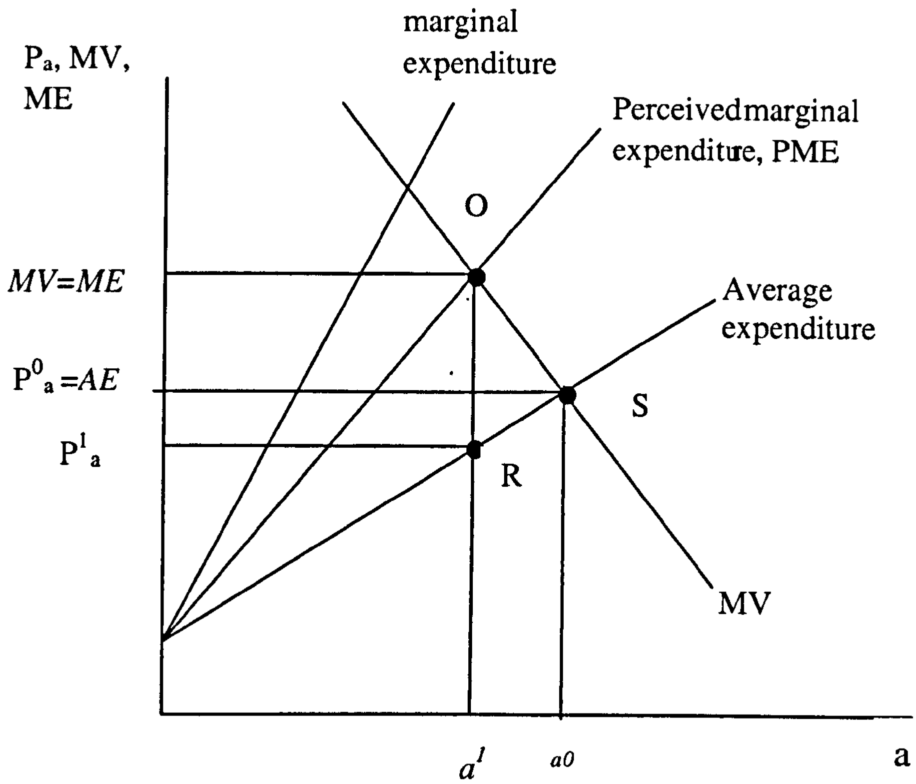

Figure 5-1: Pricing in an oligopsonistic factor market

market structures. When $\phi_i = 0$, implying the market for the farm input is perfectly competitive, perceived marginal expenditure equals average expenditure. For $\phi_i = 1$, implying the market for the farm input is monopsonistic, marginal expenditure is greater than average expenditure (see 5.13a). On the other hand, when $0 < \phi_i < 1$, implying that the market for the farm input is oligopsonistic, perceived marginal expenditure lies between the monopsonist firm's marginal expenditure and average expenditure. Assuming that the industry faces a linear supply function, this can be illustrated using Figure 5.1 where the horizontal axis represents the quantity purchased of the farm input, a while the vertical axis represents the price of the farm input, P_a the marginal value of the farm input and the marginal expenditure on the same input.

As Figure 5.1 clearly indicates, an oligopsonistic industry prices below the perfectly competitive level. When the market for the farm input is perfectly competitive, the industry maximizes profit by choosing that level of optimal purchase of the farm input, a^0, for which the marginal revenue product, MV, equals average expenditure, P_0 which is in turn equal to marginal expenditure, ME.

When the market is oligopsonistic, on the other hand, the optimal level of farm input the industry chooses to purchase, a^1, is that level for which the marginal revenue product equals perceived marginal expenditure. But at this level of optimal input, the price, P_a^1, paid the farm input is less than the marginal revenue product. It is thus evident that relative to the perfectly competitive industry, an oligopsonistic industry buys a smaller quantity of the farm input but at a lower price (average expenditure). The quantity purchased of the farm input becomes even smaller and the price paid even lower when there is a single buyer in the industry. The difference between the marginal revenue product of the farm input and the price paid this input constitutes the price mark-down, which, in the above figure, is shown as the rectangular area, $MVORP_a^1$.

5.5 Modelling vertical price transmission in the presence of oligopsony power

We now extend the multi-stage model of price transmission first developed by Gardner (1975) accounting for oligopsony power in the farm input market. As might be recalled, this model considers an industry with many identical firms which combine two factors of production (i.e., a farm input, a and marketing services, b) to produce a final product, x. The major assumptions underlying this model are that both the factor and output markets are perfectly competitive, that the factors are combined in variable proportions, and that the production function exhibits constant returns to scale. The extension introduced here will retain all these assumptions except that it will relax the assumption of the market for the farm input being perfectly competitive. In lieu of this, it will assume that this market is characterized by oligopsony power whereby there are only few buyers of the farm input

Given the measure of oligopsony power in the factor market derived in the preceding section, then extending the basic model of price transmission to account for the presence of oligopsony power in the farm input market is straight forward. This task proceeds by specifying six equations which describe initial equilibrium in the markets for the two inputs and for the final product.

The first equation describes industry production function as:

$$x = f(a, b) \tag{5.14}$$

The second equation describes the demand function for the retail product as:

$$x = D(P_x, N) \tag{5.15}$$

where N is the demand shifter.

The third and fourth equations specify, in inverse form, the input supply equations for the farm and marketing inputs respectively as:

$$P_a = g(a, W) \tag{5.16}$$

and

$$P_b = h(b, T) \tag{5.17}$$

where, W and T are exogenous shifters in their respective markets.

The fifth and sixth equations describe the demand functions in the markets for the farm and marketing inputs respectively as:

$$P_a \varphi = P_x f_a \tag{5.18}$$

and

$$P_b = P_x f_b \tag{5.19}$$

which, as might be recalled, are derived from the profit maximization problem of the industry where the farm input market is assumed oligopsonistic. Note φ in (5.18) stands for $\left(1 + \frac{\phi}{e_a}\right)$.

It is quite evident from equation (5.18), where, clearly, for $\phi > 0$, $\frac{1}{\varphi} < 1$, that when the farm input market is characterized by oligopsony power, then, unlike in the perfectly competitive model, the price paid the farm input is only a proportion of its marginal revenue product.

As a quick reading of the equations describing initial equilibrium in the industry reveals, the only innovation introduced to this stage concerns the demand function for the farm input which, unlike in the Gardner model, equalizes the marginal revenue product and the perceived marginal factor cost of the farm input.

5.5.1 Effects of a farm input supply shift

In the preceding, we have described initial equilibrium in the industry. Now we show the adjustment in initial equilibrium that follows an exogenous shock originating in the farm sector. This follows the procedure of total differentiation of each of the six equations describing initial equilibrium and then equating demand and supply equations in each of the three markets.

Total differentiation of equation (5.14) yields:

$$dx^* = \gamma_a da^* + \gamma_b db^* \tag{5.20}$$

where dx^*, da^*, and db^* denote percentage changes in the demand for output, those in the demand for the farm input and those in the demand for marketing services respectively while $\gamma_a = S_a\varphi$ and $\gamma_b = 1 - S_a\varphi$ are cost shares of the farm and marketing inputs respectively in the presence of oligopsony power[2].

Similarly, totally differentiating equation (5.15), we obtain:

$$dx^* = \eta dP_x^* \tag{5.21}$$

where η denotes the price elasticity of demand which is normally negative and dP_x^* is the percentage change in the price of the final product following an exogenous supply shock.

Total differentiation of equation (5.16) gives:

$$dP_a^* = \frac{1}{e_a} da^* + e_W \tag{5.22}$$

where dP_a^* is the percentage change in the price of the farm input which results from an exogenous shock, e_a is the elasticity of supply for the farm input whereas e_W denotes the elasticity of the farm input supply to changes in the exogenous supply shifter, $\left(\frac{\partial a}{\partial W} \times \frac{W}{a}\right)$.

Total differentiation of equation (5.17), on the other hand, yields:

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[2]Recall from (3.3a) the Euler equation, $x = f_a a + f_b b$. By virtue of (5.18) and (5.19), $f_a = P_a/P_x\varphi$ and $f_b = P_b/P_x$. Then the Euler equation can be written as:
$x = \frac{\varphi P_a a}{P_x} + \frac{P_b b}{P_x}$ which on dividing through out by x can be re-written as :
$1 = \frac{\varphi P_a a}{P_x x} + \frac{P_b b}{P_x x}$.
Denoting $\gamma_a = \frac{\varphi P_a a}{P_x x} = \varphi S_a$ and $\gamma_b = \frac{P_b b}{P_x x} = S_b$, the Euler equation can be written as:
$1 = \gamma_a + \gamma_b$ which can equivalently be written as:
$1 = \varphi S_a + S_b$.

$$dP_b^* = \frac{1}{e_b} db^* \tag{5.23}$$

where dP_b^* denotes the percentage change in the price of the marketing input subsequent to an exogenous supply shock, while e_b denotes the price elasticity of supply for the marketing input.

The percentage change in demand for marketing inputs following an exogenous supply shock is expressed as:

$$dP_b^* = dP_x^* + \frac{\gamma_a}{\sigma} da^* - \frac{\gamma_a}{\sigma} db^* \tag{5.24}$$

Finally, the percentage change in demand for the farm input following changes in its supply conditions is specified as:

$$dP_a^* = \frac{dP_x^*}{(1+\delta)} - \left[\frac{\gamma_b}{\sigma(1+\delta)}\right] da^* + \left(\frac{\gamma_b}{\sigma(1+\delta)}\right) db^* \tag{5.25}$$

where σ is the elasticity of substitution between the farm input and marketing services. The change in the price mark-down following changes in the conditions of supply for the farm input is reflected by:

$$\delta = \left(\frac{\partial \phi / e_a}{\partial e_a}\right) \left(\frac{\partial e_a}{\partial P_a}\right) \tag{5.26}$$

Obviously, a change in the price mark-down which results from changes in the conditions of supply for the farm input derives directly from a change in the price of the farm input which directly affects the supply elasticity for the farm input.

5.5.2 Functional forms of supply and movements in the price mark-down

As (5.26) clearly indicates, the change in the supply elasticity following a change in the price of the farm input is critical in determining the direction of change in the mark-down following changes in the conditions of supply for the farm input. In all normal cases, the first bracketed term in (5.26) is negative because the mark-down is inversely related to the supply elasticity. However, the sign of δ cannot be determined *a priori* because $\frac{\partial e_a}{\partial P_a}$ is signed differently for different functional forms of supply. It is therefore necessary to identify the sign of $\frac{\partial e_a}{\partial P_a}$ for different functional forms of farm input supply, i.e., for a linear and non-linear specifications of the supply function.

We show this by specifying a generalized supply function for the farm input of the form:

$$a = g(P_a) \tag{5.27}$$

from which the supply elasticity is calculated as:

$$e_a = \left(\frac{\partial g(P_a)}{\partial P_a}\right)\left(\frac{P_a}{g(P_a)}\right) \tag{5.28}$$

Differentiating e_a with respect to P_a, we obtain:

$$\frac{\partial e_a}{\partial P_a} = \left(\frac{\partial^2 g(P_a)}{\partial P_a^2}\right)\frac{P_a}{a} + \left(\frac{\partial g(P_a)}{\partial P_a}\right)\frac{1}{g(P_a)} - \left(\frac{\partial g(P_a)}{\partial P_a}\right)\left(\frac{\partial g(P_a)}{\partial P_a}\right)\left(\frac{P_a}{g^2(P_a)}\right) \tag{5.29}$$

Equation (5.29) shows that the first and second-order derivatives of the supply function for the farm input are the key determinants of the size and direction of change in the elasticity of supply for the farm input following a change in P_a. We can show that these derivatives vary for different forms of the supply function. But for the purpose of our thesis, we will show this for the linear and constant elasticity demand functions.

First consider a linear supply function of the form:

$$a = g(P_a) = \alpha + \beta P_a \tag{5.30}$$

where α and β are positive constants. The first-order derivative of $g\left(P_a\right)$ with respect to P_a is given by:

$$\frac{\partial g(P_a)}{\partial P_a} = \beta \tag{5.31}$$

and its second-order derivative by:

$$\frac{\partial g^2\left(P_a\right)}{\partial P_a^2} = 0 \tag{5.32}$$

Substituting these first and second-order derivatives into equation (5.29) and rearranging, we obtain a measure of the farm supply elasticity's response to a change in P_a as:

$$\frac{\partial e_a}{\partial P_a} = 1 - \beta\left(\frac{P_a}{a}\right) = 1 - e_a \tag{5.29a}$$

The result in (5.29a) states that given a linear supply curve, the change in e_a following a change in P_a varies with e_a itself so that it is negative for an elastic supply curve, positive for an nelastic supply curve and zero at the point of unit elasticity. Algebraically, this can be summarized as:

$$\frac{\partial e_a}{\partial P_a} < 0 \text{ for } e_a > 1; \qquad (5.29b)$$
$$\frac{\partial e_a}{\partial P_a} > 0 \text{ for } 0 < e_a < 1; \text{ and}$$
$$\frac{\partial e_a}{\partial P_a} = 0 \text{ for } e_a = 1$$

The implication of this result for movements in the mark-down following changes in the conditions of supply for the farm input is that given a linear supply curve, the change in the mark-down cannot be predicted *a priori.* This is because it changes in the same direction as P_a when supply is elastic (i.e., $\delta > 0$), in the opposite direction as P_a (i.e., $\delta < 0$) when supply is inelastic, and remains unchanged (i.e., $\delta = 0$) when supply is unitary elastic.

Now consider a constant elasticity supply function of the form:

$$a = \beta P_a^{\varepsilon} \qquad (5.30)$$

where β and ε are positive constants. The first order-derivative of this functional form with respect to P_a is given by:

$$\frac{\partial a}{\partial P_a} = \varepsilon \beta P_a^{\varepsilon - 1}. \qquad (5.31)$$

and its second order-derivative is given by:

$$\frac{\partial^2 a}{\partial P_a^2} = (\varepsilon - 1)\varepsilon \beta P_a^{\varepsilon - 2} \qquad (5.32)$$

Substituting these first and second-order derivatives into equation (5.29), we obtain e_a's response to a change in P_a as:

$$\frac{\partial e_a}{\partial P_a} = \left[(\varepsilon - 1)\varepsilon\beta P_a^{\varepsilon-2}\right]\left(\frac{P_a}{\beta P_a^{\varepsilon}}\right) + \varepsilon\beta P_a^{\varepsilon-1}\left(\frac{1}{\beta P_a^{\varepsilon}}\right) - \left(\varepsilon\beta P_a^{\varepsilon-1}\right)^2\left(\frac{P_a}{(\beta P_a^{\varepsilon})^2}\right) = 0 \tag{5.29c}$$

Given a constant elasticity supply function, this result shows that the price mark-down remains constant (i.e., $\delta = 0$) when P_a changes. The intuitive interpretation is that as the price of the farm input changes by a certain proportion so does the marginal value product change by the same proportion thus leaving the mark-down unchanged.

As the above has made evident, the functional form of the supply function assumed for the farm input is a key determinant of movements in the mark-down following an exogenous shock to farm input supply. We can summarize the major predictions regarding changes in the mark-down following an exogenous supply shock as follows. Firstly, given a linear farm input supply function, the change in the mark-down cannot be predicted *a priori*. This is because it changes in the same direction as P_a when supply is elastic (i.e., $\delta > 0$), in the opposite direction as P_a (i.e., $\delta < 0$) when supply is inelastic, and remains unchanged (i.e., $\delta = 0$) when supply is unitary elastic. Secondly, given a constant elasticity supply function, the price mark-down remains unchanged (i.e., $\delta = 0$) when P_a changes.

In the following, we show how, in the presence of oligopsony power in the farm sector, one can solve for new equilibrium values of the endogenous variables in terms of e_W.

5.5.3 Solving for new equilibrium values for the endogenous variables in terms of e_W

Earlier, we have defined the percentage changes in the endogenous variables which result from an exogenous shock to farm input supply. We can now solve for these percentage changes in terms of the elasticity of farm input supply to the exogenous shock, e_W. To this effect, we equate equations (5.20) and (5.21) to reflect equilibrium adjustment in the product market; (5.22) and (5.25) to reflect adjustment in initial equilibrium in the farm input market; and (5.23) and (5.24) to reflect equilibrium adjustment in marketing services. This task yields the following three-equation system.

$$-\eta dP_x^* + \gamma_a da^* + \gamma_b db^* = 0 \tag{5.33a}$$

$$\left(\frac{1}{1+\delta}\right) dP_x^* - \left[\left(\frac{1}{1+\delta}\right)\frac{\gamma_b}{\sigma} + \frac{1}{e_a}\right] da^* - \left(\frac{1}{1+\delta}\right)\frac{\gamma_b}{\sigma} db^* = e_W \tag{5.33b}$$

$$dP_x^* + \frac{\gamma_a}{\sigma} da^* - \left(\frac{\gamma_a}{\sigma} + \frac{1}{e_b}\right) db^* = 0 \tag{5.33c}$$

This equation system can be solved using Cramer's rule. Solving the system thus, the percentage changes in the endogenous variables of our interest, dP_a^* and dP_x^* can be expressed in terms of e_W:

$$dP_x^* = \frac{e_W (1+\delta) e_a \gamma_a (\sigma + e_b)}{D^*} \tag{5.34}$$

$$dP_a^* = \frac{e_W e_a (e_b + \gamma_a \sigma - \gamma_b \eta)}{D^*} \tag{5.35}$$

where the denominator, D^*, which is positive in all instances, is given by:

$$D^* = -\eta\left[\gamma_b e_a + (1+\delta) e_b \gamma_a + (1+\delta)\sigma\right] + e_a e_b + \sigma\left(\gamma_a e_a + (1+\delta)\gamma_b e_b\right)$$

5.5.4 The elasticity of price transmission in the presence of oligopsony power

As might be recalled, for a given exogenous shock, the elasticity of price transmission is defined as the percentage change in the price of the final product resulting from a percentage change in the price of the farm input. Given a shock to the farm input market, the transmission elasticity when this market is characterized by oligopsony power is expressed as:

$$\frac{dP_x^*}{dP_a^*} = \tau^{OSNY} = \frac{(1+\delta)\,\gamma_a\,(\sigma + e_b)}{(e_b + \gamma_a\sigma - \gamma_b\eta)} \tag{5.36}$$

Comparison of the transmission elasticity in the presence of oligopsony power to that in the perfectly competitive benchmark[3] reveals that the only difference between the two concerns the inclusion of δ in the numerator of (5.36).

As has been hinted at above, the sign of the term, δ cannot be determined *a priori* since $\frac{\partial e_a}{\partial P_a}$ is signed differently for different functional forms of farm input supply. This suggests that, relative to that in the perfectly competitive model, the magnitude of the elasticity of price transmission allowing for oligopsony power in the farm input market cannot be predetermined.

Thus, given a linear supply curve for the farm input, the transmission elasticity accounting for oligopsony power is smaller than that obtaining in the perfectly competitive

[3] The elasticity of price transmission in the perfectly competitive model is derived by setting $\delta = 0$, to obtain:

$$\tau^{PC} = \frac{S_a\,(\sigma + e_b)}{(e_b + S_a\sigma - S_b\eta)}$$

case when supply is inelastic because $\frac{\partial e_a}{\partial P_a} > 0 \Longrightarrow \delta < 0$; and greater when supply is elastic because $\frac{\partial e_a}{\partial P_a} < 0 \Longrightarrow \delta > 0$. On the other hand, the transmission elasticities for both the perfectly competitive and oligopsonistic models are equal when a constant elasticity and a unitary linear supply functions are assumed because for these functional specifications, $\frac{\partial e_a}{\partial P_a} = 0 \Longrightarrow \delta = 0$.

It thus follows from the above results that relative to when the perfectly competitive model is considered, the elasticity of price transmission is smaller for an inelastic supply. In this particular instance, we say there is 'under-shifting' in the degree of price transmission when oligopsony power is present. Furthermore, it follows that relative to when the perfectly competitive model is assumed, 'over-shifting' in the degree of price transmission occurs in the presence of oligopsony power when the elastic portion of a linear supply curve is considered. Finally, when a constant elasticity and unitary elastic linear supply functions are assumed, we say there is no shifting in the degree of price transmission in the presence of oligopsony power relative to when a perfectly competitive model is assumed.

It is to be recalled from our review of the literature that the price transmission elasticity for the oligopolistic model is always smaller than that for the perfectly competitive model when a linear demand function is assumed (McCorriston *et al.*, 1998). This means that given a linear demand function and relative to when all markets are assumed perfectly competitive, there is always 'undershifting' in the degree of price transmission when oligopoly power is present in the retail market. This suggests that results for the elasticity of price transmission assuming oligopsony power are qualitatively the same as those for a transmission elasticity assuming oligopoly power, only to the extent that an inelastic linear supply function is considered.

When the elastic portion of the linear supply function in the oligopsonistic model is considered, however, oligopsony and oligopoly power might be qualitatively different so much so that they might counteract each other's impact on the degree of price transmission. If overshifting in the oligopsonistic model outweighs undershifting in the oligopolistic model, then there will be overshifting, on net, in the degree of price transmission when both oligopsony and oligopoly interact. If, on the other hand, under the given assumptions undershifting in the oligopolistic model outweighs overshifting in the oligopsonistic model, the presence of oligopoly and oligopsony will, on net, lead to undershifting relative to when the perfectly competitive model is considered.

To show that this might indeed be the case, we need to extend the basic model of price transmission allowing for both oligopoly and oligopsony power, and this is the task we turn to next.

5.6 Modelling price transmission in the presence of oligopoly and oligopsony power

The task of extending the basic model to account for market power both at the retail and farm supply stages involves specifying the marketing industry's production and inverse demand functions as:

$$x = f(a, b) \tag{5.37}$$

and

$$P_x = D(x, N) \tag{5.38}$$

respectively, where,

$$x = \sum x_i .... \forall x_i = f(a_i, b_i) \tag{5.39}$$

and the industry's inverse supply functions for the farm and marketing inputs as:

$$P_a = g(a, W) \tag{5.40}$$

and

$$P_b = h(b, T) \tag{5.41}$$

respectively; where, as might be recalled,

$$a = \sum a_i = a_1 + a_2 + ... + a_n \tag{5.42}$$

and the industry's cost function, which, when separated into its input components, can be written as:

$$C = P_a a + P_b b \tag{5.43}$$

Having done this, the ith firm's profit maximization problem assuming firms compete on the basis of quantity in both the output and the farm input sectors, can be formulated as:

$$\max_{a_i, b_i} \pi_i \, P(x) \, x_i - P_a a_i - P_b b_i \tag{5.44}$$

where each firm in the industry maximizes profit choosing a_i subject to equations (5.38), (5.39), (5.40), and (5.42) and b_i subject to equations (5.37) and (5.39). The first-order condition with respect to the farm input is given by:

$$\frac{\partial \pi_i}{\partial a_i} = \left[P_x(x)f_{ai} + \left(\frac{\partial P_x}{\partial x}\frac{\partial x}{\partial x_i}\right) f_{ai}x_i\right] - \left[P_a + \left(\frac{\partial P_a}{\partial a}\frac{\partial a}{\partial a_i}\right) a\right] = 0 \tag{5.45}$$

Multiplying the second term in the first bracket by $\frac{x}{x}$ and then factoring out P_x, and, similarly, factoring out P_a from the second bracket yields:

$$\frac{\partial \pi_i}{\partial a_i} = P_x\left(1 + \left(\frac{\partial P_x}{\partial x}\frac{x}{P_x}\frac{\partial x}{\partial x_i}\frac{x_i}{x}\right)\right) f_{ai} - P_a\left(1 + \left(\frac{\partial P_a}{\partial a}\frac{\partial a}{\partial a_i}\frac{a}{P_a}\right)\right) = 0 \tag{5.46a}$$

or, equivalently,

$$P_x\left(1 + \frac{\theta_i}{\eta}\right) f_{ai} = P_a\left(1 + \frac{\phi_i}{e_a}\right) \tag{5.46b}$$

where θ_i and ϕ_i are the firm's conjectural elasticities in the final product and farm input markets respectively whereas $\frac{\theta_i}{\eta}$ and $\frac{\phi_i}{e_a}$ are measures of the firm's oligopoly and oligopsony power in the respective markets. Note again η is in all normal cases negative.

Equation (5.46b) states that due to the presence of market power in both the retail and farm input markets, the perceived marginal revenue of the firm from using an extra unit of the farm input equals the perceived marginal cost of using such a unit. In keeping with the aggregation conditions suggested in Appelbaum *op cit*, we can write the aggregate analogue of equation (5.46b) as:

$$P_x f_a(1 + \frac{\theta}{\eta}) = P_a\left(1 + \frac{\phi}{e_a}\right) \tag{5.46c}$$

where θ/η and ϕ/ϵ represent industry-level oligopoly and oligopsony power respectively.

Similarly, the first-order condition with respect to the marketing input, b_i can be obtained as:

$$\frac{\partial \pi_i}{\partial b_i} = P_x f_{bi} + \left(\frac{\partial P_x}{\partial x}\frac{\partial x}{\partial x_i}\right) f_{bi} x_i - P_b = 0 \tag{5.47}$$

Multiplying the second term of equation (5.47) by $\frac{x}{x}$,then factoring out P_x and aggregating over i firms and re-arranging, yields:

$$P_x f_b \left(1 + \frac{\theta}{\eta}\right) = P_b \tag{5.47a}$$

Assume that the second-order conditions for a maximum profit are satisfied such that,

$$\frac{\partial^2 \pi_i}{\partial a_i^2}, \frac{\partial^2 \pi_i}{\partial^2 b_i} \leq 0 \tag{5.48}$$

As can be noted, relative to the oligopsonistic model, the only changes introduced so far, on incorporating the oligopolistic model, relate to the factor demand functions for the farm and marketing inputs as shown in equations (6.46c) and (6.47a). On introducing these changes, adjustments in the original equilibria in all markets to a change in the conditions of supply in the farm input are expressed in the same way as in the oligopsonistic model except that the changes in the factor demand functions for the farm and marketing inputs are modified. The change in the inverse demand function for the farm input is written, in total differential form, as:

$$dP_x^* - \left[\frac{\partial(\theta/\eta)}{\partial \eta}\left(\frac{\partial \eta}{\partial P_x}\right)\right] dP_x^* + df_a = dP_a^* - \left[\left(\frac{\partial \phi/e_a)}{\partial e_a}\right)\left(\frac{\partial e_a}{\partial P_a}\right)\right] dP_a^* \tag{5.49}$$

which, on setting $\left(\frac{\partial \theta/\eta)}{\partial \eta}\right)\left(\frac{\partial \eta}{\partial P_x}\right) = \mu$, and taking note of the definition of δ can be re-written as:

$$dP_a^* = \frac{(1-\mu)}{(1+\delta)}dP_x^* + \frac{1}{(1+\delta)}df_a^* \tag{5.49a}$$

which, again, on expanding df_a,becomes:

$$dP_a^* = \frac{(1-\mu)}{(1+\delta)}dP_x^* - \left(\frac{1}{1+\delta}\right)\frac{\gamma_b}{\sigma}da^* + \left(\frac{1}{1+\delta}\right)\frac{\gamma_b}{\sigma}db^* \tag{5.49b}$$

The parameter μ reflects the change in the price-cost margin following changes in the conditions of farm supply. Given a linear demand function, μ is negative since $\left(\frac{\partial\theta/\eta}{\partial\eta}\right)$ is negative whereas $\left(\frac{\partial\eta}{\partial P_x}\right)$ is positive. On the other hand, given a constant-elasticity demand function, μ is zero because $\left(\frac{\partial\eta}{\partial P_x}\right)$ is zero.

Similarly, based on (5.47a), the change in the inverse demand function for the marketing input is written, in total differential form, as:

$$dP_b^* = dP_x^* - \mu dP_x^* + df_b^* \tag{5.50}$$

which, on factoring out dP_x^*, and on expanding df_b^*,can be expressed as:

$$dP_b^* = (1-\mu)dP_x^* + \frac{\gamma_a}{\sigma}da^* - \frac{\gamma_a}{\sigma}db^* \tag{5.50a}$$

Note that in the presence of both oligopoly and oligopsony power in the industry, the factor cost shares in (5.49a) and (5.50a) are represented by $\gamma_a = \frac{S_a\varphi}{(1+\theta/\eta)}$ and $\gamma_b = \frac{S_b}{(1+\theta/\eta)}$ respectively[4].

[4]Recall from (3.3a) the Euler equation, x = $\mathrm{f}_a a + f_b b$. By virtue of (5.46c) and (4.47a), $\mathrm{f}_a = \frac{\varphi P_a}{P_x(1+\theta/\eta)}$ and $\mathrm{f}_b = \frac{P_b}{P_x(1+\theta/\eta)}$. Then the Euler equation can be written as:

x $= \frac{\varphi P_a a}{P_x(1+\theta/\eta)} + \frac{P_b b}{P_x(1+\theta/\eta)}$ which on dividing through out by x can be re-written as :

$1 = \frac{\varphi P_a a}{P_x x(1+\theta/\eta)} + \frac{P_b b}{P_x x(1+\theta/\eta)}$.

Having thus modified the changes in the factor demand functions for both inputs, then the three-equation system can be specified as:

$$-\eta dP_x^* + \gamma_a da^* + \gamma_b db^* = 0 \tag{5.51a}$$

$$\frac{(1-\mu)}{(1+\delta)} dP_x^* - \left[\left(\frac{1}{1+\delta}\right)\frac{\gamma_b}{\sigma} + \frac{1}{e_a}\right] da^* + \left[\left(\frac{1}{1+\delta}\right)\frac{\gamma_b}{\sigma}\right] db^* = e_W \tag{5.51b}$$

$$(1-\mu)\, dP_x^* + \frac{\gamma_a}{\sigma} da^* - \left[\left(\frac{\gamma_a}{\sigma}\right) + \frac{1}{e_b}\right] db^* = 0 \tag{5.51c}$$

Solving the system using Cramer's rule yields the following percentage changes for the endogenous variables expressed in terms of the percentage change in the supply of the farm input.

$$dP_x^* = \frac{e_W (1+\delta)\, e_a \gamma_a (\sigma + e_b)}{D^{**}} \tag{5.52}$$

$$dP_a^* = \frac{e_W e_a \left[(1-\mu)(e_b + \gamma_a \sigma) - \gamma_b \eta\right]}{D^{**}} \tag{5.53}$$

Denoting $\gamma_a = \frac{\varphi P_a a}{P_x x (1+\theta/\eta)}$ and $\gamma_b = \frac{P_b b}{P_x x (1+\theta/\eta)}$, the Euler equation can be written as:
$1 = \gamma_a + \gamma_b$ which can equivalently be written as:
$1 = \frac{\varphi S_a}{(1+\theta/\eta)} + \frac{S_b}{(1+\theta/\eta)}$

5.6.1 The elasticity of price transmission in the presence of oligopoly and oligopsony

With the values of dP_x^* and dP_a^* at hand, the elasticity of price transmission under the assumption of market power in both the retail and farm input supply sectors, τ^{OLSNY} is derived as:

$$\tau^{OLSNY} = \frac{(1+\delta)\,\gamma_a\,(\sigma + e_b)}{[(1-\mu)\,(e_b + \gamma_a \sigma)] - \gamma_b \eta} \tag{5.54}$$

As perusal of equation (5.54) makes evident, the presence of δ in the numerator, and μ in the denominator renders it impossible to compare, on prima facia grounds, the magnitude of τ^{OLSNY} compares to the transmission elasticity in the perfectly competitive model. This is because the values of δ and μ are determined by the functional forms of demand for the final product and of supply for the farm input respectively. Therefore prior to determining values for the transmission elasticity in (5.54), it is necessary to determine the corresponding values of δ and μ.

First consider a linear supply curve for the farm input and a linear demand curve for the retail product. Recalling from our analysis of the oligopsonistic model, we know that for a given linear supply function δ can take on values that are either positive, negative or equal to zero. We also know, from our exposition of the oligopoly model, that μ always takes on negative values because $(1+\eta)$ is always positive.

Given these functional forms, three implications follow for the relative magnitude of the transmission elasticity when both oligopsony and oligopoly power interact. Firstly, when $(1-e_a) > 0$ and $(1+\eta) > 0$, then $\delta < 0$; $\mu < 0$ implying that, relative to the size of the price transmission elasticity that obtains in the perfectly competitive model, τ^{OLSNY} is smaller because its numerator is smaller and its denominator greater. In this particular instance, both oligopoly and oligopsony power reinforce each other to dampen the degree of price transmission from farm supply to the retail sector. Secondly, when $(1-e_a)<0$ and $(1+\eta)>0$, then $\delta>0$; $\mu<0$, implying that, relative to the magnitude of the price transmission elasticity that obtains in the perfectly competitive model, τ^{OLSNY} is indeterminate because as the denominator gets greater so does the numerator. In this particular instance, oligopoly and oligopsony power counteract each other's impact on the degree of price transmission with the relative magnitude of each determining whether $\tau^{OLSNY}$is, on net, larger or smaller than the transmission elasticity obtaining in the perfectly competitive model. Finally, when $(1-e_a)=0$ and $(1+\eta)>0$, then $\delta=0$ and $\mu<0$, implying that oligopsony power is non-existent, with the result that relative to the magnitude of the transmission elasticity that obtains in the perfectly competitive model, τ^{OLSNY} is smaller because the denominator is greater. In this particular instance, the degree of price transmission is weakened purely due to oligopoly power.

Next consider constant elasticity farm input supply and retail demand functions. As we have pointed out elsewhere when these functional forms are assumed, then $\delta=0$ and $\mu=0$. The implication is that, τ^{OLSNY} equals the price transmission elasticity in the perfectly competitive model regardless of the presence of market power in both the farm input and output markets.

Consider now the supply function for the farm input is constant elasticity and the demand function for the final product linear; then $\delta=0$ and $\mu<0$, implying that τ^{OLSNY} is smaller than the transmission elasticity in the perfectly competitive benchmark because the denominator is now greater because of the presence of oligopoly power. On the other hand, when the supply function for the farm input is assumed linear and the demand function for the final product constant elasticity, then $\mu=0$ and δ is indeterminate implying that τ^{OLSNY} is indeterminate too.

A summary of the impact of changes in the price mark-up and in the price mark-down on the transmission elasticity is shown in Table 5.1. Relative to the perfectly competitive model (-) shows weakening whereas (+) shows enhancement of the degree of price transmission.

Table 5.1: Impact of changes in the mark- up and in the mark- down on the elasiticity of price transmission: relative to the perfectly competitive bench-mark (-) shows weakening; (+) shows enhancement; (0) shows neutral

Functional forms of retail demand and supply	τ^{OSNY}	τ^{OL}	τ^{OLSNY}
Linear demand and supply:			
$\delta = 0$; $\mu < 0$	0	-	-
$\delta > 0$; $\mu < 0$	+	-	undefined
$\delta < 0$; $\mu < 0$	-	-	-
Constant elasticity supply and demand:			
$\delta = 0$; $\mu = 0$	0	0	0
Constant elasticity supply and linear demand:			
$\delta = 0$; $\mu < 0$	0	-	-
Linear supply and constant elasticity demand:			
$\delta = 0$; $\mu = 0$	0	0	0
$\delta > 0$; $\mu = 0$	+	0	+
$\delta < 0$; $\mu = 0$	<0	0	-

5.7 Summary and evaluation

In this chapter we first developed a model to analyze the effects of oligopsony power in the market for farm supply taking the degree of price transmission in the perfectly competitive market as a bench-mark. The key finding is that depending on the farm supply function faced by the industry, the degree of price transmission which obtains in the presence of oligopsony power can be smaller (or greater) than or equal to the transmission elasticity derived in the perfectly competitive benchmark. Technically, these outcomes are derived from the first-order and second-order derivatives of the farm supply function. The conclusion therefore is that, in the presence of oligopsony power in the market for farm supply, the outcome for the degree of price transmission, relative to that in the perfectly competitive benchmark, cannot be determined *a priori* without knowledge of the first- and second-order derivatives of the supply function.

We then developed a more general model whereby we account for the combined effects of oligopoly and oligopsony power on the degree of price transmission. This model predicts that depending on the nature of farm supply and retail demand functions the outcome for the interaction between oligopoly and oligopsony power cannot be determined beforehand. As this can be either to weaken the degree of price transmission in the perfectly competitive benchmark or to strengthen it or in the extreme to mimic it. The implication is that without prior knowledge of the relevant functional forms for farm supply and retail demand, no meaningful conclusions can be drawn regarding the outcome of the interaction between oligopoly and oligopsony power. Therefore any policy recommendations regarding the effects of market power on the degree of price transmission need to start with a careful examination of farm supply and retail demand functions faced by the industry.

Our analysis in this chapter of the effects of market power on the degree of price transmission has rested on the assumption that other parameters which determine the degree of price transmission, i.e., the substitution elasticity, demand elasticity, among others, are kept unchanged. Obviously, this assumption is highly restrictive in that it does not take account of the interactions which exist between any one of these parameters and market power. In the next chapter therefore we relax this assumption and take account of the possible interaction between the degree of market power and other determining parameters. We undertake this analysis by simulating the effects of market power on the degree of price transmission subject to changes in any one of the determining parameters.

Chapter 6

Simulating the effects of market power on the degree of price transmission

6.1 Background

In the preceding chapter we have shown how under the assumption of market power at both the supply and retailing sectors, our theoretical model predicts an elasticity of price transmission that is determined by the cost shares of both the farm and marketing inputs, γ_a and γ_b respectively; by the elasticity of factor substitution, σ; by the marketing supply elasticity, e_b; by the retail demand elasticity, η; by the elasticity of farm input supply, e_a and by the market power parameters representing oligopoly, θ, and oligopsony, ϕ.

As might be recalled from the preceding chapter, the elasticity of price transmission is defined as the percentage change in retail price resulting from a percentage change in the price of the farm input. For given degrees of oligopoly and oligopsony power in an industry, it is defined as:

$$\tau^{OLSNY} = \frac{(1+\delta)\,\gamma_a(\sigma + e_b)}{(1-\mu)\,(e_b + \gamma_a\sigma) - \gamma_b\eta} \tag{6.1}$$

where, as might be recalled, δ and μ denote changes in the mark-down and in the mark-up respectively which result from an exogenous shock to farm input supply.

As might be recalled, they are signed differently for different functional forms of farm input supply and retail demand respectively. For this reason, we are not in a position to determine, *a priori*, the magnitude of τ^{OLSNY} taking the transmission elasticity in the perfectly competitive model as a benchmark. In the special cases of δ being positive and μ being negative, however, τ^{OLSNY} is always smaller than the transmission elasticity in the perfectly competitive model.

Recalling from our analysis in the previous chapter, the necessary condition for these special cases to arise is that the supply curve for the farm input and the demand curve for the retail product be linear. Once these conditions are satisfied, again recalling from our theoretical exposition, the values of δ and μ are then given by:

$$\mu = \frac{\theta\,(1-\eta)}{\theta - \eta};\ \delta = \frac{\phi\,(1-e_a)}{e_a + \phi} \tag{6.2}$$

where as usual η is assumed negative.

Assume that these conditions are satisfied. We then want to show the relative effects of changes in each of the determining variables on τ^{OLSNY} taking the perfectly competitive model as a benchmark. This is the task we turn to in the subsequent sections.

6.2 The analytical framework

In the sections that follow, we simulate the relative effects of changes in the determining variables on the elasticity of price transmission. In this exercise, we allow each of the determining variables to vary within a certain range, given a possible band of values for certain other key parameters of our interest, while all other parameters are held constant. We run three sets of experiments, one assuming the industry is oligopolistic, another assuming the industry is oligopsonistic, and a final experiment assuming the industry is both oligopolistic and oligopsonistic.

In the first set of experiments, we allow oligopoly power to interact with σ, with η and with γ_a. To this effect, we allow σ to vary between 0 and 1; γ_a to vary between 0.1 and 1; and η to vary between 0.75 and 2, for possible values of θ ranging between 0 and 0.7 while holding all other parameters constant. In this set of experiments, we also allow σ to interact with e_b and with γ_a assuming θ=0.25. We do this by allowing σ to vary between 0.1 and 1, and e_b to vary between 0.5 and 2, and by allowing γ_a to vary between 0.1 and 1.0 for a given range of values of σ between 0 and 1 and again assuming θ=0.25. The choice of the lower bound of θ in this category of experiments is intended to show the possible minimum impact that oligopoly power can have on the degree of price transmission

In the second set of experiments, we analyze the same set of interactions and use the same parameter values as in the first set of experiments. The only exceptions are that we assume the presence of oligopsony power and ignore oligopoly power.

In the third set of experiments, we analyze the combined effects of oligopoly and oligopsony power on the degree of price transmission. In this set of experiments, we limit our interest to the interaction of θ and ϕ with σ and γ_a. The parameter values that we assume in this set of experiments will again be the same as those in the first and second sets of experiments.

A quick note on the rationale for the choice of parameter values is in order here. The parameter values for θ, γ_a, e_b, σ and η are all adapted from McCorriston et al. (1998) with a minor adaptation being made to η. Whereas they consider parameter values for η ranging between 0.75 and 1.25, we consider a wider range of values between 0.75 and 2. The application of these parameter values to our analysis is motivated by our interest to see whether, given the same range of values, oligopsony power works to the same effect as oligopoly power does.

6.3 Simulating the effects of oligopoly power

6.3.1 The elasticity of price transmission allowing for the interaction between θ and σ assuming $\gamma_a = 0.5; \gamma_b = 0.5; e_b = 1.0; \eta = 0.75$

In this sub-section, we aim to examine the effects of input substitution on the degree of price transmission when oligopoly power is present. To this effect, we allow σ to vary on a scale of 0 to 1, keeping all other parameters unchanged, for a range of values of θ between 0 and 0.7. The results of this simulation exercise are presented in Table 6.1. Two major outcomes seem to emerge from this experiment.

Firstly, for any given degree of oligopoly power, allowing for increased substitution possibility between the two inputs increases the elasticity of price transmission. Intuitively, this result follows because when the price of the farm input increases, retailers are induced to substitute the relatively cheaper marketing input for the relatively more expensive farm input. Suppose the supply of the marketing input cannot be increased at the going price in the short run, because the marketing sector operates at full capacity; then, the increase in demand for the marketing input raises the price of this input and thereby reinforces the initial increase in the price of the farm input.

Secondly, for a given degree of input substitution and relative to a perfectly competitive benchmark, an increase in θ works to weaken the degree of price transmission. In fact, when θ is large enough (in this case, θ =0.7), the elasticity of price transmission is forced down close to zero suggesting that a high degree of oligopoly power attenuates the effect of σ. This stems from our assumption of a linear retail demand function which has the inherent tendency to force the price mark-up to fall as the price of the farm input

Table 6.1: The interaction between the substitution elasticity and oligopoly pwer

σ	$\theta = 0.0$	$\theta = 0.25$	$\theta = 0.5$	$\theta = 0.7$
0.0	0.364	0.222	0.103	0.019
0.2	0.407	0.246	0.113	0.021
0.4	0.444	0.267	0.121	0.023
0.6	0.478	0.284	0.129	0.024
0.8	0.507	0.3	0.135	0.025
1.0	0.533	0.314	0.14	0.026

increases and to rise as the latter decreases thus rendering the retail price change, in the presence of oligopoly power, always smaller than that under perfect competition. As such, this result springs more from an *a priori* imposition of a specific functional form on the demand function than from the nature of oligopoly pricing itself.

These results are shown diagrammatically in Figure 6.1. The solid line tracks the transmission elasticity's response to changes in σ when the industry is perfectly competitive. The dashed, dotted and dash-dotted lines, on the other hand, track such a response for different degrees of θ (i.e., for $\theta = 0.25$; $\theta = 0.5$; $\theta = 0.7$ respectively).

Evidently, all lines are rising over the entire range of σ indicating the positive relationship between the transmission and substitution elasticities. Also manifest is the fact that the solid line lies above the dashed line, the dashed above the dotted line and the latter above the dash-dotted line highlighting that a growing power of oligopoly puts a downward pressure on the elasticity of price transmission. Finally, lines corresponding to successively higher degrees of oligopoly power are flatter than those corresponding to smaller such degrees. This underlines what has been pointed out earlier already; that as oligopoly power grows, the elasticity of substitution diminishes in importance as a determinant of the transmission elasticity

Figure 6-1: Interaction between elasticity of substitution and oligopoly power

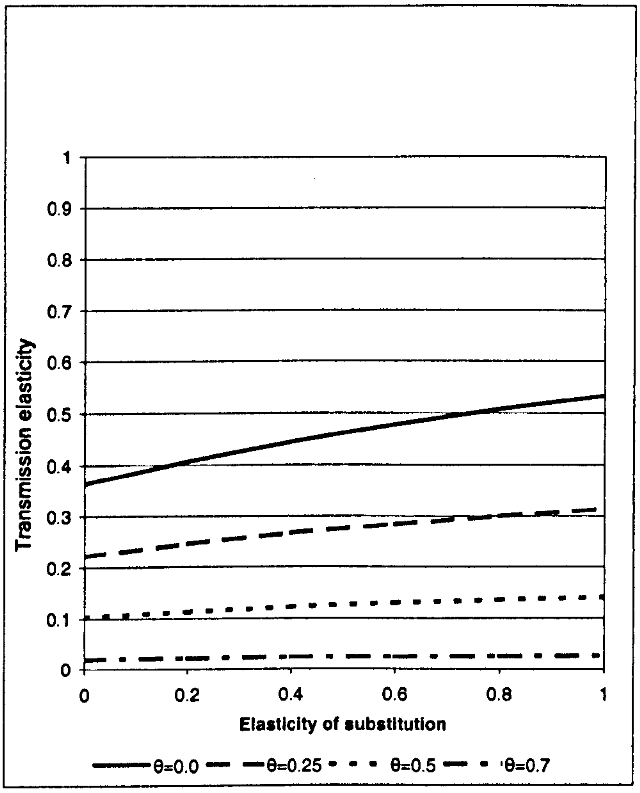


Table 6.2: Interaction between the cost share of the farm input and oligopoly power

γ_a	$\theta = 0$	$\theta = 0.25$	$\theta = 0.5$	$\theta = 0.75$
0.1	0.087	0.057	0.028	0.005
0.2	0.176	0.113	0.054	0.01
0.3	0.269	0.168	0.079	0.015
0.4	0.364	0.222	0103	0.019
0.5	0.462	0.276	0.125	0.023
0.6	0.563	0.329	0.146	0.027
0.7	0.667	0.381	0.167	0.03
0.8	0.774	0.432	0.186	0.033
0.9	0.885	0.483	0.205	0.036
1.0	1.000	0.533	0.222	0.037

6.3.2 The elasticity of price transmission allowing for the interaction between γ_a and θ assuming $\sigma = 0.5; e_b = 1.0; \eta = 0.75;$and $\gamma_b = 1 - \gamma_a$.

The aim of this experiment is to evaluate whether allowing for oligopoly power in an industry matters for the effects of γ_a on the degree of price transmission. With this aim in mind, we let γ_a vary in the range of 0.1 to 1.0, for different degrees of oligopoly power, while keeping all other parameters fixed. Table 6.2 summarizes the results of this experiment.

The results show that for any given degree of oligopoly power, a large γ_a enhances the degree of price transmission simply reflecting the composition of inputs in the final good. They also show that when the farm input is the only input used by the industry (i.e., for γ_a =1), assuming perfectly competitive markets at all stages of the industry (i.e., $\theta = 0$) produces an elasticity of price transmission equal to unity whereby a percentage change in the price of the farm input translates, one-for-one, into the same percentage change in the price of the retail product.

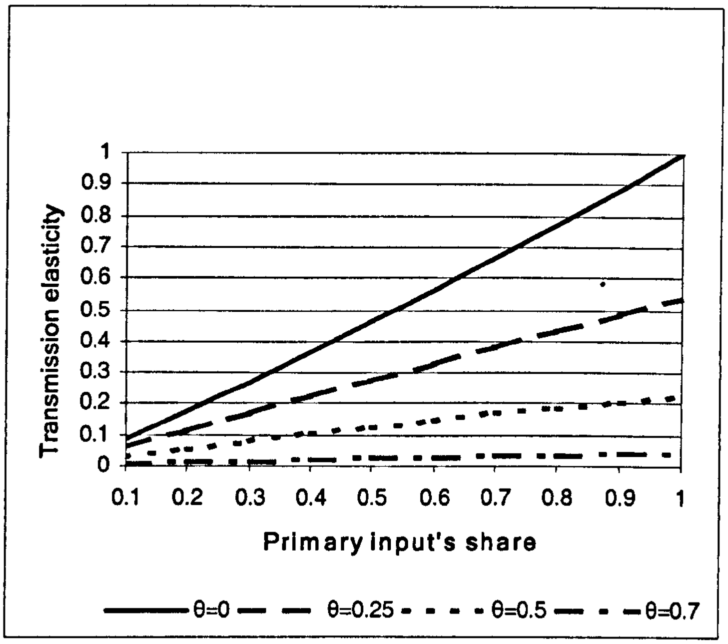
Conversely, relative to a perfectly competitive industry, and for a given γ_a, a higher θ results in a smaller elasticity of price transmission. In fact, there seems to be a threshold value of θ for which the elasticity of price transmission is very close to zero regardless of the magnitude of γ_a. In our case, this appears to be the case for $\theta = 0.7$. Given an increase in the farm input price, the explanation is that the price mark-up falls in proportion to an increase in the degree of market power.

As has been pointed out in the preceding chapter, the intuitive explanation as to why oligopoly power works to depress the impact of γ_a on the degree of price transmission has to do with the change in the price-cost margin in response to a change in the price of the farm input. Given a linear demand function, this means an increase in the price of the farm input cannot be passed on to the price of the final product, in proportion to the share of the farm input, because the margin falls at the same time that the price of the farm input increases. The magnitude of the fall in the price-cost margin is in direct proportion to the market power parameter, θ.

Figure 6.2 illustrates these simulation results. The solid line captures the effects of the farm input's cost share on the transmission elasticity when the industry is perfectly competitive (i.e., when θ =0). The dashed, dotted and dash-dotted lines, on the other hand, capture such effects for values of oligopoly power corresponding to 0.25, 0.5, and 0.7 respectively.

As can be observed from Figure 6.2, all the lines are increasing in the cost share of the farm input. It can also be observed that not only does the solid line lie above the dashed line, the dashed above the dotted line and the latter above the dashed-dotted line but that the lower the lines go the flatter they get. This highlights that not only does a given γ_a result in a larger value for the transmission elasticity but that an increasing degree of oligopoly power has an increasingly dampening effect on the degree of price transmission (i.e., the degree of price transmission weakens at an increasing rate for incremental changes in the degree of oligopoly power).

Figure 6-2: Interaction between cost share of the farm input and oligopoly power



6.3.3 The elasticity of price transmission accounting for the interaction between η and θ assuming $\gamma_a = 0.5; \gamma_b = 0.5; e_b = 1.0; \sigma = 0.5$

In this experiment we aim to evaluate the effects of retail demand elasticity on the degree of price transmission when the industry exercises oligopoly power. For a range of possible values of θ in the region of 0 to 0.7, this it does by allowing variations in the elasticity of demand in the range of 0.75 to 2 while keeping all other parameters constant. Table 6.3 summarizes these simulation results. Three major outcomes emerge from this experiment.

Firstly, relative to the perfectly competitive benchmark (i.e., for $\theta = 0$), the elasticity of price transmission falls consistently as consumer demand becomes more elastic. This indicates that with a more elastic demand, firms' ability to increase retail price in response to an increase in cost, is diminished.

Secondly, when oligopoly power is allowed for in the retail market, the transmission elasticity does not move monotonically with the elasticity of demand. Consequently, for a given degree of oligopoly power, the transmission elasticity gets larger as demand becomes more elastic then reaches a threshold beyond which it starts to fall as the elasticity of demand increases further. We might hasten to add that this threshold becomes higher as θ gets larger.

As might be recalled from our theoretical exposition, the ambiguous effect of the elasticity of demand when oligopoly power is present has been well brought out by comparative statics. The explanation for this might be as follows. Starting with an inelastic demand, oligopolist firms feel that they can widen their price-cost margin at the same time that they increase the price of the final product, following an increase in the price of the farm input, in spite of demand becoming more elastic. As a result, the elasticity of price transmission increases since the widening of firms' price-cost margin compounds the increase in the price of the final product.

But there is a point beyond which demand becomes very elastic such that they feel they cannot widen their margin anymore at the same time that they increase the final product price. At this stage, they decide to narrow their margin at the same time that they increase retail price with the result that the elasticity of price transmission falls because the fall in the margin dilutes the increase in the final product price.

Thirdly, relative to when $\theta = 0$, and for a given value of η, the transmission elasticity falls as oligopoly power increases. We have presented an intuitive explanation for this earlier in relation to changes in the price-cost margin that follow changes in the price of the final product. We will therefore not repeat it here

We illustrate these results in Figure 6.3. The solid line captures the effects, on the transmission elasticity, of changes in η for θ=0. The dashed, dotted and dash-dotted lines, on the other hand, capture such effects for θ=0.25; θ=0.5; θ=0.7 respectively.

It is clearly shown that the solid line is falling over the entire range of η, while lines corresponding to the different degrees of θ are rising over a certain range, and, depending

Table 6.3: Interaction between demand elasticity and oligopoly power

η	$\theta = 0.0$	$\theta = 0.25$	$\theta = 0.5$	$\theta = 0.7$
0.75	0.462	0.276	0.125	0.023
1.0	0.429	0.290	0.176	0.099
1.25	0.400	0.291	0.200	0.137
1.50	0.375	0.286	0.213	0.151
1.75	0.353	0.278	0.214	0.170
2.0	0.333	0.269	0.214	0.176

Figure 6-3: Interaction between elasticity of demand and oligopoly power

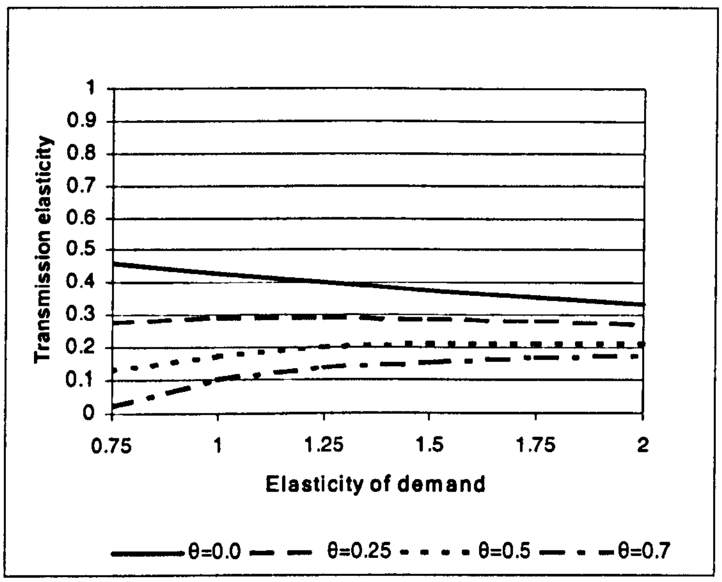


Table 6.4: Interaction between elasticities of substitution and marketing supply

σ	$e_b = 0.5$	$e_b = 1.0$	$e_b = 2.0$
0.1	0.213	0.235	0.249
0.2	0.233	0.246	0.255
0.3	0.251	0.257	0.261
0.4	0.267	0.267	0.267
0.5	0.281	0.276	0.272
0.6	0.293	0.284	0.277
0.7	0.305	0.292	0.282
0.8	0.315	0.300	0.287
0.9	0.324	0.307	0.292
1.0	0.333	0.314	0.296

on the value of θ, are either falling or tapering off over a certain other range, reflecting the ambiguity of η's effect on the transmission elasticity when the market is oligopolistic.

It is also shown that, relative to the line which corresponds to a perfectly competitive benchmark, lines corresponding to successively higher degrees of θ lie far lower than those corresponding to smaller such degrees. The implication is that, even though generally, for any value of η, the degree of price transmission is higher when the industry is perfectly competitive rather than oligopolistic, this degree of transmission is lowered as market demand gets more elastic, when the industry is less oligopolistic.

6.3.4 The elasticity of price transmission allowing for the interaction between σ and e_b assuming $\gamma_a = 0.5; \gamma_b = 0.5; \eta = 0.75; \theta = 0.25$

In this exercise, we aim to examine movements in the elasticity of price transmission allowing for the interaction between e_b and σ for a degree of θ equal to 0.25. This we do by allowing variations in σ, assuming all other parameters are held constant, for a range of values of e_b between 0.5 and 2. The results are presented in Table 6.4.

Table 6.4 makes evident that in the presence of θ (i.e., for θ=0.25), and for any given value of e_b, the degree of price transmission is enhanced as greater substitution is allowed for between the two inputs.

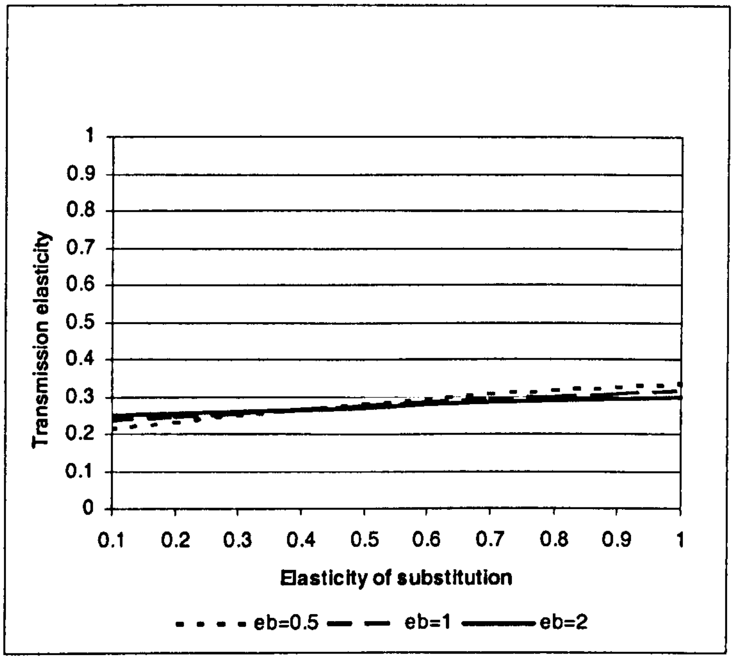
It also transpires that over a lower range of values for σ (in our case, $0.1 \leq \sigma < 0.4$), the elasticity of price transmission increases, as e_b gets more elastic. When σ reaches a certain threshold (in our case, σ=0.4), the transmission elasticity assumes a unique value for any given value of e_b. On the other hand, for values of σ above this threshold (i.e., for σ greater than 0.4), it seems to be the case that, for a given value of e_b, the transmission elasticity falls with e_b. As might be recalled, the comparative static results that were obtained in the theoretical literature review have very well anticipated the ambiguity of e_b's effect on the degree of price transmission.

The ambiguity of e_b's impact on the degree of price transmission can be explained as follows. For a given degree of market power, assume that firms' price-cost margin remains unchanged as the price of the farm input changes, which is likely to be the case when η is assumed to remain unchanged. It is then probable that, for a relatively lower degree of input substitution, the price of the marketing input will decrease as the price of the farm input increases if marketing supply is inelastic. For a given degree of substitution, this results in the elasticity of price transmission being smaller than when a very elastic marketing supply is assumed.

Conversely, if the degree of input substitution is very high, then an increase in the price of the farm input induces retailers to demand more marketing input, which has become relatively cheaper. Assuming the latter's supply is inelastic, this leads to an increase in its price. As such, the increase in the price of the farm input is compounded by the increase in the price of the marketing input. The upshot of this is that relative to when marketing supply is very elastic, and given a very high degree of input substitution, the transmission elasticity increases as marketing supply gets more inelastic.

Figure 6.4 brings out these interactions. The solid line tracks changes in the price transmission elasticity when marketing supply is very elastic (i.e., for e_b =2); the dashed line tracks these changes when marketing supply is unitary elastic (i.e., for e_b =1) while the dotted line tracks these changes when marketing supply is less elastic (i.e., for e_b=0.5).

Figure 6-4: Interaction between elasticities of substitution and marketing supply



It is quite evident from Figure 6.4 that for a lower range of values for σ (in our case for a value of σ up to 0.4), the solid line lies above the dashed line and the latter above the dotted line, suggesting that a more elastic marketing supply is associated with a larger price transmission elasticity. For a unique value of σ (in our case for σ=0.4), all lines merge suggesting that, given this value, the elasticity of marketing supply does not have any impact on the degree of price transmission. On the other hand, for an upper range of values for σ (in our case for σ>0.4), the dotted line lies above the dashed line and the latter above the solid line implying that a more elastic marketing supply is associated with a smaller value for the elasticity of price transmission.

6.3.5 The elasticity of price transmission allowing for the interaction between γ_a and σ assuming $\gamma_b = 0.5; \eta = 0.75; e_b = 1; \theta = 0.25$

The aim here is to see whether, in the presence of oligopoly power, allowing for larger γ_a enhances the degree of price transmission given our assumption regarding σ and the demand elasticity. To this end, we run an experiment allowing for variations in γ_a between 0.1 and 1.0, for a range of values of σ running from 0 to 1 and for θ=0.25 with all other parameters held constant. Table 6.5 summarizes these simulation results. Three outcomes are prominent and are summarized as follows.

Firstly, regardless of the proportion in which inputs are combined, allowing for larger γ_a increases the elasticity of price transmission. This is because changes in the price of the final product following changes in that of the farm input are in direct proportion to γ_a.

Secondly, relative to when the two inputs are combined in a fixed proportion (i.e., σ=0), allowing for increased input substitution increases the elasticity of price transmission. To reiterate a point that we have made earlier, this is because an increase in the price of the marketing input, which results from an increase in demand for this input, in turn resulting from the farm input becoming relatively more expensive, compounds the initial increase in the price of the farm input assuming marketing supply is inelastic.

Thirdly, as the share of the farm input approaches unity, so does the elasticity of price transmission attain its maximum value no matter in what proportion inputs are combined.

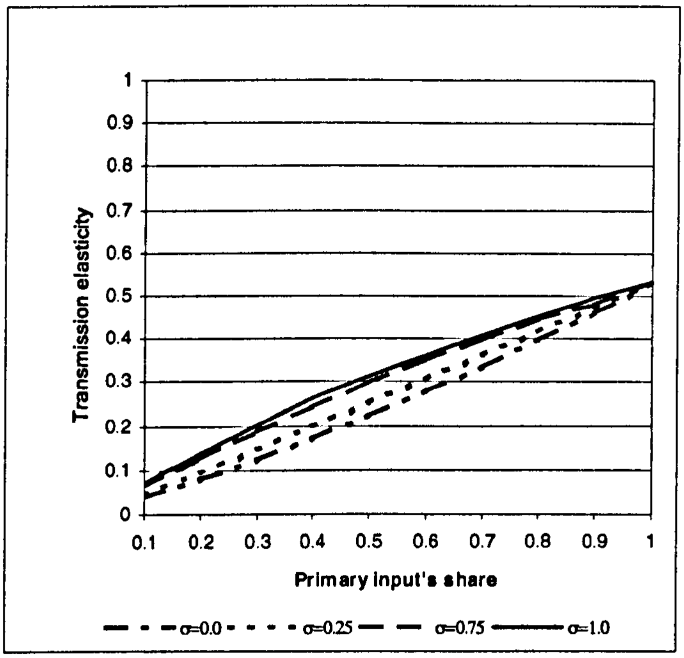
Figure 6.5 illustrates these results. The solid line tracks changes in the elasticity of price transmission when inputs are combined in a fixed proportion (i.e., $\sigma = 0$). The dashed, dotted and dot-dashed lines, on the other hand, track such changes for different cost shares of the raw input for σ=0.25, σ=0.5 and σ=1.0 respectively.

As the figure makes evident, all lines are rising over the entire range of the farm input's

Table 6.5: Interaction between farm input's cost share and substitution elasticity

γ_a	$\sigma = 0$	$\sigma = 0.25$	$\sigma = 0.75$	$\sigma = 1$
0.1	0.039	0.048	0.065	0.073
0.2	0.081	0.097	0.127	0.140
0.3	0.125	0.148	0.186	0.202
0.4	0.172	0.199	0.242	0.26
0.5	0.222	0.251	0.296	0.314
0.6	0.276	0.305	0.348	0.363
0.7	0.333	0.36	0.397	0.41
0.8	0.395	0.416	0.444	0.454
0.9	0.461	0.474	0.481	0.495
1.0	0.533	0.533	0.533	0.533

Figure 6-5: Interaction between cost share of farm input and elasticity of substitution



cost share suggesting that larger shares of the farm input are associated with larger values for the transmission elasticity. Furthermore, lines corresponding to higher degrees of input substitution lie above those corresponding to lower such degrees indicating that, for a given share of the farm input, a greater possibility for input substitution enhances the degree of price transmission. Finally, the slope of the line tracking changes in the transmission elasticity becomes flatter as the substitution elasticity increases from 0 to 1, suggesting that as the share of the farm input increases, the transmission elasticity attains its maximum value for different values of the substitution elasticity. In fact, when this share takes on the value of unity, then all lines vanish to a point on the right vertical axis.

Under the given assumptions of all other parameters remaining unchanged, this result comes as no surprise. In the absence of any possibility for input substitution, movements in the elasticity of price transmission are exclusively driven by changes in the share of the farm input.

6.3.6 The effects of oligopoly power on the degree of price transmission: a summary of simulation results

The previous analysis has brought to light movements in the elasticity of price transmission which result, *ceteris paribus*, from the interplay between any two of the determining variables (i.e., γ_a, e_b, η, σ and θ) assuming all others remain constant. Apart from results for the interaction between the demand elasticity and oligopoly power, results for the degree of price transmission that we have derived assuming oligopoly power in the retail sector are identical to those found by McCorriston et al. (1998). From the repeated simulation exercises that we have undertaken, the following conclusions seem to emerge consistently.

Firstly, wherever the substitution elasticity, σ, interacts with either θ, or with e_b, its impact, for a given value of the latter, is always to strengthen the degree of price transmission .

Secondly, wherever θ interacts with either σ, γ_a or with η, its effect, for a given value of the latter, is always to weaken the degree of price transmission.

Thirdly, wherever γ_a is observed interacting with either θ or with σ, its impact always appears to be to enhance the degree of price transmission.

Fourthly, wherever e_b is interacting with σ, its impact on the degree of price transmission always seems to be ambiguous for different values of the latter. For a certain range of values for σ, its impact is to strengthen the degree of price transmission; whereas for a certain other range, its impact is to weaken it. However, there seems to be a unique value of σ for which e_b does not have any impact on the degree of price transmission.

Fifthly, wherever the elasticity of demand, η, interacts with oligopoly power (θ>0), its impact on the degree of price transmission always seems to be ambiguous for any given value of the latter.

Finally, given our assumption regarding the functional form of demand, the presence of oligopoly power affects not so much the qualitative outcomes for the transmission elasticity under perfectly competitive markets as the quantitative outcomes.

In the following, we replicate the above simulation exercises allowing for oligopsony power and see whether doing so produces similar results for the degree of price transmission as those produced by allowing for oligopoly power.

6.4 Simulating the effects of oligopsony power on the degree of price transmission

In this section, we simulate the effects of oligopsony power on the degree of price transmission assuming a linear farm input supply function which is inelastic. As pointed out in the introduction, we carry out this experiment using the same parameter values as in the previous set of experiments. Our major interest is to see if oligopsony power impacts on the degree of price transmission in a qualitative manner which is any different from that of oligopoly power.

6.4.1 The elasticity of price transmission allowing for the interaction between ϕ and σ assuming $\gamma_a = 0.5; \gamma_b = 0.5; e_b = 1.0; \eta = 0.75$.

The aim of this experiment is to see whether the presence of oligopsony power in the farm sector of an industry attenuates the impact of σ on the degree of price transmission, as theoretically predicted by our model. To this end, we run an experiment whereby, *ceteris paribus*, σ is made to vary within the range of 0 and 1, for values of ϕ running from 0 to 0.7. Table 6.6 presents the results of this simulation exercise. The major observations that come out of this experiment can be summarized as follows.

Firstly, relative to that in the competitive benchmark, the elasticity of price transmission in the presence of oligopsony power is smaller. This is because for a given change in the price of the farm input, the change in the price of the retail product reflects as a change in the marginal cost when the input market is competitive. When the market is oligopsonistic, on the other hand, the change in the price of the retail product reflects both as a marginal cost change and as a change in the price mark-down. Given the inelastic portion of a linear supply curve, the latter moves in the opposite direction as the change in the price of the farm input. Therefore, the net change in the price of the retail product, following a change in farm input price, is smaller when the farm input market is oligopsonistic than when it is perfectly competitive.

Secondly, taking the perfectly competitive market as the base case (i.e., for ϕ=0), it transpires that, for a given value of the elasticity of substitution, the elasticity of price transmission falls as the industry becomes more oligopsonistic. This is because the more oligopsonistic the industry is, the wider the mark-down and the larger the change in this mark-down becomes when the price of the farm input changes and *vice versa*.

Finally, for any given value of oligopsony power, and relative to when inputs are combined in a fixed proportion, the transmission elasticity increases as the possibility for input substitution is greater. The explanation we provided with regard to the effects

Table 6.6: Interaction between substitution elasticity and oligopsony power

σ	$\phi = 0.0$	$\phi = 0.25$	$\phi = 0.5$	$\phi = 0.7$
0.0	0.364	0.342	0.273	0.258
0.2	0.407	0.339	0.305	0.289
0.4	0.444	0.371	0.333	0.316
0.6	0.478	0.398	0.358	0.339
0.8	0.507	0.423	0.38	0.36
1.0	0.533	0.445	0.4	0.379

of oligopoly power applies here as well. As might be recalled, we reasoned that for a highly inelastic marketing supply, the increase in demand for the marketing input, as the farm input becomes relatively more expensive, puts an upward pressure on its price thus compounding the initial increase in the latter's price.

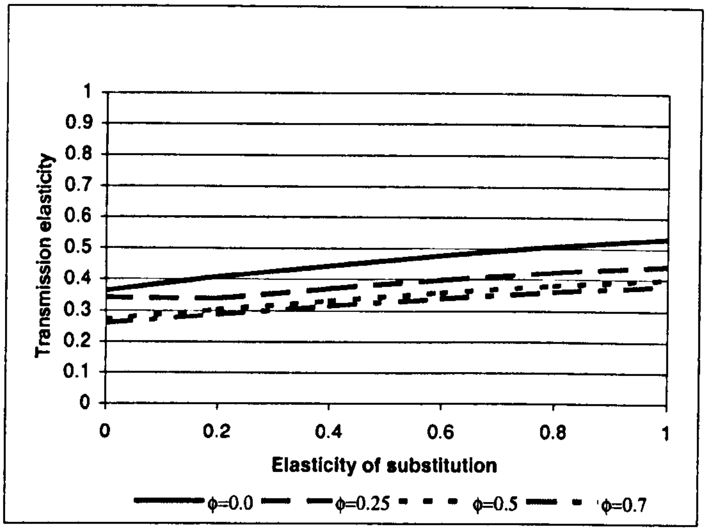
These results are very well highlighted in Figure 6.6. For different degrees of input substitution, the solid line tracks changes in the transmission elasticity when perfect competition is assumed in all markets (i.e., for ϕ=0) while the dashed, dotted and dot-dashed lines track such changes for ϕ=0.25; for ϕ=0.5; and ϕ=0.7 respectively.

All the lines are rising over the entire range of σ highlighting that, *ceteris paribus*, higher degrees of input substitution produce larger values for the elasticity of price transmission. It is also clearly shown that the solid line lies above the dashed, the dashed above the dotted line and the latter above the dashed-dotted line illuminating the fact that, given a linear farm input supply function which is inelastic, a higher degree of oligopsony power depresses the degree of price transmission.

6.4.2 The elasticity of price transmission allowing for the interaction between γ_a and ϕ assuming $\gamma_b = 1 - \gamma_a$; $e_b = 1.0$; $\eta = 0.75; \sigma = 0.5$.

In this experiment, we analyze the effects of γ_a on the degree of price transmission when the industry exercises oligopsony power. This we do by assigning different values to γ_a for a range of values of ϕ between 0 and 0.7. Table 6.7 summarizes the results of this

Figure 6-6: Interaction between elasticity of substitution and oligopsony power



simulation exercise. Three major outcomes are evident here.

Firstly, for any given γ_a, and relative to when the industry is perfectly competitive (i.e., for ϕ=0), the transmission elasticity falls as the degree of oligopsony power rises (i.e., for ϕ>0). At the risk of repetition, the change in the mark-down moderates the change in the price of the farm input so that, relative to when the market is perfectly competitive, the change in the price of the retail product is smaller when the market is oligopsonistic.

Secondly, in the absence of oligopsony power in the farm input market, there is a one-to-one correspondence between farm input price and retail price when the cost share of the farm input is unity so that a percentage change in the former leads to a percentage change in the latter.

Finally, for any given value of oligopsony power, the transmission elasticity increases as we allow for larger shares of the farm input simply reflecting the monotonic relationship between γ_a and the elasticity of price transmission.

The above results are illustrated in Figure 6.7. The solid line represents values of the transmission elasticity for different shares of the farm input when ϕ=0, while the dashed,

Table 6.7: Interaction between the farm input's cost share and oligopsony power

γ_a	$\phi = 0$	$\phi = 0.25$	$\phi = 0.5$	$\phi = 0.7$
0.1	0.087	0.072	0.066	0.062
0.2	0.176	0.015	0.132	0.125
0.3	0.269	0.224	0.202	0.191
0.4	0.364	0.303	0.273	0.258
0.5	0.462	0.385	0.346	0.328
0.6	0.563	0.469	0.422	0.399
0.7	0.667	0.556	0.5	0.474
0.8	0.774	0.646	0.581	0.550
0.9	0.885	0.738	0.664	0.629
1.0	1.0	0.834	0.75	0.71

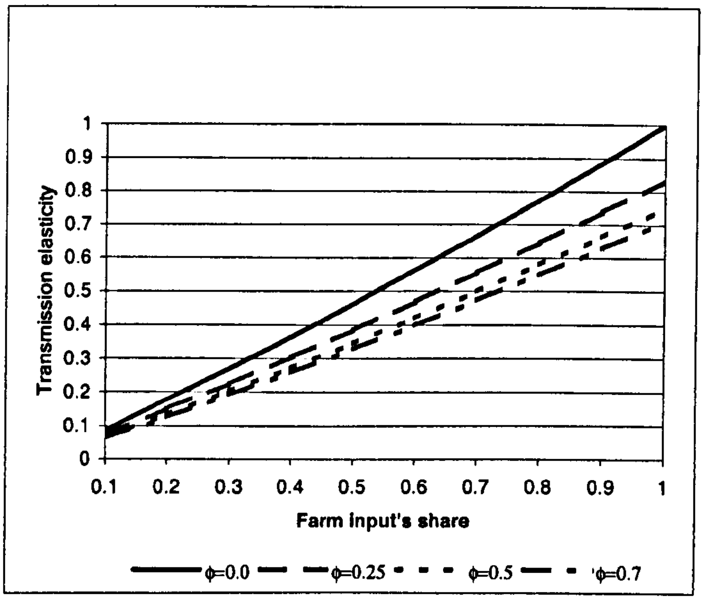
dotted and dash-dotted lines represent such values for $\phi = 0.25$; $\phi = 0.5$; and $\phi = 0.7$ respectively.

As is clearly shown in the figure, for any given degree of oligopsony power, all lines are rising over the entire range of γ_a, signifying the positive impact of larger farm input cost shares on the elasticity of price transmission. Also evident is the fact that not only do lines associated with larger values for oligopsony power fall below those associated with smaller such values (e.g., the solid line above the dashed) but also that the lower the lines get the flatter they become. This implies that not only does a more oligopsonistic industry lessen the transmission elasticity for any given share of the farm input but that every successive increase in this share contributes little to enhancing the transmission elasticity.

6.4.3 The elasticity of price transmission allowing for the interaction between e_a and ϕ assuming $\gamma_a = 0.5; e_b = 1.0; \sigma = 0.5; \eta = 0.75$

The main aim of this experiment is to examine the relative impact of the elasticity of farm input supply on the degree of price transmission when the industry exercises oligopsony power. With the view to achieving this aim, we allow e_a, *ceteris paribus*, to vary within

Figure 6-7: Interaction between farm input's cost share and oligopsony power



a range of 0.1 and 1 given a range of values for ϕ between 0 and 0.7. Our choice of values for e_a is not arbitrary. As we have already pointed out earlier, when analyzing oligopsony power, only the inelastic portion of a linear supply curve yields results that are analogous to those for the model assuming oligopoly power, and since our aim is to compare the relative effects of oligopoly and oligopsony power, this assumption serves a good purpose here. We summarize the results of this simulation exercise in Table 6.8. Two observations are worthy of note here.

Firstly, for a given value of e_a, and relative to when perfect competition is assumed (i.e., for ϕ=0), the transmission elasticity falls as oligopsony power rises highlighting that a higher degree of oligopsony power reduces the degree of price transmission. As we have just explained in the preceding, this highlights the role of the price mark-down in moderating movements in the transmission elasticity when the industry is oligopsonistic.

Secondly, as the industry gets oligopsonistic (i.e., for $\phi > 0$), a relatively more elastic e_a works to enhance the degree of price transmission. This follows because, for a given degree of oligopsony power, the more elastic farm input supply becomes, relative to

Table 6.8: Interaction between farm input supply elasticity and oligopsony power

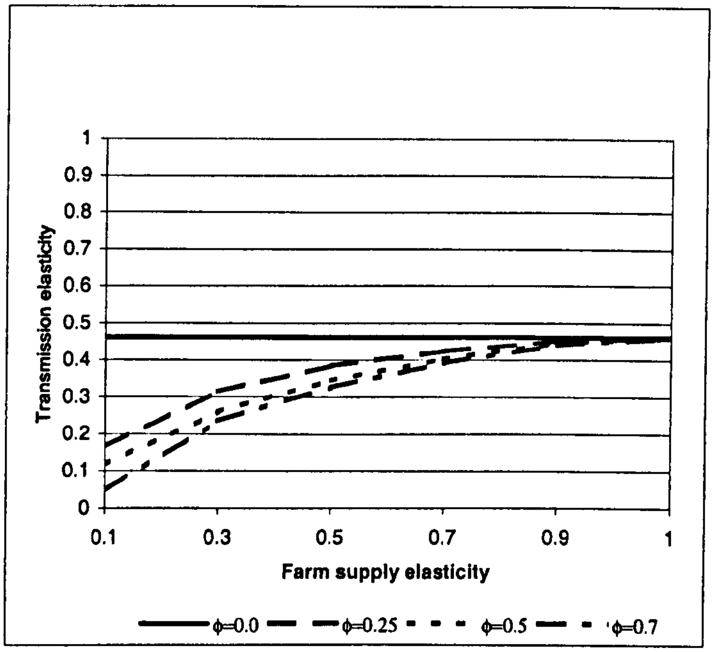
e_a	$\phi = 0$	$\phi = 0.25$	$\phi = 0.5$	$\phi = 0.7$
0.1	0.462	0.165	0.116	0.046
0.3	0.462	0.315	0.26	0.236
0.5	0.462	0.385	0.346	0.327
0.7	0.462	0.425	0.404	0.393
0.9	0.462	0.452	0.446	0.441
1.0	0.462	0.462	0.462	0.462

its initial position, the less the oligopsonist's power over price of the farm input, and, consequently, the narrower the mark-down becomes. When the industry is perfectly competitive, on the other hand, the elasticity of price transmission becomes insensitive to changes in e_a. This is because when an exogenous shock arises in the farm input market, e_a does not enter the expression for the transmission elasticity as shown in equation (6.1) early on in the chapter apart through the market power parameter, ϕ. This being the case, changes in e_a do not affect the degree of price transmission.

These observations are illustrated in Figure 6.8 where, in the absence of oligopsony power, i.e., for ϕ=0, the solid line represents values of the transmission elasticity for different values of e_a whereas the dashed, dotted and dash-dotted lines represent such values for ϕ=25, ϕ=0.5 and ϕ=0.7 respectively.

As Figure 6.8 clearly shows, lines corresponding to larger values of oligopsony power (e.g., ϕ=0.7) lie lower than those corresponding to smaller such values (e.g., ϕ=0.25) indicating that, for any given value of e_a, the price transmission elasticity is smaller for a more oligopsonistic industry than for a less oligopsonistic one. The figure also shows that as e_a approaches unity, all lines tend to converge suggesting that, when this obtains, oligopsony power does not have any impact on the elasticity of price transmission. This can be interpreted as saying that, given a unitary-elastic supply of the farm input, any change in the price of the farm input is matched by a proportionate change in the marginal revenue product so that, on net, the mark-down remains unchanged.

Figure 6-8: Interaction between farm supply elasticity and oligopsony power



6.4.4 The elasticity of price transmission allowing for the interaction between e_b and σ assuming $\gamma_a = 0.5$; $\gamma_b = 0.5$; $e_a = 0.5$; $\eta = 0.75$; $\phi = 0.25$

Assuming oligopsony power is present in the industry, and for a given range of σ, the effects of changes in the marketing supply elasticity on the degree of price transmission are examined. To this end, σ is allowed to vary, *ceteris paribus*, given a range of values for e_b running from 0.5 to 2 and for ϕ=0.25. Our choice of the lower range of values for ϕ is intended to bring out the minimum possible effects that oligopsony power can have on the degree of price transmission. We summarize our simulation results in Table 6.9. Under the given assumptions, the following patterns emerge for movements in the price transmission elasticity.

Firstly, over the entire range of e_b, a greater possibility for input substitution increases the degree of price transmission. To repeat a point that we have just made elsewhere,

Table 6.9: Interaction between substitution and marketing supply elasticities

σ	$e_b = 0.5$	$e_b = 1$	$e_b = 2$
0.1	0.27	0.322	0.361
0.2	0.299	0.339	0.371
0.3	0.326	0.355	0.38
0.4	0.349	0.371	0.389
0.5	0.371	0.385	0.397
0.6	0.391	0.398	0.405
0.7	0.408	0.411	0.413
0.8	0.426	0.423	0.421
0.9	0.441	0.434	0.428
1	0.455	0.445	0.435

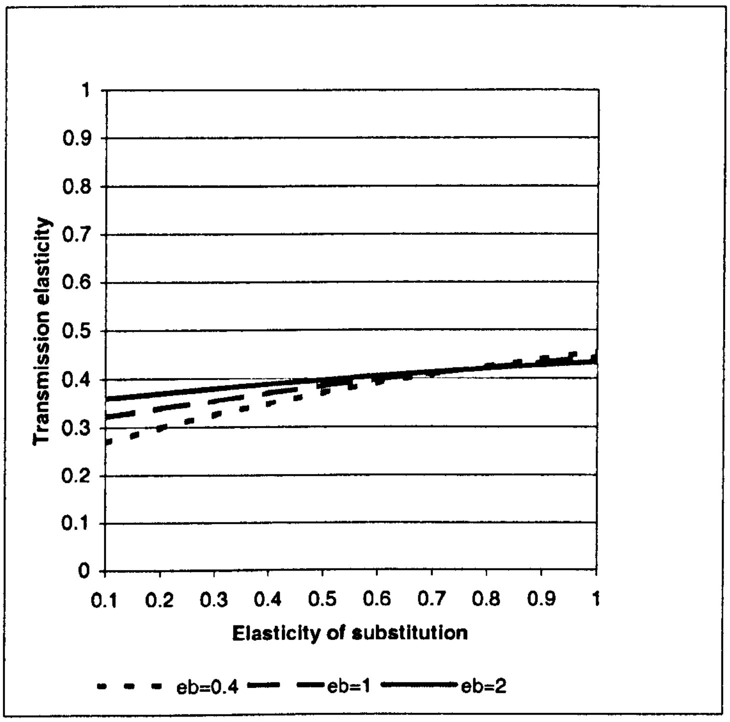
this follows because the increase in demand for the marketing input, as a result of the farm input becoming relatively more expensive, increases the price of this input in the short-run and thereby enhances the degree with which the increase in farm input price is passed on to the price of the retail product.

Secondly, for a certain range of values for σ (in our case, for $0.1 \leq \sigma \leq 0.8$), the degree of price transmission is greater for a more elastic marketing supply than for a less elastic such supply. For a certain other range of values (in our case, $0.8 \leq \sigma \leq 1$), on the other hand, the degree of price transmission is weaker for a more elastic marketing supply. A possible explanation for the ambiguity surrounding the effect of e_b on the degree of price transmission has been offered earlier. We will not, therefore, repeat it here.

The patterns that we have summarized above are illustrated in Figure 6.9. The solid line tracks values of the transmission elasticity for different degrees of input substitution when e_b=0.5 while the dashed and dotted lines track such values for e_b =1 and e_b =2 respectively.

Evidently, all lines are rising over the entire range of e_b emphasizing the result that σ impacts positively on the transmission elasticity over the entire range of values for e_b. It is also apparent that the dotted line lies above the dashed and solid lines for some values of σ and below them for other such values. For different degrees of substitution, this shows the ambiguity of the marketing elasticity's impact on the degree of price transmission.

Figure 6-9: Interaction between substitution and marketing supply elasticities



6.4.5 The elasticity of price transmission allowing for the interaction between γ_a and σ assuming $\gamma_b = 1 - \gamma_a$; $e_a = 0.5; \eta = 0.75; \phi = 0.25; e_b = 1$

In this experiment, we aim to show the impact of the cost share of the farm input on the degree of price transmission, for a given range of values for σ, when the industry exercises a certain degree of oligopsony power. To this effect, we run a simulation exercise whereby we allow γ_a to vary within a range of 0.1 and 1, for a range of values of σ between 0 and 1, and for ϕ=0.25. Table 6.10 summarizes these simulation results. The most salient features can be summarized as follows.

Firstly, for a given γ_a, and relative to when factors are combined in a fixed proportion (i.e., for σ=0), the elasticity of price transmission increases as the possibility for input substitution is greater. We have offered an intuitive explanation for this more than once. So we do not repeat it here. Secondly, for any given combination of inputs (i.e., for any given value of σ), a larger γ_a is associated with a higher degree of price transmission indicating the composition of inputs in the industry. Finally, as γ_a approaches unity, so does the elasticity of price transmission approach its maximum value regardless of the proportion in which inputs are combined. This is quite intuitive because if γ_a is unity, then factor combination vanishes and σ=0. Consequently, the maximum degree of price transmission that is achievable when σ=0.0 applies to all other factor combinations as well.

These results are illustrated in Figure 6.10 where the elasticity of price transmission is shown on the vertical axis and the farm input's cost share on the horizontal axis. The solid, dashed, dotted and dash-dotted lines capture the transmission elasticity's response to changes in γ_a for $\sigma = 0$; for σ=0.25; for σ=0.75 and for σ=1.

It is clearly shown that all lines are rising over the entire range of γ_a emphasizing the point that, for any given value of σ, the larger γ_a, the more forceful the pass-through of changes in the price of the farm input to the price of the retail product.

Table 6.10: Interaction between farm input's cost share and substitution elasticity

γ_a	$\sigma = 0$	$\sigma = 0.25$	$\sigma = 0.75$	$\sigma = 1$
0.1	0.05	0.061	0.083	0.095
0.2	0.104	0.127	0.167	0.186
0.3	0.164	0.196	0.25	0.274
0.4	0.23	0.269	0.334	0.356
0.5	0.303	0.347	0.417	0.445
0.6	0.385	0.432	0.501	0.527
0.7	0.477	0.521	0.584	0.607
0.8	0.58	0.618	0.667	0.684
0.9	0.699	0.722	0.751	0.76
1	0.834	0.834	0.834	0.834

The figure also shows that over the entire range of γ_a, lines that correspond to higher degrees of input substitution lie higher than those that correspond to lower such degrees emphasizing the key role that input substitutability plays in price transmission. As the cost share of the farm input becomes unity, however, all lines converge at a point on the right vertical axis.

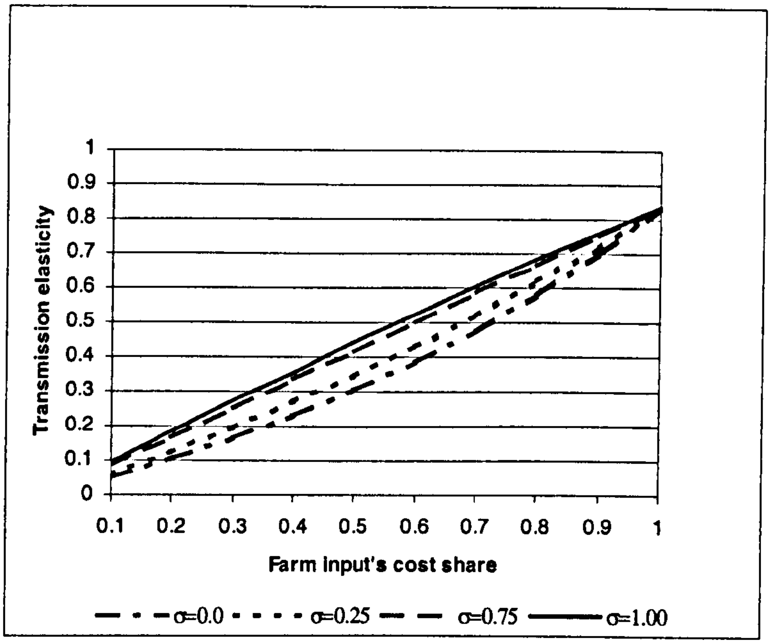
6.4.6 The effects of oligopsony power on the degree of price transmission: a summary of simulation results

The simulated experiments that we have carried out to analyze interactions between any two of the key determining variables, assuming the industry exercises oligopsony power, seem to have generated a pattern of results, which, in qualitative terms, is similar to that generated by assuming an oligopolistic industry.

Firstly, on interacting with the measure of oligopsony power, ϕ, the cost share of the farm input, γ_a, or the marketing supply elasticity, e_b, the effect of the substitution elasticity always appears to strengthen the degree of price transmission

Secondly, on interacting with, the elasticity of substitution, σ, the elasticity of the farm input supply, e_a, or the farm input cost share, γ_a, and for a linear farm input supply

Figure 6-10: Interaction between farm input's cost share and substitution elasticity



function, oligopsony power always appears to weaken the degree of price transmission.

Thirdly, on interacting with either ϕ or σ, an increasing the cost share of the farm input always appears to stand to strengthen the degree of price transmission.

Fourthly, on interacting with σ, the effect of the marketing supply elasticity always seems to be ambiguous; it being the case that for a relatively lower range of values for σ, its effect is to strengthen the degree of price transmission while for an upper range of such values, its effect is to weaken it.

Fifthly, on interacting with oligopsony power, a more elastic supply of the farm input always appears to stand to enhance the degree of price transmission.

Finally, relative to the competitive benchmark, and assuming a linear supply function, the impact of oligopsony power on the degree of price transmission is not so much qualitative as it is quantitative.

Abstracting from the theoretical model of price transmission that we have developed in the previous chapter, we can therefore conclude that, for comparable values of the parameters that determine the elasticity of price transmission, the effects of oligopsony power on the degree of price transmission are in qualitative terms similar to those of oligopoly power. But in quantitative terms they are not identical. This is because the determinants of changes in the mark-down and in the mark-up are different. For comparable values of oligopsony and oligopoly power, the former is determined by the elasticity of farm supply while the latter is determined by the elasticity of retail demand. While the farm supply elasticity takes on values between 0 and 1, the elasticity of retail demand takes on any value.

From this perspective therefore it can be conjectured that, given linear farm supply and retail demand functions, the combined effect of both oligopoly and oligopsony power is to weaken the degree of price transmission further. This is because at the same time that the price of the farm input changes, both the mark-up and the mark-down change as well. However, the extent to which they work to weaken the degree of price transmission can be evident only when we simulate, in the manner we have just done in the previous two sections, allowing for both forms of market power. And this is the task we turn to in the following section.

6.5 Simulating the combined effects of oligopoly and oligopsony power on the degree of price transmission

In this section, we set out to examine the combined effects of both oligopoly and oligopsony power on the degree of price transmission. In doing this, we adopt all parameter values which we assumed in the previous sets of experiments. To see whether the assumption of both forms of market power produces predictions, for movements in the elasticity of price transmission, that are any different from those we derived in the previous sets of experiments, it suffices considering only the interaction between market power and the elasticity of substitution and that between the former and the share of the raw input.

6.5.1 The elasticity of price transmission allowing for the interaction between σ and $(\theta;\phi)$ assuming $\gamma_a = 0.5$; $\gamma_b = 0.5$; $e_b = 1.0$; $\eta = 0.75$; $e_a = 0.5$

The aim of this experiment is to examine how changes in input combination bear on the degree of price transmission when both oligopoly and oligopsony power are present in the industry. This it does by allowing σ to vary, *ceteris paribus*, for a range of comparable values of oligopoly power, θ, and oligopsony power, ϕ. Table 6.11 summarizes the results of this simulation exercise. We abstract two major observations from this table.

Firstly, for a given degree of input substitution, and relative to when the industry is perfectly competitive (i.e., for θ=0; ϕ=0), the degree of price transmission decreases as the degrees of both forms of market power increase. In fact, for very large values of these forms of market power (in our case, for θ=0.7 and ϕ=0.7), the price transmission elasticity is forced close to zero no matter what value is assigned the substitution elasticity. As a result, the substitution elasticity is made neutral in its effect on the transmission elasticity, and, as such, whether factors are combined in fixed or variable proportions matters very little for the degree of price transmission. The intuition is that as the price of the farm input increases, both the mark-down and the mark-up fall and *vice versa* and thereby lower the elasticity of price transmission further than when either oligopoly or oligopsony alone is assumed.

Secondly, for given comparable values of oligopsony and oligopoly power, and relative to when a fixed input proportion is assumed, a greater possibility for input substitution enhances the degree of price transmission.

The above results are plotted in Figure 6.11. The solid, dashed, dotted and dash-dotted lines represent values of the transmission elasticity, given a range of values for σ between 0 and 1, and for θ=0, ϕ=0; θ=0.25, ϕ=0.25; θ =0.5, ϕ=0.5; and θ =0.7,

Table 6.11: Interaction between the substitution elasticity, oligopoly and oligopsony power

σ	$\theta = 0; \phi = 0$	$\theta = 0.25; \phi = 0.25$	$\theta = 0.5; \phi = 0.5$	$\theta = 0.7; \phi = 0.7$
0.0	0.364	0.185	0.077	0.014
0.2	0.407	0.205	0.087	0.015
0.4	0.444	0.222	0.091	0.016
0.6	0.478	0.237	0.096	0.017
0.8	0.507	0.25	0.101	0.018
1.0	0.533	0.262	0.105	0.018

ϕ=0.7 respectively. As this figure clearly shows, over the entire range of σ, the solid line lies above the dashed line, the dashed above the dotted line, and the latter above the dot-dashed line signifying that large comparable values for θ and ϕ work to dilute the substitution elasticity's impact on the transmission elasticity. Also evident is the fact that the lower the lines get, the flatter their slopes become, indicating that as θ and ϕ grow in magnitude, subsequent increases in the substitution elasticity contribute little to enhancing the degree of price transmission.

6.5.2 The elasticity of price transmission allowing for the interaction between S_a and $(\theta; \phi)$ assuming $\gamma_b = 1 - \gamma_a; \sigma = 0.5; e_b = 1; \eta = 0.75; e_a = 0.5$

In this experiment, we simulate, *ceteris paribus*, and for different degrees of market power, the effects of the raw input's cost share on the degree of price transmission. Table 6.12 summarizes these simulation results. The most important features are presented as follows.

Firstly, relative to when all markets in the industry are competitive, and for a given cost share of the farm input, the degree of price transmission decreases as the degrees of both forms of market power increase due to the simultaneous movements in the mark-up and in the mark-down. Secondly, for comparable degrees of market power, θ and ϕ, the degree of price transmission increases as the cost share of the farm input increases again

Figure 6-11: Interaction between oligopoly, oligopsony and substitution elasticity

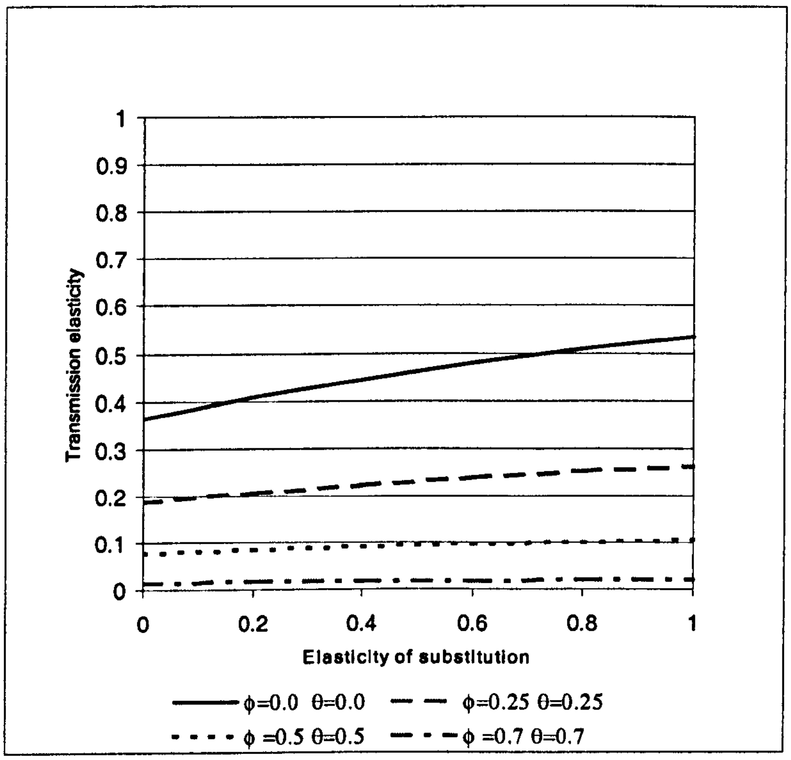


Table 6.12: Interaction between oligopoly, oligopsony and farm input's cost share

γ_a	$\theta=0;\phi=0$	$\theta=0.25;\phi=0.25$	$\theta=0.25;\phi=0.25$	$\theta=0.25;\phi=0.25$
0.1	0.087	0.047	0.021	0.004
0.2	0.176	0.094	0.041	0.007
0.3	0.269	0.14	0.059	0.011
0.4	0.364	0.185	0.077	0.014
0.5	0.462	0.23	0.094	0.017
0.6	0.563	0.274	0.11	0.019
0.7	0.667	0.318	0.125	0.022
0.8	0.774	0.361	0.14	0.024
0.9	0.885	0.403	0.153	0.026
1	1	0.445	0.167	0.028

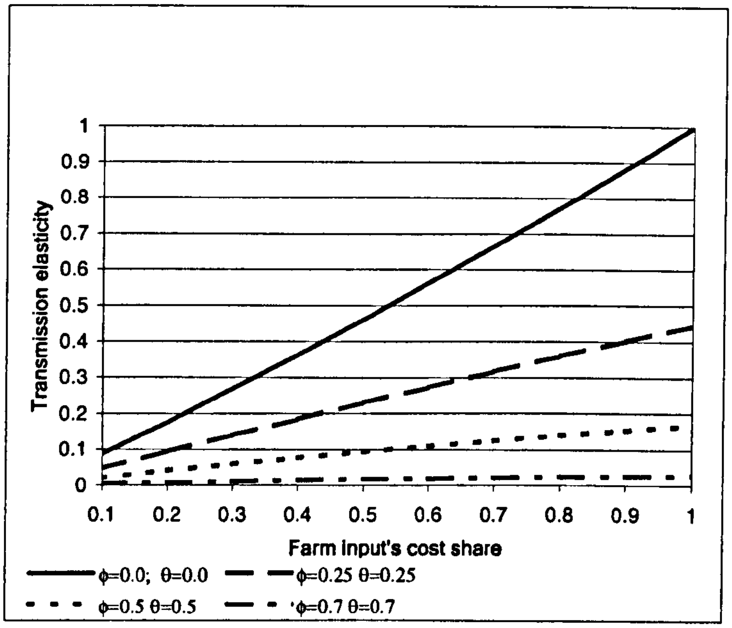
suggesting the proportion in which inputs are combined.

These results are illustrated in Figure 6.12 where the effects of the farm input's cost share on the transmission elasticity, for θ=0, ϕ=0; θ=0.25,ϕ=0.25; θ=0.5, ϕ=0.5 and θ=0.7 ϕ=0.7 are shown by the solid, dashed, dotted and dot-dashed lines respectively. It is shown that over the entire range of γ_a, the solid line lies way above the dashed, the dashed above the dotted line and the latter above the dot-dashed line suggesting that successively large values of oligopoly and oligopsony power dampen the positive effects of γ_a. It is also shown that the slopes of the lines representing successively large values of market power get flatter suggesting that every increment in γ_a results in a smaller incremental change in the transmission elasticity as the degrees of both forms of market power increase. In fact, as market power gets large enough (in our case, for θ=0.7 and θ=0.7), the slope gets very close to zero.

6.5.3 Simulating the effects of oligopoly and oligopsony power on the degree of price transmission: a summary of results

As the above simulation exercise has clearly shown, in qualitative terms, the presence of market power at both the farm supply and retail sectors works to dampen the degree of price transmission as does the presence of market power at only one stage. In quantitative

Figure 6-12: Interaction between oligopoly, oligopsony and cost share of the farm input



terms, however, the presence of market power at both stages of the industry stands to dampen the degree of price transmission far more than does its presence at only one stage of the industry.

6.6 Summary: the elasticity of price transmission and the relative significance of its determinants

With the view to assessing the relative significance of each of the parameters which determine the elasticity of price transmission under different market structures, this chapter has run a series of simulated experiments which, *ceteris paribus*, control for the interplay between any two determining variables. The results are summarized as follows.

Firstly, for any given form of market structure (i.e., for any given degree of market power either in the retail sector or in the farm sector or in both), *ceteris paribus*, increasing the degree of substitutability between the farm and marketing inputs increases the elasticity of price transmission. However, not only are the effects of this parameter diluted by higher degrees of market power but they are also ambiguous for different magnitudes of the elasticity of marketing services. As such, the role of the substitution elasticity as a determinant of the transmission elasticity cannot be considered of first-order significance as this critically depends on the relative magnitudes of market power and of the marketing supply elasticity.

Secondly, for any given form of market structure, increasing the cost share of the farm input increases, *ceteris paribus*, the elasticity of price transmission. In fact, for a cost share of the farm input equal to unity, a one-to-one correspondence arises between the transmission elasticity and the cost share of the farm input when perfect competition is assumed in the input and output markets. However, like that of the substitution elasticity, the effect of the cost share of the farm input is sensitive to the presence of market power with the latter's increase resulting in smaller values for the transmission elasticity. And yet, for any form of market structure, its impact is always to enhance the degree of price transmission. Therefore the role of the cost share of the farm input as a determinant of the price transmission elasticity can be considered of first-order significance.

Thirdly, the elasticity of retail demand impacts negatively on the elasticity of price transmission, *ceteris paribus*, when the input and output markets are perfectly competitive. Once market power is allowed for in the retail market, however, its impact cannot be predicted *a priori*. This also seems to be the case with the elasticity of farm input supply which enters into the expression for the transmission elasticity when oligopsony power is present in the farm input market. It appears that when this market is assumed perfectly competitive, the farm input supply elasticity plays no role as a determinant of the transmission elasticity. When oligopsony power is assumed, however, a more elastic farm input supply impacts positively on the transmission elasticity over the relevant range. The roles of both the farm supply and retail demand elasticities, as determinants of the transmission elasticity, are therefore conditional on the forms of market structure.

As such, they cannot be considered of first-order significance.

Fourthly, for any given form of market structure, the impact of the marketing supply elasticity cannot be determined *a priori* as it critically depends on the range of values other parameters take on. We have shown this for a wide range of values for the substitution elasticity. This means, as the supply of the marketing input becomes more elastic, the elasticity of price transmission can either increase or decrease depending on the range of values for the substitution elasticity. This being the case, the role of the marketing supply elasticity as a determinant of the price transmission elasticity is indeterminate.

Finally, the effects of market power in both the retail and farm supply sectors are, *ceteris paribus*, and assuming linearity in the demand function for the retail product and for farm supply, to consistently weaken the degree of price transmission; and, this, regardless of the range of values other parameters take on. But caution needs to be exercised when making this assertion.

The outcome for the effect of market power arises more from an *a priori* imposition of specific forms of retail demand and farm supply functions than from the nature of market power as such. Otherwise, we have shown that market power's impact on the degree of price transmission is ambiguous. Given these irregularities in the behavior of market power, its effects can be considered of a first-order significance only to the extent that we assume a linear demand function for the retail product and the inelastic portion of a linear supply function for farm supply.

To this stage of the thesis we have accomplished several tasks. First, using a simple diagrammatic approach, we have shown in chapter 2 how, given perfectly competitive input and output markets, and given different assumptions regarding input proportions, we can predict changes in the marketing margin and the degree of price transmission following changes in the conditions of demand for the retail product and of supply for the farm and marketing inputs. Second, we have shown, through our exposition of the theoretical literature in chapters 3 and 4, how price transmission works theoretically in vertically-related markets. Third, building on existing theory, we have developed in chapter 5 a model of price transmission accounting for seller power in the retail sector of the vertical market and for buyer power in the purchase of the farm input. We then have carried out a simulated experiment in chapter 6 to evaluate the effects of market power on the degree of price transmission controlling for its interaction with other determining parameters.

In the following we embark on an attempt to see if there exists a link between the predictions of the theoretical model that we have developed in chapter 5 and cointegration. In the literature there seems to have been no attempt to identify, based on the predictions of price transmission models, the conditions under which a cointegrating relation exists between the prices of the farm and retail products. There seems to be a widespread perception that on the basis of information relating to the prices of the farm and retail products alone one can establish a cointegrating relation. Against this backdrop, we set out to make a contribution to the literature by attempting to make inferences about a co-integrating relation between the farm and retail product prices based on the predictions of the theoretical model of price transmission that we have developed in chapter 5.

To the build up to our theoretical development of a model of price transmission allowing for the interaction between oligopoly and oligopsony power, we have been preoccupied solely with the exposition of the theoretical framework of price transmission given different market structures. Indeed, to this stage we have not looked into the literature dealing with the empirical estimation of the degree of price transmission. However, now that we have set ourselves a task of establishing a link between the theoretical models of price transmission and cointegration, we need to explore the extant empirical literature with the view to introducing the theory and application of cointegration. As the review will show, the literature offers a wide range of empirical methodologies that have been employed to measure the degree of price transmission. In the following chapter, we make an exposition of these methodologies and present results of selected studies which utilize each of these methodologies.

To lay bare our plans for the rest of the thesis, we set out in chapter 8 to build on what we have learned about co-integration in chapter 7 and attempt to make inferences about a co-integrating relation between the prices of the farm input and of the retail product based on the predictions of our model in chapter 5. Once we identify the conditions under which a co-integrating relation arises between the price pair, we then test, in chapter 9, for the existence of a co-integrating relation between a time series of 11 price pairs in the UK to evaluate whether our predictions in chapter 8 are borne out. We then conclude our thesis in chapter 10.

Chapter 7

Price transmission in vertical markets: a review of the empirical literature

7.1 Background

Following the seminal work of Gardner (1975) which set out the basic determinants of changes in farm input and retail level prices, a huge body of empirical literature has developed revolving around the issue of price transmission in vertical markets. This body of literature has made use of different methodological approaches depending on the level of sophistication attained in econometric techniques. We can categorize these approaches into four. The approach followed by the early models, the structural approach, the approach advocated by co-integration (or the error-correction model) and the approach which combines the structural modelling approach and co-integration. In the following, we discuss these modelling approaches each in detail.

7.2 Early models of vertical price transmission

Early empirical work on vertical price transmission focuses on testing the direction of causality in price transmission and (or) on estimating a correlation coefficient for prices at different stages of the marketing chain using time series data.

Examples of this approach for the US food industry include Heien (1980) who considers monthly data over the period 1960-1976, and Lamm and Westcott (1981) who consider quarterly data over the period 1968-1977 and Kinnucan and Forker (1981) who consider monthly data over the period 1971-1981. Examples for the UK along this methodological line include those by Bacon (1986) who considers monthly data for the oil industry over the period 1977-1985, and Trail and Hansen (1994) who examines the yellow fats market over the period 1980-1990 using monthly data.

The empirical strategy followed by these studies involves estimation of a regression equation to test causal direction and of another regression equation to estimate the raw input-retail price relationship.

The former task implements the causality test developed by Sims (1972) based on a concept of causality first formulated by Granger (1969). This test proceeds by first filtering the distributed lag model to achieve serially uncorrelated regression residuals. This involves measuring all variables used in the regression equation as natural logs and then pre-filtering (i.e., first-differencing) them.

Once this is achieved, then the filtered dependent variable, $\bar{Y}$ is regressed on lagged and future values of the filtered independent variable, $\bar{X}$. For expository purposes, let the lagged and future values of $\bar{X}$, be set to two. The regression equation can then be written as:

$$\bar{Y} = \beta_0 + \beta_1 \bar{X}_{t+2} + \beta_2 \bar{X}_{t+1} + \beta_3 \bar{X}_t + \beta_4 \bar{X}_{t-1} + \beta_5 \bar{X}_{t-2} + u_t \qquad (7.1)$$

where u_t is a white noise residual. A unidirectional causality from X to Y is said to exist if the coefficients on the future values of $\tilde{X}$ do not enter the regression equation; i.e., when $\beta_1 = \beta_2 = 0$, or when both are insignificantly different from zero. To evaluate whether causality runs from Y to X as well, then one can run the reverse regression.

Once causality is established, the next task involves specifying retail price as a distributed lag in raw input (or wholesale) price as:

$$\ln r_t = \beta_0 + \beta_1 \ln w_t + ... + \beta_k \ln w_{t-k} + u_t \tag{7.2}$$

where r_t and w_t represent retail and raw input (or wholesale) prices respectively and k is the lag period. Given equation (7.2), ordinary least squares (OLS) estimates of the price transmission coefficient are then obtained and standard significance t and F tests conducted.

7.2.1 Evaluation of the early models

The procedure for making inferences about the transmission coefficient using conventional t and F significance tests is quite legitimate providing that the price series considered are stationary (i.e., have zero mean and constant variance) and form a long run economic relationship. However, these requirements are mutually exclusive, in that for two or more variables to constitute a long run relationship, they must be non-stationary.

Indeed the limitation of these econometric approaches emanates from the fact that the time series data of interest are usually non-stationary, i.e., their mean and variance changes over time. While this allows for the possibility of long run relationship between them, it invalidates hypothesis testing. Given the recurrence of non-stationarity among economic time series, regressions involving these series are likely to be spurious and the resulting inferences from the standard significance tests misleading. In other words, as Granger and Newbold (1974) have shown, it is possible for the regressions to establish correlation when in fact such does not exist.

Even if these series can be made stationary by differencing, so that the regression residuals are serially uncorrelated, the process which induces stationarity is liable to removing any critical long run information that may link the price series. As such, getting around the problem of serially correlated residuals involves a loss of critical long-run information. This 'mis-match' between the econometrics used to estimate the economics remained until the seminal works of Granger in the 1980's.

Time series econometrics had long recognized the need to avoid loss of long-run price information to achieve serially uncorrelated residuals, and it was in response to this critical need that the error correction model was formulated by Phillips (1957), Sargan (1964), and Salmon (1982), among others. The practical advantage of this model is that while the long run components of the variables are made to obey equilibrium constraints dictated by the underlying economic theory, the short run components are made to follow a flexible dynamic specification.

But it was not until Granger (1981) introduced the concept of co-integration that it was recognized that not only does the error correction model generate co-integrated series but also that the co-integrated series have an error correction representation. Granger (1983) proved the duality between co-integration and the error correction mechanism in the Granger Representation Theorem.

Following the work of Engle and Granger (1987) which suggested a formal procedure for testing and estimation of a co-integrated series, testing for co-integration prior to regressing any price relationships has become almost mandatory in empirical work. The rationale for doing this is to ensure that only variables which are tied to each other in a long run relationship enter the regression equation. In other words, a co-integration test advises the analyst against running regressions that involve variables which are not locked in a long run relationship. To clarify this point, we need to undertake a brief exposition of co-integration and the error-correction mechanism implied therein, a task we set ourselves next.

7.3 Co-integration and the error-correction mechanism (ECM)

In keeping with the notations that we have used elsewhere in the thesis, consider two price series representing producer's price, P_{at} and retailer's price, P_{xt},. Now assume that these price series are integrated of order 1 (i.e., P_{at}, P_{xt} $\sim$ I(1)) so that, in their raw form, they are non-stationary. This means that they need differencing once to make them stationary (i.e., $\triangle P_{at}$, $\triangle P_{xt}$ $\sim$ I(0)). Granger (1981) shows that a linear combination of two I(1) series is in general I(1). But there can arise a special case whereby, for a given a constant, *m,* a linear combination of these series, specified as,

$$Z_t = m + aP_{at} + bP_{xt} \tag{7.3}$$

is both I(0) and has a zero mean. When this obtains, P_{at} and P_{xt} are said to be co-integrated.

To clarify this point, consider the following example by Engle and Granger (1992) which runs thus:

$$\begin{aligned} P_{at} &= AW_t + \tilde{P}_{at} \\ P_{xt} &= W_t + \tilde{P}_{xt} \end{aligned} \tag{7.4}$$

where W_t is I(1), $\hat{P}_{at}$ and $\hat{P}_{xt}$ are I(0) and A is a constant term. Given that a linear combination of an I(1) and an I(0) series is I(1), it follows that P_{at} and P_{xt} are I(1). To show that their linear combination can be I(0), multiply P_{xt} in (7.4) by A. Subtracting P_{xt} from P_{at}, one then obtains:

$$Z_t = \tilde{P}_{at} - A\ \tilde{P}_{xt} \tag{7.5}$$

Since $\tilde{P}_{at}$ and $\tilde{P}_{xt}$ are I(0) from (7.4), it follows that their linear combination, Z_t is also I(0). Co-integration between P_{at} and P_{xt} arises because they share an I(1) common factor, W_t, which makes them both I(1). In other words, P_{at} and P_{xt} co-integrate (i.e., possess a linear combination that is of lower order of integration than the variables themselves) where A is the co-integrating parameter.

As might be recalled, if pre-testing establishes that two series are co-integrated then there is an error- correction mechanism through which the analyst can capture both the short run dynamics and the long run relationship. To see this clearly, consider, in the manner of Harris (1995), a simple dynamic model of the form,

$$P_{xt} = \alpha_0 + \gamma_0 P_{at} + \gamma_1 P_{at-1} + \alpha_1 P_{xt-1} + u_t \tag{7.6}$$

where u_t is a white noise residual, i.e., $u_t \sim NI(0,\sigma^2)$.

Subtracting $P_{xt\text{-}1}$ from the left-hand and right-hand sides of (7.6), we obtain:

$$\Delta\ P_{xt} = \alpha_0 + \gamma_0 P_{at} + \gamma_1 P_{at-1} + (a_1 - 1)\ P_{xt-1} + u_t \tag{7.7}$$

Now adding and subtracting $(\alpha_1 - 1)P_{at-1}$ from the right-hand side of equation (5.7) and re-arranging yields,

$$\Delta\ P_{xt} = \alpha_0 + \gamma_0\,\Delta\ P_{at} + (\gamma_0 + \gamma_1)\ P_{at-1} + (\alpha_1 - 1)\ P_{xt-1} + u_t \tag{7.8}$$

which, upon grouping like terms, may be reparametrized as an ECM formulation of the dynamic model in equation (7.6) as:

$$\Delta P_{xt} = \gamma_0 \Delta P_{at} - (1-\alpha_1)\left[P_{xt-1} - \beta_0 - \beta_1 P_{at-1}\right] + u_t \tag{7.9}$$

where $\beta_0 = \frac{\alpha_0}{1-\alpha_1}$; and $\beta_1 = (\gamma_0 + \gamma_1) / (1-\alpha_1)$.

The parameter γ_0 in equation (7.9) measures the short run response of P_{xt} to a change in P_{at}, as indeed can be seen from (7.6). The coefficient $(1-\alpha_1)$ measures the speed at which P_{xt} adjusts to long-run equilibrium. The term in bracket, $[P_{xt-1} - \beta_0 - \beta_1 P_{at-1}]$ measures the system's deviation from long run equilibrium in any period t and represents the error correction term. If the system is in equilibrium, this term will be zero. On the other hand, if the system is out of equilibrium, it will be non-zero. As such, the error correction model incorporates both short run and long run effects of a shock.

Now conjecture that P_{xt} and P_{at}, which have been assumed to be I(1), are co-integrated. Then it follows that the error correction term in (7.9) will be stationary, as a linear combination of two non-stationary variables that are co-integrated is stationary. The term, $\gamma_0\ \Delta P_{at}$ is stationary because the first difference of an I(1) series is stationary. For the same reason, so too is ΔP_{xt}. Thus clearly, an error correction model allows the dependent variable, which is stationary, to be explained purely by a stationary process. The corollary of this is that if P_{xt} and P_{at} are not co-integrated, then the error correction term will no longer be stationary, and, consequently, a stationary dependent variable will not be explained by non-stationary variables, i.e., by $(1-\alpha_1)$.

Thus it follows that the error-correction mechanism is valid only when the variables in levels in (7.9) are co-integrated. When such is the case, it also follows that the error correction model is free from the spurious regression problem. In this instance, the application of ordinary least squares regression is valid. In fact, Stock (1987) has shown that if two non-stationary series co-integrate, the OLS estimator of the long run co-integrating parameter, β_1 in (5.9) converges in probability to its true value at a much faster rate than the usual OLS estimator of the same parameter that is obtained using stationary I(0) variables. As the sample size, T, grows, then for any positive α, this speed of convergence is $T^{1-\alpha}$ as opposed to a conventional rate of asymptotic convergence which is $T^{1/2}$. That's why, the OLS estimator for a co-integrating parameter is called 'superconsistent'.

Note also that (7.8) and (7.9) are equivalent, in that each has the same error term . Hence, the economic formulation 'squares the circle' alluded to previously in that it may legitimately estimate by OLS (since all terms are stationary) and yet contains all the long run information contained in the I(1) components of the variables.

7.3.1 The test for co-integration

The two most popular tests for the existence of co-integration between two non-stationary variables are the Engle-Granger two-step procedure (Engle and Granger, 1987) and the Johansen full information maximum likelihood procedure (Johansen, 1988). Whereas the former assumes prior knowledge of the endogenous and exogenous variables, the latter does not require such knowledge and instead assumes all variables to be potentially endogenous. Since the Engle-Granger procedure assumes the existence of a single endogenous variable, it proceeds by estimating a single co-integrating regression. On the other hand, the latter estimates as many equations as there are endogenous variables.

The test for stationarity: the unit root test

A feature which is common to these two procedures is that they proceed by first testing for stationarity of the individual time series. The test for stationarity is equivalent to testing whether there is a unit root in the level of each individual series. Despite the plethora of test procedures to detect a unit root in economic time series, the procedure by Dickey and Fuller, DF (1979, 1981) has come out the most popular in empirical work[1].

To see how it is implemented in practice, consider the following autoregressive process of the first order, AR(1).

[1]For other unit root tests, see, among others, Phillips and Perron (1988); Kwiatkowski, Phillips and Schmidt (1990).

$$P_{xt} = \rho P_{xt-1} + u_t \tag{7.10}$$

which, when converted into its lag polynomial equivalent, can be written as:

$$\triangle\, P_{xt} = (\rho - 1)\, P_{xt-1} + u_t \tag{7.10.1}$$

where u_t is iid(0, σ^2).

Given equation (7.10.1), the test for stationarity proceeds by setting the null and the alternative hypotheses as:

$$\begin{aligned} H_0 &: \rho = 1 \\ H_1 &= -1 < \rho < 1 \end{aligned} \tag{7.10.2}$$

If the null hypothesis of a unit root is true, P_{xt} is a non-stationary I(1) series with no drift the implication being that the first difference is stationary. If the null is rejected in favor of the alternative hypothesis, then P_{xt} is said to be stationary.

The underlying data generating process (d.g.p.) in equation (7.10.1) is assumed to have a zero mean. If it has a non-zero mean, then it is necessary to modify this equation to allow for a constant, μ. Modifying this equation thus yields:

$$\triangle\, P_{xt} = \mu + (1 - \rho)\, P_{xt-1} + u_t \tag{7.10.3}$$

Given this modification, the null and alternative hypothesis of the test are as shown in equation (7.10.2). Non-rejection of the null shows that the original series, P_{xt}, are non-stationary while their first-differences are stationary.

If pre-testing suggests that the drift in the original series is significant, it is recommended to include a trend component in the maintained model. Doing this modifies (7.10.3) as:

$$\Delta P_{xt} = \mu + \beta t + (1-\rho) P_{xt-1} + \gamma_t \tag{7.10.4}$$

where t is a time trend. If given (7.10.4), the null hypothesis of non-stationarity cannot be rejected, then this suggests that the original series, P_{xt}, are non-stationary with a drift while their first differences are stationary.

If a simple AR(1) model is used when P_{xt} follows an AR(p) process, a problem arises in testing whereby the error term will be autocorrelated to make up for the mis-specification in the d.g.p. of P_{xt}. When such is the case, the specification in equation (7.10.4) is augmented with lagged differences so that the residuals are white noise. The Augmented Dickey-Fuller (ADF) representation of equation (7.10.4), as it is called, is thus written as:

$$\Delta P_{xt} = \mu + \beta t + (1-\rho) P_{xt-1} + \sum_{i-1}^{p} \delta_i \Delta P_{xt-i} + u_t \tag{7.10.5}$$

where p is the number of lags which is large enough to make the residuals white noise.

Having chosen the right specification, then OLS regressions can be run to test the null hypothesis of a unit root. It should, however, be noted that the t and F tests of the null hypothesis do not follow the standard distributions. They rather follow the Dickey-Fuller distributions. Therefore the tests for the null hypothesis of non-stationarity must be carried out using the t and F critical values constructed by Fuller (1976) and Dickey and Fuller (1981).

The Engle-Granger two-step procedure

Once the unit root test is carried out in the manner shown above, the next step is to test if the two series co-integrate. The Engle-Granger procedure for testing co-integration involves two steps.

The first step determines the long-run steady state relationship between the variables in the model. This proceeds by estimating the co-integrating regression involving non-stationary series using OLS as:

$$P_{xt} = \beta P_{at} + \varepsilon_t \tag{7.11}$$

The second step involves the test for stationarity in the residuals which result from (7.11). Assume the estimated residuals, $\hat{\varepsilon}_t$, follow an AR(1) process without any drift, then this step involves running a standard unit root test on the residuals,

$$\hat{\varepsilon}_t = \rho \hat{\varepsilon}_{t-1} \tag{7.11.1}$$

There have been alternative procedures to testing for co-integration using (7.11.1). Of these the most popular are the Augmented Dickey Fuller (ADF) test suggested by Dickey and Fuller (1981) and the Co-integrating Regression Durbin-Watson (CRDW) statistic suggested by Bhargava (1983).

Given its popularity, only the ADF is considered here. This procedure modifies equation (7.11.1) by allowing for lagged residuals as:

$$\Delta \hat{\varepsilon} = \psi \hat{\varepsilon}_{t-1} + \sum_{i=1}^{q} \psi_i \, \Delta \, \hat{\varepsilon}_{t-i} + \mu + \delta t + w_t \tag{7.11.2}$$

where q is the number of lags large enough to produce white noise u_t, μ is a constant term and t is a time trend.

As in a standard unit root test, the null hypothesis tests whether the residuals in levels, $\hat{\varepsilon}_t$, have a unit root (i.e., H_0: ψ=0). If the null cannot be rejected, then the model's variables are not co-integrated. If on the other hand, the null is rejected, the residuals in levels are stationary implying the variables are co-integrated. To repeat a point that has been made earlier on, the null hypothesis is based on a t test that has a non-normal distribution. Hence, modified Dickey-Fuller tables of critical values are used, i.e., critical values that depend on the number of regressors in equation (7.11).

In spite of its simplicity in application, the Engle-Granger two-step procedure has been criticized on many counts. Lloyd (1992) summarizes these criticisms as follows. Firstly, even though the OLS estimator of the true long run parameter is superconsistent in large samples, the bias in small samples could be substantial, and for a bivariate case is related to ($1-R^2$) as suggested by Banerjee et al.. (1987). Secondly, when there are more than two non-stationary variables in the model, the co-integrating vector may not be unique. Consequently, any vector that is detected may not be identified and thus not have economic interpretation but merely represents a linear combination of multiple stationary vectors. Thirdly, the procedure makes a prior assumption as to which variable is endogenous and which one is exogenous. Even though this assumption might have been inspired by economic theory, in practice, all the variables can be potentially endogenous.

The Johansen full information maximum likelihood procedure

To (at least partially) overcome the limitations of the Engle-Granger approach to testing for co-integration, Johansen (1988) and Johansen and Juselius (1992) propose a full information maximum likelihood procedure. This approach first proceeds by forming a multivariate vector autoregressive (VAR) model containing n potentially endogenous non-stationary variables, z_t, regressed on lagged values of themselves and on those of others as:

$$\mathbf{z}_t = \mathbf{A}_1\mathbf{z}_{t-1} + \ldots + \mathbf{A}_k\mathbf{z}_{t-k} + \mathbf{u}_t \tag{7.12}$$

where $\mathbf{z}_t$ is $(n\times 1)$ and $\mathbf{A}_{1\text{-}k}$ is an $(n\times n)$ matrix of parameters and k is the number of lags.

In its vector error-correction (VECM) form, equation (7.12) can be written as:

$$\Delta\,\mathbf{z}_t = \Gamma_1\Delta\,\mathbf{z}_{t-1} + \ldots + \Gamma_{k-1}\Delta\,\mathbf{z}_{t-k+1} + \Pi\mathbf{z}_{t-k} + \delta\mathbf{D}_t + \mathbf{u}_t \tag{7.12.1}$$

where ($\Gamma_i = -\mathbf{I}\text{-}\mathbf{A}_1\text{-}\ldots\text{-}\mathbf{A}_i$ for $i=1,\ldots,k\text{-}1$); and $\Pi = -(\mathbf{I}-\mathbf{A}_i-\ldots-\mathbf{A}_k)$ and D represents deterministic variables (e.g., seasonal dummies, shocks). The estimates of $\hat{\Gamma}_i$ and $\hat{\Pi}$ represent the short and long-run adjustments to changes in z_t. The vector Π represents $\boldsymbol{\alpha\beta}'$, where α denotes the speed of adjustment to disequilibrium, while $\boldsymbol{\beta}$ is a matrix of long-run coefficients such that $\Pi\mathbf{z}_{t-k}$ represents up to (n-1) co-integrating relationships in the model. For non-stationary I(1) variables in the vector z_t that form co-integrating relationships, then equation (7.12.1) can reduce to a stationary process only when $\Pi\mathbf{z}_{t-k}$ are stationary. Given that $\Gamma_i\Delta\mathbf{z}_{t-i}$ is stationary by assumption, then the stationarity of the former can only be guaranteed when $\boldsymbol{\beta}'\mathbf{z}_{t-k}$ forms (n-1) co-integrating relationships.

The fact that there are at most (n-1) co-integrating vectors in $\boldsymbol{\beta}$ means that there are at least r ($r \leq n\text{-}1$) columns of $\boldsymbol{\beta}$ that form stationary linearly independent combinations of the variables in z_t. But this also means that there are (n-r) vectors in $\boldsymbol{\beta}$ that do not form linearly independent combinations in the variables and as such are non-stationary. Now coming back to the requirement that equation (7.12.1) be a stationary process containing both short- and long-run elements, it follows that this can be guaranteed when $\boldsymbol{\beta}$ contains only r=n-1 linearly independent vectors and zero (n-r) vectors.

Thus according to the Johansen maximum likelihood procedure, the test for co-integration constitutes the test for finding the rank (i.e., the number of r linearly independent columns) of Π. This proceeds by running a reduced rank regression which yields n eigen values, $\hat{\lambda}_1 > \hat{\lambda}_2 ... \hat{\lambda}_n$, and the corresponding eigenvectors $\hat{\mathbf{V}}$. Those r elements in $\hat{V}$ which form the (*n-1*) co-integration vectors correlate with Δz_t, which are stationary. On the other hand, the last (n-r) elements in $\hat{\mathbf{V}}$ do not correlate with the stationary, Δz_t since they form I(1) combinations. This being the case, the reduced rank regression produces zero values for $\hat{\lambda}$ for those eigen vectors that correspond to (n-r) elements of β and non-zero values of $\hat{\lambda}$ for those eigen vectors that correspond to r elements of β.

The null hypothesis for the reduced rank regression can therefore be formulated to test whether there are (n-r) unit roots, i.e.,

$$H_0 = \lambda_i = 0 \qquad \forall i = r+1, ..., n \tag{7.13}$$

The statistic used to test the null hypothesis is called the trace statistic. It is a standard likelihood ratio test computed using the log of the maximized likelihood function for the restricted model, which requires that the first r eigenvalues be non-zero, and the log of the maximized likelihood function for the unrestricted model. Having a non-standard distribution, the trace statistic is expressed as:

$$\lambda_{trace} = -2\log(Q) = -T \sum_{i=r+1}^{n} \log(1 - \hat{\lambda}_i) r = 0,1,2, ..., n-2,\ n-1 \tag{7.14}$$

where Q is the ratio of the restricted maximized likelihood to the unrestricted maximized likelihood. If the null can be rejected, at a given significance level, there are at least r co-integrating vectors in the model. If on the other hand, the null cannot be rejected, there is no co-integrating vector in the model.

Once r co-integrating vectors are detected in the model, then a test is carried out whether there are r+1 co-integrating vectors. This is carried out using the maximaleigenvalue or λ-max statistic:

$$\lambda_{\max} = -T\log(1-\hat{\lambda}_{r+1}) \quad r=0,1,2,\ldots,\ n\text{-}2,\ n\text{-}1 \tag{7.15}$$

The null hypothesis of r co-integrating vectors is rejected if there are $r+1$ co-integrating vectors. If such do not exist, the null cannot be rejected.

Testing restrictions on α and β So far, the Johansen maximum likelihood reduced rank regression procedure only determines how many co-integration vectors there are in the co-integration space. However, it does not say whether these are unique, i.e., whether they can explain the structural relationship of the model. Having detected the number of co-integrating vectors, therefore a final step in the Johansen maximum likelihood estimation involves testing whether these are unique. This is carried out by imposing various restrictions on the co-integrating matrix, $\boldsymbol{\beta}$ that are motivated by economic arguments and then testing whether the column vectors are identified.

For instance, we might be interested to test whether the predictions of economic theory are borne out by the estimated values of some of the parameters in the co-integrating matrix. This can be done either by setting some of the column vectors of the co-integrating space, $\boldsymbol{\beta}_{ij}$, to zero or by imposing homogeneity restrictions so that any two variables of the co-integrating space are made to enter this space with a unit coefficient but with opposite sign. Formally, these hypotheses about β can be formulated as:

$$H_\beta = (H_1\varphi_1, H_2\varphi_2, \ldots, H_r\varphi_r) \tag{7.16}$$

where the set of matrices H, denotes a $(n\times s_i)$ linear restrictions to be tested on each of the r co-integrating relationships and φ is a $(s_i\times 1)$ vector of parameters to be estimated in the ith co-integration relation.

To clarify this point, consider an example from Doornik and Hendry (2001). Assume the Johansen procedure identifies two co-integrating vectors with a rank, $r = 2$. Then the unrestricted vectors can be written as:

$$\beta' y = \begin{pmatrix} \beta_{11} y_1 + \beta_{21} y_2 + \beta_{31} y_3 \\ \beta_{12} y_1 + \beta_{22} y_2 + \beta_{32} y_3 \end{pmatrix}$$

Suppose we wish to test that the first two variables enter the co-integrating vector with opposite signs. We can then impose $\beta_{21} = -\beta_{11}$, $\beta_{22} = -\beta_{12}$ to obtain:

$$H = \begin{pmatrix} 1 & 0 \\ -1 & 0 \end{pmatrix}, \ \varphi = \begin{pmatrix} \varphi_{11} & \varphi_{12} \\ \varphi_{21} & \varphi_{22} \end{pmatrix}, \varphi' H' = \begin{pmatrix} \varphi_{11} & -\varphi_{11} & \varphi_{21} \\ \varphi_{12} & -\varphi_{12} & \varphi_{22} \end{pmatrix}$$

Next, given the above example, i.e., for r=*2*, suppose we wish to impose known co-integrating vectors. Suppose that the first vector is y_1, y_2, y_3. Then the hypothesized restriction can be formulated as:

$$H = \begin{pmatrix} 1 \\ -1 \\ -1 \end{pmatrix}, \ \varphi = \begin{pmatrix} \varphi_{11} \\ \varphi_{21} \\ \varphi 31 \end{pmatrix}, (H : \varphi)' = \begin{pmatrix} 1 & -1 & -1 \\ \varphi_{11} & \varphi_{21} & \varphi_{31} \end{pmatrix}$$

Once these restrictions are imposed, we then wish to test whether these restrictions are supported by the data. This is carried out using a likelihood ratio test given by:

$$-2\ln(Q) = T\sum_{i=1}^{r} \ln\left\{ \frac{\left(1 - \hat{\lambda}_{H_i}\right)}{\left(1 - \hat{\lambda}_i\right)} \right\} \tag{7.17}$$

where $\hat{\lambda}_{H_i}$s are the eigenvalues of the VAR estimated under the null hypothesis. The test statistic follows a $\chi^2 r\,(n-s)$ distribution under the null as specified in (7.16). If the null cannot be rejected, we say the restrictions are congruent with the data.

In a similar fashion, we might wish to impose restrictions on the loading vector, α of the long-run relationship, $\Pi = \alpha\beta'$ as shown in (7.12.1) above to see if some of its rows are all zeros. By way of an example, suppose, in the manner of Harris, *op cit.*, a VAR of three equations, $z_t=(y_{1t}, y_{2t}, y_{3t})'$ and *r=2*. Further suppose the length of lag, *k=2*. Then the vector error-correction mechanism can be modelled as:

$$\begin{bmatrix} \Delta\, y_{1t} \\ \Delta\, y_{2t} \\ \Delta\, x_t \end{bmatrix} = \Gamma_1 \begin{bmatrix} \Delta\, y_{1t-1} \\ \Delta\, y_{2t-1} \\ \Delta\, x_{t-1} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \\ \alpha_{31} & \alpha_{32} \end{bmatrix} \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{31} & \beta_{12} \\ \beta_{22} & \beta_{32} \end{bmatrix} \begin{bmatrix} y_{1t-1} \\ y_{2t-1} \\ x_{t-1} \end{bmatrix}$$

Say the last row of the α vector contains all zeros, i.e., $\alpha_{31} = 0$; $\alpha_{32} = 0$. Then, we wish to test if this restriction is admitted by the data. If it is, then it means that the equation for $\Delta\, x_t$ can be excluded from the left-hand side of the system as this contains no information about the long-run vector, β. When such is the case, we say the variable, x_t is weakly exogenous, and, hence, can be used as a conditioning variable.

The test procedure for imposing a restriction on α is the same as the hypothesized restriction on β. First, set the null hypothesis, $H_0{:}\alpha_{ij}=0$ for *j=1,..., r,* i.e., row *i* contains all zeros. Then calculate the likelihood ratio statistic, as shown in (5.17) to test if the resulting estimate of the parameters in the restricted model occupy the same co-integrating space as the unrestricted model. To repeat a point that we have made earlier, this test statistic has a χ^2 distribution. If this statistic is smaller than the corresponding critical value, the null cannot be rejected and therefore the restriction is admitted by the data.

7.4 Price transmission studies based on the error-correction model.

Following the introduction and adoption of co-integration recent years have seen a burgeoning of research on vertical price transmission. The two major hypotheses this research has set out to test are (i) whether producers' and consumers' prices in vertically-related markets are tied in a long run economic relationship; i.e., whether they are co-integrated; and (ii) whether price changes in the raw input stage are fully transmitted to the retail stage in this form of market where full (or perfect) transmission is understood to occur when the coefficient on the long run co-integrating parameter is equal to unity.

Palaskas (1995) seeks to test these hypotheses for the food marketing system in seven countries of the EU. Using a monthly log of consumer and producer price pairs for five commodities over the period 1971.1- 1990.12, the author applies the Engle-Granger (EG) two-step procedure to test for co-integration and to estimate the corresponding error correction model. The only modification the author introduces is that the EG is enhanced with a third step, in the manner of Engle and Yoo (1987)[2], whereby the estimated error term from the ECM, $\hat{\epsilon}_t$, is regressed on the short-run price transmission elasticity, α_1,and on the product of a lagged producer's price and the estimated coefficient of adjustment to disequilibrium ($\hat{\beta} P \times P_{t-1}$) as:

$$\hat{\epsilon}_t = \alpha_1 + \gamma \left(\hat{\beta} P \times P_{t-1} \right) + v_t \tag{7.18}$$

where v_t is a white noise residual.

On the basis of this procedure, the author finds that for five countries out of seven, all the price pairs are co-integrated at the 5 per cent level of significance, while for two

[2]The object is to obtain a three-step estimator of the cointegrated system with t ratios having limiting normal distributions. These t-ratios can be compared with the maximum-likelihood t-ratios when testing the hypothesis relating to the cointegrating parameter.

countries, all the price pairs are co-integrated at the 10 percent level of significance. He also finds that for seventeen pairs of prices out of thirty-five, the hypothesis of a unit coefficient on the long-run co-integrating parameter cannot be rejected whereas the hypothesis of a unit coefficient on the short-run adjustment parameter is uniformly rejected suggesting that short run adjustment of consumer price to changes in producer price is sluggish.

Using a monthly log of prices for the beef market in Australia, for the period, 1971-1994, Chang and Griffith (1998) implement the Johansen procedure to test for co-integration among the farm-gate, wholesale and retail prices of the market and to estimate the corresponding ECM. They find that not only are the three price series co-integrated, with one co-integration relation being identified, but that the coefficients on the wholesale and beef price series sum to one suggesting that there is a long run perfect price transmission in the market. But they find that two-thirds of the estimated short-run coefficients are statistically insignificant suggesting that farm-gate price changes take time to transmit to wholesale and retail prices. In fact, they find that it takes 15 months for an initial price shock to be fully transmitted to the wholesale and retail price series.

Using a triplet of logs of monthly price series for crude oil, four-star petrol and the dollar-sterling exchange rate for the UK over the period 1982.1-1995.6, and assuming exogeneity for crude oil and for the exchange rate, Reilly and Witt (1998) estimate an unrestricted dynamic error correction model and then test for co-integration using the resulting error correction term. This is in keeping with the procedure advocated by Kremers *et al.* (1992). Their results show that the triplet price series are co-integrated. They do not, however, identify a unity coefficient for the long run co-integrating parameter.

In its investigation into the relationship between monthly real producer, wholesale, and retail prices for beef, lamb and pork in the UK over the period 1990.1- 1998.12, a report commissioned by the Ministry of Agriculture, Fisheries and Food (MAFF, 1999) applies the Johansen procedure to test for co-integration and for the degree of price transmission in this particular market. The report finds that, on their own, the triplet price series are not co-integrated, but are co-integrated when a food publicity index is incorporated into the regression. The food publicity index measures the response of meat retail price to stories in the press about food scares, more particularly about BSE.

As far as the dynamics of price transmission is concerned, the report finds that for all the product categories, between a third and 40 per cent of the initial change in producer price is transmitted to the retail price in the first one month. On the other hand, in the long-run, the initial change in the producer price is either fully transmitted, as in the case of pork, or largely transmitted as in the case of lamb and beef (with a transmission coefficient of between 0.70 and 0.80). They find that, it takes between 4 and 6 months before 90 % of the initial change in producer's price feeds through to the retail stage.

Building on the report's findings, Lloyd *et al.*. (2001) examine the role of the food publicity index in price formation. They perform this by formulating the impulse response functions of the three beef prices to a unit shock in the index. They do this by imposing a recursive structure on the moving average representation of the VAR in equation (7.12) above. This is in keeping with Lütkepohl and Reimers (1992) who show that the impulse response function of a VAR representation is given by:

$$\Phi_s = \left(\varphi_{ij,s}\right) = \sum_{l=1}^{s} \Phi_{s-1} A_l \quad s=1,2,...n \tag{7.19}$$

where $\Phi_0 = I_n$, $A_l = 0$ for $l > k$. Assuming all other variables at the time of the shock and earlier are held constant, the impulse response function of variable i with respect to a unit shock to variable j, s periods ago is given by a plot of $\varphi_{ij,s}$.

The results for the impulse response function are sensitive to the order in which the variables appear in the VAR. Taking this into account, they treat the food publicity index as exogenous to prices in the impulse response analysis. They find that even though in the short-run heightened publicity regarding food safety initially increases beef prices at all stages of the marketing chain, in the long-run it leads to a reduction in all the three prices. The degree of price reduction at the retail, wholesale and producer stages in response to a percentage change in the index are 1.70p/kg, 2.25p/kg and 3.0p/kg respectively.

Using monthly data for beef, lamb and pork in the UK over the period 1986.1 - 2000.12, Sanjuan and Dawson (2003) test for co-integration and for the degree of transmission between producer and retail prices allowing for structural breaks in the co-integration space in keeping with the procedure suggested by Johansen *et al.* (2000). Allowing for the structural breaks that occurred in February 1996 for beef, in December 1992 and August 1998 for lamb and in April 1997 for pork, their study identifies a long-run relationship between producer and retail prices for each meat item. The study further finds that whereas in the beef relationship this long-run relationship obtains in spite of the occurrence of a structural break at the height of the bovine spongiform encephalopathy (BSE) crisis, in the lamb or pork relationships this long-run relationship obtains in the absence of any evidence of BSE-related breaks.

Applying the structural error correction model following Boswijk (1992) and Johansen (1992), a recent study by Feuerstein (2002) investigates the degree of price transmission in the coffee market in Germany over the period 1971.1- 1995.12.

The study first specifies and estimates, by OLS, a structural error correction model considering the price of roasted coffee (P_t) as the endogenous variable and the price of green coffee beans ($CATT$) as the conditioning variable as follows,

$$\begin{aligned}\triangle P_t &= c_1 + \lambda\,(P_{t-1} - \theta CATT_{-1} + \mu TREND - c_2) \qquad (7.20)\\ &+ \sum_{i=0}^{n} \kappa_i \triangle CATT_{t-i} + \sum \pi_i \triangle P_{t-i} + \varepsilon_t \qquad (7.1)\end{aligned}$$

It then goes on to test the model for stability using the Wald-type test as in Boswijk (1994) with the null hypothesis of instability being $\lambda = 0$. If the null hypothesis is rejected based on the relevant critical values tabulated by (Boswijk,1994), then the model is considered stable, and consequently, co-integration is implied between the price series.

Based on the above test, the study finds that the null hypothesis of instability is rejected at the 1% significance level implying that the above pair of prices are co-integrated. The study also finds that not only are the pair of prices co-integrated but also that the long run price transmission coefficient is not significantly different from unity suggesting the complete shifting of costs to consumer prices in the long run. The short-run price dynamics are such that current cost changes (i.e., first month changes) do not have any impact on consumer price and it takes more than a year before the cost shock to green coffee prices is completely passed through to roasted coffee prices.

Applying the Johansen procedure to logs of a monthly series of ex-vessel prices of cod and those of domestic fresh consumption, exported dried salted cod and exported frozen fillets, Asche *et al.* (2002) set out to test for co-integration among these series and for price proportionality, i.e., for a unity coefficient on the co-integrating parameter. They find that the ex-vessel price is co-integrated with all other prices. On the other hand, they find that whereas the hypothesis of price proportionality cannot be rejected for the bivariate relation between ex-vessel and domestic prices and between ex-vessel and dried salted cod prices it is rejected for the bivariate relation between the former and frozen fillets prices.

More recently, Asche *et al.* (2003) apply the Johansen procedure to test for co-integration among logs of monthly prices of crude oil and four major refined oil products, i.e., gas oil, fuel oil, kerosene and naphta in north-west Europe over the period, 1992.1-2000.11. They find that crude oil price is co-integrated with gas oil, kerosene and naphta but not with heavy fuel oil. They also find that the null hypothesis that the coefficient on the long-run co-integrating parameter is unity is rejected for the bivariate relationship between crude oil and naphta while it cannot be rejected for the relationship between crude oil and kerosene and between the former and gas oil.

To sum up, application of the Engle-Granger and Johansen procedures for testing co-integration and for estimating the error-correction model to price data for various products in different countries seems to bring out three major characteristics of the degree of price transmission. First, it suggests that in most cases, price series at different levels of a vertical market are tied in a long run economic relationship as the test for the existence of co-integration testifies. Second, in many instances, the existence of co-integration seems to be associated with a unit co-integrating parameter. Whilst in some special cases this suggests that in the long-run cost changes at the raw stage are fully transmitted to the retail and (or) wholesale stages, in general the unit co-efficient does not have this interpretation. Third, for many products, the transmission of price from the producer to consumers is not instant. In fact, for the food industry, it is sluggish as it takes between 6 and 15 months for the initial price change in producers' price to fully or largely be transmitted to the retail and (or) wholesale price.

These results seem to be consistent with findings from spatial market models (for instance, Goodwin and Schroeder, 1991) and those from a present value model (for instance, Lloyd, 1994).

7.4.1 Co-integration analysis and the error-correction model: an evaluation

It goes without saying that the application of co-integration techniques has dramatically improved the analysis and understanding of price transmission in vertical markets. Of critical significance of these techniques has been their ability to identify and quantify the short-and long-run retail price adjustments to changes in producer price. As such, their usefulness in bringing to the open the nature of price relationships at different levels of vertically-related markets has been substantial. But the findings concerning the nature of such short- and long-run adjustments need always be accepted with caution. The major reasons for sounding this caution have to do with the sensitivity of these findings to seasonal integration (i.e., seasonal unit roots), to data periodicity and to whether prices are rising or falling.

Palaskas (1996) points to the widespread tendency for studies to assume that only one unit root obtains at the zero frequency and that there are not any unit roots in the price series that occur at seasonal frequencies. He sounds warnings about the dangers of undertaking unit root tests at zero frequency without first checking the price series for seasonal integration. From a theoretical perspective, these dangers had already been sounded by Hyllberg *et al.* (1990) who pointed to the lack of power and consistency of unit root tests at the zero frequency.

To make his point that the consequences of overlooking the test for seasonal unit roots could be serious, Palaskas examines quarterly price series for bread and soft wheat, butter and milk and cheese and milk for seven countries in Europe over the period 1971.1 to 1994.4 and tests for seasonal unit roots. His test rejects the existence of seasonal unit roots in the consumer price series but fails to reject seasonal unit roots for some producer price series.

He next tests for co-integration at zero frequency in the presence of seasonal unit roots using the Engle-Granger methodology. He finds that, where without filtering the seasonal components from the original series co-integration was established for many price pairs, on filtering the seasonal components, three sets of co-integration results come out. First, for three countries and for two price pairs, co-integration was not established at all where previously it was; second, for two price pairs, the number of countries where the pairs co-integrated fell relative to when there was no filtering; and third, for two countries and for a price pair, co-integration was established where previously it did not exist. It is thus evident that the test for co-integration not allowing for seasonal unit roots can provide misleading information regarding the nature of long run price transmission. However, caution is warranted here since filtering (such as that involved in seasonal unit roots) will also distort the performance of standard unit root tests if the variables do not actually contain seasonal unit roots. Given that unit roots in seasonals imply 'unusual behavior' not normally observed in economics, their application should only be motivated by strong information rather than adoption as a general pre-test.

Even if seasonal integration is not considered a serious problem as is often the case with most economic time series, the issue of data periodicity poses a potential challenge to the credibility of co-integration results based on standard unit root tests. The importance of this challenge has been noted by Bernard and Willet (1998) who evaluate the robustness of tests for a unit root, Granger causality and asymmetry to data periodicity on the basis of weekly and monthly data for the broiler industry in the US over the period, 1983- 1992.

They find that for all weekly prices in levels, the hypothesis of a unit root at the zero frequency is rejected at the 0.05 significance level, whereas for monthly data, rejection of such a hypothesis is achieved at the 0.10 level. Their causality test also points to differing results for weekly and monthly data. For the former, causality runs from the farm, through wholesale, to the retail sector while for the latter, it runs from the farm to the retail sector directly without affecting the wholesale sector. The results for asymmetry tests are also mixed; the weekly data rarely suggest asymmetry while the monthly data do. On the basis of these comparisons, they thus make the point that specific policy recommendations based on a single data set are misleading.

The implications of this study for co-integration results are clear. While the weekly price series are co-integrated as they are all stationary, the monthly series may not be so at significance levels below 0.10 as all depends on whether the linear combination of the series is stationary.

It is also a well recognized fact that the existence of a co-integrating relation between prices can be due to some exogenous common factor such as inflation and not due to a change in the data generating process, as much as its absence can be due to the non-inclusion of a non-stationary common factor. This does not, however, emanate from the inherent weakness of co-integration. As is well known, co-integration is merely a mis-specification test. Prices need not necessarily be co-integrated in a pair (in general they will not be) but may need other variables to co-integrate. For instance, Lloyd *et al.*., 2001, show that, where, without the inclusion of a food publicity index, co-integration is not established among the producer, wholesaler and retail price series for beef, pork and lamb, in the presence of this index, co-integration is established among the series.

Another major criticism is that the price transmission coefficient on the long-run co-integrating parameter does not provide much information on the degree of price transmission. This is because the parameter does not contain information regarding the structure of the industry, particularly the cost share of the raw input. Recalling from our theoretical exposition in the earlier chapters, the elasticity of price transmission, for a given exogenous shock, is defined as the percentage change in the price of the retail product in response to a percentage change in the price of the farm input, i.e., as $\left(\frac{\Delta P_r}{\Delta P_a}\right) \times \left(\frac{P_a}{P_r}\right)$.

For a given exogenous shock originating in the farm sector, producer price changes are said to have been fully transmitted to retail price if farm input cost changes are passed-through to the price of the retail product in proportion to the cost share of the farm input in total industry cost (McCorriston *et al.*., *op cit.*). But this shouldn't necessarily imply a price transmission elasticity which is unity. The latter is a special case arising when there is only one input, in our case the farm input. This means the elasticity of price transmission can take on any value irrespective of the degree of price transmission.

To explicate this point, consider the following simple example. Let the farm-gate and retail prices, P_a and P_r take on the values of £10 and £15. Assume that due to an exogenous shock, farm-gate price has doubled to £20 resulting in an absolute change, $\Delta\ P_a=$ £10. Also assume that this change is fully passed through to P_r so that $\Delta\ P_r=$£10. Clearly, this is what we can describe as full price transmission. But since the relative changes, $\Delta\ P_a/P_a$ and $\Delta\ P_r/P_r$ are not identical because the starting values (or the price levels) are not identical, the elasticity of price transmission is not going to be unity. Rather, it will be 0.67. If for a unit quantity of the farm input and of the final product, we evaluate the transmission elasticity is exactly the same as the cost share of the farm input in total industry cost, then we say price changes at the producer level have been fully transmitted to the retail level. In this particular case, a co-integration co-efficient of unity is in no way an indication of full price transmission. This is a clear indication of how a mere look at the elasticity of price transmission without an adequate knowledge of the structure of market can be misleading.

The implication which follows from the above example is therefore that by merely looking at the price transmission coefficient and without first having looked into the structure of the market (i.e., the cost share of the farm input in our case), we cannot make inferences about the extent of transmission between retail and producer prices in that market. And most often, the analysis of price transmission carried out within a co-integration framework is not likely to take account of market structure.

From this vantage point, now evaluate the interpretation that can be attached to the long-run coefficient of the co-integrating parameter. Consider the following long-run co-integrating relation for the UK energy sector found by Reilly and Witt, *op.cit.*

$$p = -0.639 + 0.580\,[c - x] + 0.02t$$

where at the cost of repetition p denotes net four-star petrol price, c denotes crude oil price and x is the sterling-dollar exchange rate and t is a time trend.

Allowing for the sterling-dollar exchange rate, we can interpret the above relation as saying that, relative to a one percent change in the price of crude oil, the change in the price of petrol is 0.58%. However, we cannot say anything about whether the degree of price transmission is complete. This is because we cannot tell whether the percentage change in the price of petrol is in proportion to the cost share of crude oil in total industry cost. This is not surprising because co-integration analysis operates within the framework of a reduced form model. As such, it can only identify and quantify the short- and long-run components of price transmission and not its structural determinants. For instance, it does not say anything concerning why price adjustment in the short run is sluggish, as it were, with reference to market structure. We can therefore say that co-integration analysis provides little by way of information relating to market structure that is vital to interpreting the degree of price transmission. That is why it is advocated that co-integration analysis be supplemented with structural analysis of the market. Thus, in the following, we introduce the structural approach to modelling price transmission in vertical markets.

7.5 The structural modelling approach

Following the emergence of the New Empirical Industrial Organization (NEIO) beginning in the early 1980s, there have been attempts to develop a structural model of price transmission in vertically-related markets whereby not only are analysts able to measure the degree of such transmission but they are also able to identify its determinants[3]. Early attempts in this direction include Holloway (1991); Wann and Sexton (1992); Suzuki *et al.*. (1993). In this review, we do not aim to present a comprehensive inventory of studies which have applied the structural modelling approach as our aim is more to highlight the major features of the approach and less to do such an inventory. With this in view, we opt to present the structural model of price transmission as it is applied in Bettendorf and Verboven (2000).

With the objective of understanding the determinants of coffee bean price transmission to consumers in the Netherlands, they estimate an econometric model which consists of demand for and supply of the final product (i.e., roasted coffee). Assuming coffee is an homogeneous good, they estimate an aggregate demand function homogeneous of degree zero in prices and in income of the form,

$$Q_t = Q\left(\frac{p_t}{p_t^0}, \frac{p_t^s}{p_t^0}, \frac{y_t}{p_t^0}\right) \tag{7.21}$$

where Q_t represents total coffee demand in period t; p_t is the retail price of coffee; p_t^s represents the price of tea, which is coffee's close substitute; p_t^o is the price of other goods; and y_t is consumers' income.

The functional form of demand which they specify is of the form,

[3]For a comprehensive review of the literature see Bresnahan (1989)

$$Q_t = \alpha_0 + \alpha_1 \frac{(p_t/p_t^0)^\lambda - 1}{\lambda} + \alpha_2 D_t^2 + \alpha_3 D_t^3 + \alpha_4 D_t^4 + \alpha_5 \frac{p_t^s}{p_t^0} + \alpha_6 \frac{y_t}{p_t^0} \qquad (7.22)$$

where D_t^i denotes a seasonal dummy (for i=2,3,4); λ is a parameter which captures the curvature of demand through the Box-Cox transformation, taking the value of unity for a linear demand, a value of zero for a logarithmic demand and a value of two for a quadratic demand.

Their aggregate supply relation assuming constant marginal costs and a fixed input proportions technology is specified as:

$$\frac{1}{1+\tau}\left[p_t + p'(Q_t)Q_t\theta_t)\right] = MC \qquad (7.23)$$

where $p'(Q_t)$ is the marginal revenue; θ_t is an average industry conduct parameter to be estimated; τ is a tax parameter; and MC is marginal cost which is also to be estimated using the following specification:

$$MC(w_t) = \beta_0 w_t^0 + \beta_1 w_t^b + \beta_2^l w_t \qquad (7.24)$$

where w_t^o, w_t^b, and w_t^l represent the prices of coffee beans, the wage rate and the price of other inputs.

Re-writing the retail price of roasted coffee as,

$$p_t = (1+\tau)\, MC(w_t) + \frac{\theta}{\varepsilon_t} p_t \qquad (7.24.1)$$

where ε_t represents the elasticity of demand which is to be estimated. Computing the derivatives of demand from (7.21) and substituting for MC, the supply relation in (7.23) can then be re-written as:

$$\frac{p_t}{p_t^0} = (1+\tau)\left(\beta_0 \frac{w_t^0}{p_t^0} + \beta \frac{w_t^b}{p_t^0} + \beta_2 \frac{w_t^l}{p_t^0}\right) - \frac{\theta}{\alpha_1}\left(\frac{p_t}{p_t^0}\right)^{1-\lambda} Q_t \qquad (7.24.2)$$

Adding error terms to (7.22) and (7.24.2) they next estimate the system simultaneously using a generalized method of moments (GMM). The estimator that is obtained is believed to be consistent and asymptotically efficient and takes into account the endogeneity of price and quantity using the exogenous demand and cost shifters as instruments.

Using monthly data on green beans and roasted coffee for the Netherlands over the period 1992-1996, they then evaluate the changes in the price of roasted coffee that followed the jump in coffee beans price after the frost in Brazil in 1994. This proceeds, in the manner of McCorriston *et al.* (1998), by decomposing a retail price change into a marginal cost change and into a change in the mark-up as,

$$\frac{\triangle p_t}{p_{t-1}} = \frac{\triangle MC}{MC_{t-1}} - \frac{\theta}{\epsilon - \theta} \frac{\triangle \epsilon_t}{\epsilon_{t-1}} \qquad (7.25)$$

Assuming a linear retail demand function and a 60 per cent cost share of coffee beans in average industry cost, they find that, in one year's time (i.e., Jan 1994 to Jan 1995), roasted coffee price rose by little above 44.5 per cent in response to a 100 per cent increase in the price of coffee beans. Evidently, relative to the given cost share of coffee beans in total average industry cost, the increase in the price of roasted coffee beans is smaller. This suggests that the degree of price transmission from green coffee beans to roasted coffee prices is incomplete.

The explanation for the incomplete price transmission observed during the reference period is that at the same time that marginal cost rose by 57 per cent mark-up fell by 8.1 per cent. The weak relationship between green beans price and roasted coffee price is thus explained by the relatively large share of costs other than bean costs.

But given the long time it takes for coffee bean cost changes to feed through to roasted coffee price, as pointed out earlier (see Feuerstein *op cit.*), it can be said that it might not be so much that price transmission is incomplete as that a year is not long enough to observe price adjustment in the long-run.

In a similar exercise, Coterill and Dhar (1999) build a structural model to estimate the cost pass-through rate (CPTR) for individual firms in the US assuming an oligopolistic market for differentiated milk products. They estimate CPTRs for four supermarket retailers and processors assuming firm-specific as well as industry-wide shocks. They find that for raw milk price increases at the industry level, the estimated pass-through rates for retailers are not significantly different from 0.90. For processors, they are higher than 0.9 but slightly less than one. On the other hand, for a given shock to the wholesale sector, the processor to retailer CPTRs for two supermarket retailers are one but for the other two they are less than one. The results for firm-specific unobservable shocks indicate that the CPTRs vary widely.

7.5.1 The structural modelling approach: an evaluation

On counts of its ability to decompose retail price changes into cost and mark-up changes, the structural model fares better than the error correction model which focuses exclusively on the short- and long-run price adjustment to the neglect of the structural components of price adjustment.

But on the other hand, the structural modelling approach neglects the short- and long run components of price adjustment which the error correction model works towards identifying. As such, this modelling approach is inherently static as it neglects the time dimension of price transmission. It is also highly sensitive to the assumption made regarding demand and supply functions. The corollary of this is that the structural model can produce different predictions concerning the degree of price transmission depending on the specific assumptions that are made regarding demand and supply functions.

The structural modelling approach also assumes that changes in the mark-up are influenced by, among other things, market power. The problem with this assumption is that market power can be identified unambiguously only under the assumption of constant returns to scale. As Milan (1999) has shown, for an industry characterized by non-constant returns to scale, market power cannot be identified unambiguously. This means, given a non-constant returns to scale technology, the mark-up too cannot be identified. And in the face of growing evidence that vertical markets are characterized by non-constat returns to scale technology (see, for instance, Milan *op cit.*, and Bhuyan an Lopez, *op cit.*), the task of identifying the degree of price transmission using information related to cost and the mark-up is made all the harder.

Even if market power is identified, Wohlgenant (1999) warns that for a heterogeneous product market, attributing a change in the mark-up purely to market power resulting from imperfect competition can be misleading. The reason is that in such a market, mark-up (margin) changes could as well result from substitution of inputs following changes in raw input price.

To see Wohlgenant's point clearly, let n firms produce differentiated products and engage in Bertrand price-setting. In this environment, the profit maximization problem faced by the ith firm is to choose optimum price p^i so as to maximize

$$\pi^i = \left(p^i - c^i(w)\right) D^i\left(p^1, ..., p^{i-1}, p^i, ..., p^n\right) - f^i \tag{7.26}$$

where $c^i(w)$ denotes the cost function of the ith firm for a given input vector w. D^i denotes the ith firm's output demand function for a given $n \times 1$ vector of prices associated with the differentiated prices whereas f^i denotes fixed cost of the ith firm. Given certain restrictions on consumer preferences across commodities within the product group, the ith firm's pure-strategy Bertrand-Cournot equilibrium price can be specified as:

$$p^i = \left(1 + \beta^i\right) c^i(w) \tag{7.27}$$

where $(1+\beta^i)$ denotes the *ith* firm's markup over marginal cost and β^i is the ith firm's market power arising from its selling of a differentiated product.

It is also assumed that the ith firm purchases factors whose input demands are derived from Shephard's lemma:

$$x_k^i = c_k^i\,(w)\,y^i \text{ for } k=1,\ldots,\ m. \tag{7.28}$$

where x_k^i is the ith firm's demand for the kth factor; $c_k^i(\ )$ denotes the partial derivative of the ith firm's cost function with respect to the kth factor price; whereas y^i denotes demand for the ith firm's differentiated output.

Consistent aggregation condition in an imperfectly competitive market requires that $(p^i/P)/c^i{=}(p^j/P)/c^j$, which, given (7.27), implies that $p^i/c^i{=}(1{+}\beta^i)$ and $p^j/c^j{=}(1{+}\beta^j)$. And, for this to hold, it is necessary that $\beta^i{=}\beta^j$, or $\beta^i{=}\beta$ for all i. Given these requirements, aggregation over firms yields industry analogs of (7.27) and (7.28) which can be written as:

$$P = (1+\beta)c\,(w) \tag{7.29}$$

and

$$x_k = c_k\,(w)\,Y \tag{7.30}$$

Let the marketing margin be defined as:

$$m = P - (x_1/Y)\,w_1 \tag{7.31}$$

which, using (7.29) into (7.30) can be re-written as:

$$m(w) \equiv (1+\beta)\, c(w) - c_1(w)\, w_1 \qquad (7.31.1)$$

where $c_1(.)$ denotes the industry's marginal cost with respect to w_1, the raw material's price.

Differentiating (7.31.1) with respect to w_1 assuming $w_2,\ldots, w_m$ are exogenous yields the marketing margin's response to a change in the raw input's price. This is written as:

$$\partial m/\partial w_1 = (1+\beta)\, c_1 - c_1 - w_1 c_{11} = \beta c_1 - w_1 c_{11} \qquad (7.32)$$

where c_{11}represents the partial derivative of c_1 with respect to w_1.

The function c_{11} can be defined in terms of the Allen elasticity of substitution, σ_{11}, as:

$$\sigma_{11} = c(w)\, c_{11}/\,(c_1 c_1)\,.$$

Solving for c_{11} and substituting into (7.31) yields,

$$\partial m/\partial w_1 = (\beta - s_1(1+\beta)\sigma_{11})x_1/Y \qquad (7.33)$$

where $s_1 \equiv w_1 x_1/c(w)\,Y = w_1 x_1/PY$ is the cost share of raw materials in total costs and $x_1/Y = c_1$ from (7.30).

Assuming that the Allen elasticity of substitution is non-positive, it is clear that for a given degree of market power which the industry exercises, and for $\mid \sigma_{11} \geq 0 \mid$, (7.33) clearly indicates that the marketing margin is positively related to the price of the raw material. An interesting result is that when the composite product is produced with variable input proportions, both imperfect competition and input substitutability can account for movements in the mark-up. For instance, for a given β, an increase in the price of the raw input increases the mark-up if factor substitutability, σ_{11}, is large. On the other hand, for a given σ_{11}, an increase in the raw input price increases the mark-up as market power, β, increases. Finally both market power, β and σ_{11} can compound each other to increase the mark-up as the raw input price increases.

This result hinges on the assumption that consumer demand at the retail level has a steeper slope than derived demand at the farm level. In other words, it hinges on the assumption that the price spread narrows as retail or raw input price falls.

A final criticism of the structural modelling approach is that it estimates a single elasticity of price transmission assuming the existence of a relationship between the retail and raw input prices without first empirically establishing this relationship. And, this, disregarding the number of possible transmission elasticities that could be derived depending on the origin of exogenous shocks. Even if the origin of shocks is identified when estimating the elasticity of price transmission, the direction of causality in the transmission process is imposed rather than identified by testing. Often, causality is assumed to be from the raw input to the retail sector rather than the other way around.

Currently, there seems to be no single model which incorporates the strengths of the structural modelling approach and those of the error correction modelling approach. But by themselves, results from either model cannot be fully informative of the degree of price transmission. Evidently, results from the structural model provide information on the structural determinants of price transmission, and as such, they can inform on the extent of market failure, by drawing attention to the size of the mark-up (and market power), for instance. But they do not provide information on the speed of price adjustment. On the other hand, results from the error correction model are informative in terms of the speed of price adjustment. But they cannot provide information on the determinants of price transmission.

Given that a single model is not able to provide full information regarding the degree of price transmission, the most feasible strategy seems to be to use both models side by side. Apart from its utility to provide information on the structural determinants, speed and degree of price transmission, this strategy helps the analyst to compare the price transmission elasticities which these models independently yield. Any discrepancy can then be accounted for.

In the spirit of Wohlgenant and Haidacher (1989) and Wohlgenant (1999), which we have already reviewed in the theoretical part of the thesis Reed and Clark (2000) develop an empirical model that inputs information on retail, farm and non-farm prices, and such structural information as cost share of the raw input in total industry cost, oligopsony power as proxied by the supply shifter, and technology. Using data for seven major U.S. food markets, they use the model to test for market power, for co-integration between the retail and producer prices of these markets, and to estimate consumer demand, factor cost shares, and the elasticity of price transmission.

To briefly highlight their model, they estimate a quasi-reduced-form system of two equations,

$$\begin{aligned} \ln P_{rj} &= A^j_{rf} \ln F_j + A^j_{rw} \ln W + A^j_{rz} \ln Z_j + e^*_{rj} \\ \ln P_{fi} &= A^j_{ff} \ln F_j + A^j_{fw} \ln W + A^j_{fz} \ln Z + e_{fj} \end{aligned}$$

where $\ln P_{fj}$ and $\ln P_{rj}$ represent the natural logarithms of farm input and retail prices used in the jth market respectively. W is a vector of logged non-farm input prices, Z_j is the consumer demand shifter, whereas e_{rj} and e_{fi} are error terms for the retail and farm input price equations respectively.

Based on this model they undertake several tests. The first of these tests is whether oligopsony power exists in the industry. To run this test, they re-formulate the quasi-reduced form,

$$\ln P_{rj} = B_f^j \ln P_{fj} + B_w^j \ln W + B_z^j \ln Z_j + B_s^{(j)\prime} \ln S_j + v_r$$

where S_j is a vector of supply shifters and v_r is the error term.

This test is based on the premise that if the industry exercises market power in purchasing the farm input, this will show up as a gap between the farm price and the industry's demand for the farm input. Then this gap will be defined by the supply shifters, S_j. In other words, if market power exists, the null hypothesis of no market power will be rejected implying $B_s^{(j)\prime} = 0$. Based on this test, they fail to reject the null that in national markets the selected food industries purchase farm inputs competitively.

They run a second test to see if the retail and producer price pairs for the seven food industries are co-integrated. To run this test, they apply the Dickey-Fuller and Phillips-Perron tests of spurious regression based on a specification that includes six stochastic regressors, a constant, and a deterministic time trend for each retail and farm price equation. According to these tests, a model is said to be spurious (or not stochastically co-integrated) if the residual errors follow a unit process, i.e., they are non-stationary. If, on the other hand, the residual errors are stationary, then the model is said to be stochastically co-integrated. They find that whereas the Dickey-Fuller test fails to reject the null of spurious regression for each of the retail and farm price equations for the seven food industries, and thereby rejects the null of co-integration for these series, the Phillips-Peron test rejects the null for 6 out of the 14 price equations at reasonable levels of rejection and thereby finds co-integration for 8 out of the 14 price equations.

They run a third test to estimate the degree of price transmission. According to this test, if the joint hypotheses of symmetry and constant returns to scale in technology cannot be rejected, then in the long-run, a 1-percent increase in the price of a farm commodity results in an increase in the price of the retail product by a percentage equal to the cost share of the farm commodity used in the retail product. On counts of this test, they find that in 2 out of 7 industries, the joint restriction of symmetry and constant returns to scale is rejected. These results suggest that full transmission of farm price to retail is a characteristic feature of industries in which final products undergo a minimal amount of food processing (in this case, fresh fruit and fresh vegetables).

They run a fourth test to estimate the quasi-reduced system of equations to assess long run responses of the farm input and retail prices to changes in the stochastic and deterministic regressors which appear therein. They find, in keeping with the predictions of theory, that, for each of the industries, the long run industry demand for farm ingredients is negatively sloped; that positive shifts in the consumer demand function trace an upward sloping long run industry schedule; that a contraction in farm supply raises consumer food prices just to name few among others.

They run a final test to determine whether a particular industry operates with fixed- or variable-input proportions technology. This test is carried out by evaluating whether the restriction, A^j_{ff} $=1/(S^j_f\ e_{jj})$ (which we have explained earlier in the thesis) holds for a particular industry or not. e_{jj} represents the own-price elasticity of consumer demand for the jth consumer product. If this restriction holds, then the industry is said to operate with fixed input proportions technology. They find that across the seven food industries, the above restriction does not hold for all the seven food industries as significant substitution possibilities exist.

As can be seen from this methodological approach, by undertaking the structural and the co-integration models side by side, one is in a position to evaluate not only whether the price pair relating to the farm and retail prices are co-integrated but also whether the degree of price transmission that is estimated can be explained with reference to such market structure parameters as market power, returns to scale, input proportions and share of the farm input in total industry cost.

7.5.2 Summary and evaluation

This chapter has attempted to review the existing empirical literature on price transmission in vertically-related markets. It has identified four strands of methodological approaches to analyzing the degree of price transmission.

The first strand of methodology focuses on determining the direction of causality and on estimating a correlation coefficient for prices at different stages of a marketing chain. This methodology was shown to be limited in its usefulness to inform on the degree of price transmission. This is because prior to estimation, it does not evaluate whether these prices are tied in a long run economic relationship. As such, it has been shown to be susceptible to the spurious regression problem. Consequently, any estimates of the price transmission elasticity have been shown to be not robust.

The second strand of methodological approach is the error correction model. This has been shown to be a useful tool for analyzing the degree of price transmission. Not only is it able to identify the long-run relation between prices but it is also able to identify the short-run price adjustment. A such, it nests both short- and long-run information in a single model. Furthermore, it is not susceptible to the spurious regression problem because prior to estimation, it identifies a co-integrating relation among the variables of interest. Empirical findings using this approach show that most often prices at different levels of vertically- related markets are co-integrated, that shocks from the raw input sector transmit fully to consumers in the long-run, and that price adjustment in the short run is sluggish.

However, the methodological approach based on the error-correction model has been shown to have its limitations. Firstly, it is sensitive to seasonal integration and data periodicity. Secondly, it does not identify the key structural factors which determine the speed and degree of price transmission. And, thirdly the existence of co-integration may be due to the presence of a common factor non-stationary variable in the co-integration regression as its non-existence can be due to the latter's absence. Of these limitations, the second is thought to be the most critical.

The third strand of methodological approach is structural modelling. The major advantage of this approach is that the key structural parameters which determine the degree of price transmission are identified. However, in its own, it offers limited information regarding the degree of price transmission. Firstly, the price transmission elasticities that are obtained using this approach have been shown to be sensitive to the assumptions that are made in relation to demand and supply functions. Secondly, it does not identify the time path of the adjustment process into its short- and long-run components, and, as such, remains a static model. And, thirdly, it assumes the existence of a relationship between the price series rather than prove it by testing.

The fourth methodological approach is a marriage between the structural modelling approach and co-integration analysis. This has been shown to fare better than either of the partners. This is because not only is it capable of showing whether the price pair of interest are co-integrated but is also able to explain the degree of price transmission with reference to such market structure parameters as market power, returns to scale, input proportions and the cost share of the farm input in total industry cost.

As far as we are aware, there seems to have been no attempt in the price transmission literature to make an inference about a co-integrating relation between the farm and retail prices based on the predictions of economic theory. However, the literature is replete with studies reporting a co-integrating relation between the farm and retail prices on the basis of information supplied by the price pair alone. A potentially important avenue of research to pursue is therefore to evaluate whether this claim is consistent with the predictions of the theoretical models of price transmission that we have reviewed so far and which we will extend further in the subsequent chapter. To give a snapshot of this research avenue, recall the Gardner model of price transmission. It predicts that the elasticities of price transmission that derive for given retail demand and input supply shocks are in all normal cases different. On the other hand, the theory of co-integration predicts that the co-integrating parameter in a regression of two prices does not vary for different sources of shock. Now assume a co-integrating relation between the price pair has been discovered; then the intuition is that the elasticities of price transmission which derive from the price transmission models for different sources of an exogenous shock are identical. As we will show later, the whole exercise involves identifying the conditions under which the elasticities of price transmission that derive for demand and input supply shocks.

Chapter 8

Theoretical models of price transmission and inferences about a co-integrating relation between retail and farm input prices

8.1 Background

Our review of the empirical literature has highlighted the strengths and weaknesses of the major methodological approaches to estimating the price transmission coefficient. As might be recalled, one of these methodological approaches applies the concept of co-integration. As we have explained in our review of the empirical literature, co-integration analysis advocates that any estimation of a price transmission coefficient from regressions involving any two or more price series in a vertical market should proceed conditional on the existence of a co-integrating relation between these series. In the following, we evaluate whether it is possible to make inferences about the existence of such a co-integrating relation on the basis of information about price transmission elasticities that are derived from the theoretical models of price transmission assuming different exogenous shocks. We then derive implications for the validity of price transmission elasticities that are estimated from a structural modelling approach.

By way of restating the meaning of co-integration following Granger *op cit.*, consider two stochastic price series P_{xt} and P_{at}, both of which are of the same order of integration, I(d). Then it is generally true that any linear combination of these series,

$$u_t = P_{xt} - \beta P_{at} \tag{8.1}$$

will be I(d). There can, however, arise a situation where, for a constant β, such a linear combination is of a lower order of integration, I(d-b), where $b>0$. When this situation holds, P_{xt} and P_{at} are said to be co-integrated of order CI(d,b) with β representing the co-integrating parameter.

Co-integration presumes that the two series are intertwined in a long-run economic relationship. This means that even if the series are characterized by stochastic trends, i.e., they are non-stationary, they can nevertheless move together over time so that the difference between them will be stable, i.e., stationary. In other words, they share the same stochastic trend.

In (8.1), the co-integrating parameter, β, describes an equilibrium and not a normal functional relation between the price series. Therefore, regardless of the source of causality, it assumes the same unique value. This is because the decomposition of the movement of two series is symmetric so that if P_{at} and P_{xt} are co-integrated, then P_{xt} and P_{at} are co-integrated as well (Engle and Yoo, in Engle and Granger, 1991).

8.2 Empirical estimation of price transmission coefficients

As the review of our empirical literature has shown, early empirical models of price transmission used OLS regressions on price levels to estimate the price transmission coefficient for a set of price series in vertically-related markets. Often inferences about the parameters of interest were made using the standard t and F significance tests. To reiterate a point that we have made earlier on, the procedure for estimating the price transmission coefficient using the conventional t and F significance tests is valid only to the extent that these price series are stationary (i.e., have constant mean and variance).

However, price series which enter such regression equations are often non-stationary, I(1), and, in general, regressions involving two non-stationary series are very likely to produce apparently significant relationships when there is none. It is now a well known fact that statistical relationships involving I(1) variables are likely to be spurious and inferences from the standard significant tests misleading (Granger and Newbold, op cit).

Recent years have witnessed the widespread application of co-integration techniques to price regressions. The major motivation for using these techniques emanates from the belief that any price series in vertical markets which enter price regression equations should be tied in a long-run economic relationship so that, even if independently they are I(1) as indeed many of them are, the difference between them can be I(0). Under these circumstances, conventional OLS regressions are believed to yield estimates of price transmission coefficients that are 'superconsistent' (Stock, op cit.) although the 't' distribution is non-standard. Consequently, the spurious regression problem is overcome.

Consider the following simple example whereby, for a given farm input price P_a, and proportional marketing costs (φ), the retail price can be specified as $P_x = P_a(1 + \varphi)$. In this example, the retail and farm input prices are believed to be tied together with a constant margin. More generally, for a given time, t,

$$P_{xt} = \alpha + \beta_1 P_{at} \tag{8.2}$$

where α represents proportional (constant) marketing costs. Given (8.2), estimation of β_1 by OLS yields the long-run price transmission coefficient since $\beta = \frac{\sum \beta_i}{1-\sum \alpha_i}$ in the dynamic specification,

$$P_{xt} = \alpha_0 + \alpha_i \sum_{i=1}^{n} P_{xt-i} + \beta_i \sum_{i=0}^{m} P_{at-i} \tag{8.3}$$

In such simple cases, we might expect, *a priori*, that prices are co-integrated because the difference between P_x and P_a, namely, α, is constant (or at least stationary). However, as we will demonstrate, a number of factors may be responsible for the absence of a co-integrating relation between two or more price series. Indeed, as we will show later, finding such a co-integrating relation in vertical markets is very much a special case. Prior to making such inferences, however, it is necessary that we restate the definition of the pass-through elasticity.

8.3 Pass-through and pass-back elasticities defined

For given farm input and retail output prices in a vertical market and for a given exogenous shock originating in any one stage of this market, the pass-through elasticity (i.e., $\frac{dP_x}{P_x} \div \frac{dP_a}{P_a}$), is defined as the percentage change in the price of the retail product associated with a percentage change in the price of the farm input. Note that this pass-through elasticity can be calculated for shocks originating from each sector; i.e., we may calculate it when shocks originate from the retail, farm and marketing sectors. Theoretically, it is also possible to measure a pass-back elasticity (i.e., $\frac{dP_a}{P_a} \div \frac{dP_x}{P_x}$), with respect to a shock originating in any one stage of the market (McCorriston *et al.*, 1999). It is defined as the percentage change in the price of the farm input associated with a percentage change in the price of the retail product.

In empirically estimating the pass-through elasticity, the source of shock is an issue that has not received much attention. Implicitly, it has been assumed that the same pass-through elasticity is derived for all sources of shock. However, as theory has shown, the pass-through elasticity cannot be identical for all sources of shock. In fact, corresponding to each of the three exogenous shocks three different pass-through elasticities are derived. The only instance when the source of the exogenous shocks does not matter and consequently when these elasticities are identical arises under highly restrictive assumptions. As we will show in the following, this special case arises when the pass-through elasticity for each source of shock takes on the value of unity. In all other cases, the three pass-through elasticities will not be identical.

An interesting question to ask is whether the special case for which all the three sources of shock generate an identical pass-through elasticity is also a case for which there exists a co-integrating relation between the price pair. This is a question which we set out to answer next.

8.4 Making inferences about co-integration

Theory tells us that the source of an exogenous shock determines the degree of price transmission, as proxied by the pass-through elasticity. As we have just pointed out, in general, the pass-through elasticities corresponding to each of the three exogenous shocks are not identical. However, there are special conditions under which all three elasticities are identical. From an empirical point of view, identifying these conditions is important because in theory there are several theoretical price transmission coefficients that can be estimated each corresponding to the pass-through elasticities that are derived for different shocks. But in practice, there is only one empirically estimable parameter, and estimation of this single parameter by OLS is legitimate only if there exist conditions under which the pass-through elasticities for all exogenous shocks are identical.

As might be recalled, we pointed out that when any two price series in a vertical market co-integrate, the co-integrating parameter, β (i.e., the price transmission coefficient), in equation (8.1), is unique regardless of the source of shock. It is now possible to evaluate whether any inferences can be made regarding the uniqueness of the co-integrating parameter from the pass-through elasticities derived for different exogenous shocks.

For a start, let us state that the co-integrating parameter, β, does not represent the pass-through elasticity. The reasoning is because whereas β is derived from a reduced form model, the pass-through elasticities are derived from a structural model. To clarify the latter point, consider the pass-through elasticity which is derived for an exogenous shock originating in the farm sector and assuming that the input and output markets are perfectly competitive.

$$\frac{dP_x^*}{dP_a^*}\,|_{dW} = \frac{S_a(e_b+\sigma)}{e_b+S_a\sigma-S_b\eta}$$

Clearly, all right-hand side terms are structural parameters. To start with, the cost share of the farm input in total industry cost, S_a, is a function of output and farm input quantities and their price (i.e., $S_a = \frac{P_a a}{P_x x}$, where a and x denote farm and retail quantities respectively). The marketing supply elasticity, e_b, is a function of price paid the marketing input, P_b, and quantity purchased of this input, b (*i.e.*, $e_b = \frac{db}{dP_b} \times \frac{P_b}{b}$). The cost share of the marketing input is a function of output and marketing input quantities and their price (i.e., $S_b = \frac{P_b b}{P_x x}$). Finally, the Allen elasticity of substitution, σ, is a function of the first and cross-partial derivatives of x with respect to a and b and of x itself (i.e., $\sigma = \frac{f_a f_b}{x f_{ab}}$).

However, even if β and the pass-through elasticity are not identical, inference about β's occurrence can be made on the basis of information pertaining to the relative magnitudes of the pass-through elasticity for different exogenous shocks. Evidently, if these magnitudes are not identical, then our conjecture is β does not exist, and, hence, is not estimable. If, however, these magnitudes are identical, then β exists and, consequently, its estimation is possible. This inference is made possible because by definition β is thought to be unique regardless of the source of shock.

From this, it follows that the only instance when the co-integrating parameter, β, can inform on price transmission is when the pass-through elasticities for different sources of exogenous shock are identical. For all other cases for which they are not identical, then β is not identified, and, hence, cannot inform on price transmission.

To make inferences about the existence of β, therefore, we need to identify the conditions under which a pass-through elasticity arising from an exogenous shock to any one sector in the vertical market is identical to that arising from an exogenous shock to any other sector. If any such conditions exist, then our conjecture is that, regardless of the source of the shock, there is a unique value to which the pass-through elasticities tend to converge. The existence of this unique value to which the elasticities tend is what we conjecture would imply the existence of a co-integrating relation between the retail and farm input prices, and, hence, the existence of a co-integrating parameter, β.

In the following, we consider different market structures and technologies to identify the conditions under which the pass-through elasticities corresponding to different exogenous shocks are identical; and, hence, the co-integrating parameter is identified. We first consider a model whereby the input and output markets are perfectly competitive, inputs are combined in variable proportions and industry technology exhibits constant returns to scale.

8.4.1 Price transmission under perfect competition, variable input proportions and constant returns to scale and conditions under which pass-through elasticities for different exogenous shocks are identical.

Before we identify the conditions under which the pass-through elasticities corresponding to different sources of shock are identical, such that the co-integrating parameter is identified, first define the pass-through elasticities for different sources of shock given our assumptions regarding market structure and industry technology.

Given the assumptions of perfectly competitive markets, variable input proportions and constant returns to scale, the pass-through elasticities that are derived given exogenous shocks which originate in the raw, retail and marketing sectors respectively are given by:

$$\frac{dP_x^*}{dP_a^*}\Big|_{dW} = \frac{S_a(e_b + \sigma)}{e_b + S_a\sigma - S_b\eta} \tag{8.4}$$

$$\frac{dP_x^*}{dP_a^*}\Big|_{dN} = \frac{S_b e_a + S_a e_b + \sigma}{e_b + \sigma} \tag{8.5}$$

$$\frac{dP_x^*}{dP_a^*}\Big|_{dT} = \frac{e_a + \sigma}{\eta + \sigma} \tag{8.6}$$

As equations (8.4) - (8.6) clearly show, the measures of pass-through elasticities are different for different exogenous shocks. Only under special conditions is the source of the shock irrelevant with the result that all three pass-through elasticities are identical.

Note that under no normal condition is the pass-through elasticity derived for an exogenous shock originating in the marketing sector, as in (8.6) identical to the pass-through elasticities that are derived for exogenous shocks which originate in the retail and farm input supply sectors. This is because in all normal cases, the former is indeterminate because η is in all normal cases negative, while the latter two are positive. For this reason, in the subsequent analysis we will disregard the pass-through elasticity for a marketing shock and instead focus on those for farm supply and retail shocks.

Under the given assumptions, the necessary condition under which (8.4) and (8.5) are identical states that the cost share of the farm input in total industry cost be unity (i.e., $S_a = 1$). Recalling from our exposition of the theoretical model, the condition that S_a=1 is one for which the transmission elasticities in (8.4) and (8.5) are equal to unity.

It is worth emphasizing the fact that even if we relax the assumption of variable input proportions and instead hold the assumption of fixed input proportions, this result still holds. As such, it is robust to the assumption made regarding the proportion in which inputs are combined. On the other hand, the result does not hold if the assumption of constant returns to scale is relaxed and instead non-constant returns to scale are assumed.

The implication which follows from the above result is that under the given assumptions of a perfectly competitive vertical market whose technology is characterized by variable input proportions and constant returns to scale, and for given exogenous shocks that originate only in the farm input and retail sectors (i.e., not in marketing sector), the co-integrating parameter is identified when conditions are present in both pass-through elasticities for which $S_a = 1$. For all other conditions, it appears that it is not identified.

While this result is important in itself, it has also a very important corollary for empirical testing. In general, estimation of a single price transmission parameter will not be possible since for any given model structure, the parameter obtained by estimating a price regression such as (8.2) will depend on the proportion of shocks emanating from each sector. Since different proportions will lead to different estimates, estimates obtained empirically will not be unique, i.e., they will be unidentified. Since co-integration defines a unique relationship between two prices, regressions such as (8.2) should not co-integrate in general unless the above condition is satisfied. Furthermore, even this is only true if it can be shown that the marketing sector does not shock the vertical market.

Next, we evaluate whether relaxing the assumption of perfect competition at all stages of the industry invalidates the above result. With this aim in mind, we assume that the retail stage is dominated by few sellers, then identify the conditions under which the pass-through elasticities for farm supply and retail shocks are identical and hence the co-integrating parameter is identified.

8.4.2 Price transmission assuming oligopoly power in the retail sector and conditions under which pass-through elasticities for different exogenous shocks are identical

Given the assumption of oligopoly power in the retail sector, variable input proportions and constant returns to scale in technology, we can now identify the pass-through elasticities resulting from farm supply and retail sector shocks.

Given price changes for the farm input and for the retail product, the pass-through elasticities that are derived for exogenous shocks which originate in the farm and retail sectors respectively are given by:

$$\frac{dP_x^*}{dP_a^*}\Big|_{dW} = \frac{\gamma_a(e_b + \sigma)}{(1-\mu)(e_b + \gamma_a\sigma) - \gamma_b\eta} \tag{8.7}$$

$$\frac{dP_x^*}{dP_a^*}\Big|_{dN} = \frac{\gamma_b e_a + \gamma_a e_b + \sigma}{(1-\mu)(e_b + \sigma)} \tag{8.8}$$

where the parameters γ_a and γ_b represent the value shares of the farm and marketing inputs in the presence of oligopoly in the retail sector (see chapter 4, eqns. 4.15*a* and *4.15b* for definition).

Given a model whereby the retail sector of an industry is oligopolistic, the conditions under which the pass-through elasticities in (8.7) and (8.8) will be identical is when the industry's demand function is constant elasticity, i.e., for $\mu = 0$ and when the cost share of the farm input in total industry cost is unity, i.e., for $\gamma_a = 1$. Recalling from our exposition of the theoretical model, given that $\mu = 0$ the condition, $\gamma_a = 1$ is one for which the transmission elasticities in (8.7) and (8.8) are unity under an oligopolistic market, i.e., when the oligopolist firms act as if they were perfectly competitive.

A result that follows from the above is therefore that given exogenous farm input and retail sector shocks to which the industry is subject, and given the assumptions of oligopoly power in the retail sector, variable input proportions and constant returns to scale in technology, a constant elasticity demand function facing the industry seems to be the only scenario under which γ_a=1 leads to the pass-through elasticities in (8.7) and (8.8) being identical. The implication is that, under the given assumptions, the only instance when farm input and retail prices might co-integrate is when the demand function facing an industry is constant elasticity and when the share of the farm input in total industry cost is unity. The corollary of this is that, for other forms of the demand function, i.e., for $\mu > 0$ (or $\mu < 0$), the farm input and retail price pairs, on their own, will not co-integrate when oligopoly power is present in the retail sector.

8.4.3 Price transmission assuming oligopsony power in the farm input sector and conditions under which the pass-through elasticities for different exogenous shocks are identical.

Consider now the conditions under which the pass-through elasticities are identical for given exogenous shocks in the farm and retail sectors assuming that, *ceteris paribus*, the farm input sector is oligopsonistic.

For given changes in the farm input and retail product prices, the pass-through elasticities that are derived for exogenous shocks which originate in the farm and retail sectors respectively are given by:

$$\frac{dP_x^*}{dP_a^*}\Big|_{dW} = \frac{(1+\delta)\,\gamma_a(e_b+\sigma)}{e_b+\gamma_a\sigma-\gamma_b\eta} \tag{8.9}$$

$$\frac{dP_x^*}{dP_a^*}\Big|_{dN} = \frac{\gamma_b e_a+(1+\delta)\,(\gamma_a e_b+\sigma)}{e_b+(1+\delta)\,\sigma} \tag{8.10}$$

where the parameters γ_a and γ_b represent the value shares of the farm and marketing inputs in the presence of oligopsony in the farm sector (see chapter 5, eqn. *5.20)*

Given a model whereby the farm input market is oligopsonistic, the conditions under which the pass-through elasticities in (8.9) and (8.10) are identical arise for δ=0 and γ_a=1. Recalling from our exposition of the theoretical model, for δ=0, the condition γ_a=1 is one for which the transmission elasticities in (8.9) and (8.10) are unity. And, the condition, $\delta = 0$ obtains when the supply function for the farm input is either linear, where the supply elasticity is unity, or constant elasticity.

The result which follows from the above is therefore that given the assumptions of oligopsony power in the farm sector and variable input proportions and constant returns to scale in technology and given exogenous farm and retail shocks to which the industry is subject, a constant elasticity supply function facing an industry or a linear supply function for which the supply elasticity is unity seems to be the only scenario under which the condition, γ_a=1 leads to the pass-through elasticities in (8.9) and (8.10) being identical.

The implication which follows from the above result is therefore that in the presence of oligopsony power in the farm sector, the condition, γ_a=1 can only lead to the identification of a co-integrating relation between the farm input and retail output prices if there is a unitary linear (or constant elasticity) supply function for the farm input i.e., for $\delta = 0$. For other functional forms of farm supply, i.e., for $\delta > 0$ (or $\delta < 0$), however, the condition, $\gamma_a = 1$, on its own, will not be sufficient to identify a co-integrating relation between the price pair when oligopsony power is present in the industry.

To this stage, we have assumed the existence of market power either in the retail or farm sector of a vertical market. In the following, we assume the existence of market power in both the retail and farm sectors at the same time that we hold the assumptions of variable input proportions and constant returns to scale in industry technology.

8.4.4 Price transmission assuming both oligopoly and oligopsony power and conditions under which the pass-through elasticities for different exogenous shocks are identical

Finally, consider the conditions under which the pass-through elasticities for given exogenous shocks in the farm input and retail sectors are identical assuming, *ceteris paribus*, the farm input sector is oligopsonistic and the retail sector is oligopolistic.

Given these assumptions, and for given changes in the farm and retail product prices, the pass-through elasticities that are derived for exogenous shocks which originate in the farm and retail sectors respectively are given by:

$$\frac{dP_x^*}{dP_a^*}\,|_{dW} = \frac{(1+\delta)\,\gamma_a(e_b+\sigma)}{(1-\mu)\,(e_b+\gamma_a\sigma)-\gamma_b\eta} \tag{8.11}$$

$$\frac{dP_x^*}{dP_a^*}\,|_{dN} = \frac{\gamma_b e_a+(1+\delta)\,(\gamma_a e_b+\sigma)}{(1-\mu)\,(e_b+(1+\delta)\,\sigma)} \tag{8.12}$$

where the parameters γ_a and γ_b represent the cost shares of the farm and marketing inputs in the presence of oligopoly power in the retail sector and oligopsony power in the raw input sector (see chapter 5, eqn. 5.50a).

Given the assumption of market power in the farm and retail sectors, three conditions can be identified as being necessary for the pass-through elasticities in (8.11) and (8.12) to be identical. These conditions are that the demand function facing the industry is constant elasticity, i.e., $\mu = 0$; that the supply function facing the industry is either constant elasticity or a linear function for which the supply elasticity is unity, i.e., $\delta = 0$; and that the cost share of the farm input in total industry cost is unity; i.e., $\gamma_a = 1$.

The implication of this result is that in the presence of market power in both the retail and farm sectors, and given the assumptions of variable input proportions and constant returns to scale in industry technology, a co-integrating relation between retail and farm input prices can only be identified, given exogenous shocks to the farm input and retail sectors, if and when the retail demand function facing an industry is constant elasticity, i.e., $\mu = 0$ and the farm supply function is constant elasticity (or unitary linear); i.e., $\delta = 0$ and when the cost share of the farm input in total industry cost is unity; i.e., $\gamma_a = 1$. The corollary of this is that for other forms of farm supply and retail demand functions, the condition, $\gamma_a = 1$ would not in itself be sufficient for a co-integrating relation to be identified between the prices of the farm input and the retail product following exogenous shocks originating in the farm and retail sectors.

8.5 Summary

In this chapter, we have attempted to show how a co-integrating relation between the industry's retail and farm input prices can be inferred from the existing models of price transmission for given assumptions that are made regarding market structure and industry technology.

Given the assumptions of perfect competition at all stages of a vertical market, of variable input proportions and of constant returns to scale in industry technology, and for given exogenous shocks that originate in the farm and retail sectors, a co-integrating relation between the industry's retail and farm input prices would be identified under a condition whereby the cost share of the farm input in total industry cost is unity, i.e., when $S_a = 1$. This implies that the pass-through elasticities are all equal to unity. No other value seems to be theoretically consistent. This result assumes no exogenous marketing shocks exist. Where there are marketing shocks, then even the special case is denied.

Given the assumptions of market power in the farm and (or) retail stages of the vertical market, of variable input proportions and of constant returns to scale in technology, on the other hand, a co-integrating relation between retail and farm input prices can only be identified if, further to the condition that $\gamma_a = 1$, constant elasticity (or linear) farm supply and constant elasticity demand functions are assumed for the industry, i.e., if the price mark-up and price mark-down are constant. For other forms of supply and (or) demand functions, the condition, $\gamma_a = 1$ on its own is not sufficient for a co-integrating relation between retail and farm input prices to be identified. Therefore, for these other functional forms, the co-integrating relation is unidentified when market power is assumed in a vertical market.

One major implication which follows from these results is that, given a particular market structure, the price transmission coefficient implied by different models, i.e., perfect competition, oligopoly, and (or) oligopsony will not be unique except in very special cases, as it depends on the source of the shock. In other words, it is unidentified in the co-integration relation in all cases except where markets are perfectly competitive (or imperfectly competitive but with constant mark-up and (or) mark-down) and the value share of the farm input is unity. Consequently, under the given assumptions, farm input and retail prices will never co-integrate in general.

This implication follows because for any given market model, there are several theoretical pass-through elasticities measuring the degree of price transmission. These theoretical elasticities correspond to the exogenous shocks originating in the farm and retail sectors of the market. Given these theoretical elasticities, estimation of a single price transmission coefficient is only valid if all these elasticities are equal to unity. And when this obtains, one can identify a co-integrating relation between the price pair. The corollary of this is that, when these theoretical elasticities are not identical, one cannot identify a co-integrating relation between the price pair. Consequently, one is not able to estimate a price transmission coefficient from the co-integration regression.

Another major implication which follows from the above result concerns the way structural modelling is practiced. As our review of the empirical literature has shown, the structural modelling approach to estimating the degree of price transmission assumes the existence of a relationship between the retail and farm input prices rather than establish it by testing. It also estimates the existence of a single elasticity of price transmission from the farm to the retail sector. But as the above inference suggests, the existence of a single price transmission elasticity can only be assumed if the pass-through elasticities which correspond to different exogenous shocks are identical. As the above results suggest, these elasticities are identical only if they take on the value of unity regardless of the source of the exogenous shock, and it is only under this condition that one can assume the existence of a relationship between the price pair.

This suggests that estimation of the elasticity of price transmission should be carried out conditional on the existence of a co-integrating relation between the prices of the farm input and of the retail product. This means that, in the course of structural modelling, estimation of the degree of price transmission has to be preceded by a test for co-integration. If the test identifies a co-integrating relation between the price series, then estimation of a single price transmission elasticity is legitimate. If, however, the test fails to identify any such a co-integrating relation between the price pair, then estimation of a single price transmission elasticity is not possible. Because several such elasticities can exist simultaneously for different shocks.

8.6 Caveat

In the preceding, it has been shown that given information related to a price pair, cointegration arises much as a special case rather than in general. However, this inference should be interpreted with caution. The fact that a price pair do not cointegrate by themselves does not necessarily imply that inherently they do not cointegrate. What it probably suggests is that the model on which the the cointegration test is based is not adequately specified. It is generally believed that the empirical test for cointegration in vertically related markets is sensitive to model specification and particularly to omission of industry-wide shocks. It is thus not uncommon, in empirical work, to find no cointegration between a price pair in the absence of shocks when in fact they are cointegrated when the regression is re-estimated allowing for these shocks. The theoretical price transmission models we have reviewed are explicit about the importance of industry-wide shocks in determining the degree of price transmission. Thus any empirical test for cointegration between a price pair in vertically related markets that does not allow for these shocks is likey to be misspecified. In this respect, it is not difficult to see that the price equation (8.2) is not adequately specified. as it does not incorporate shocks that originate in the retail, supply and marketing sectors. Consequently, given (8.2), one should expect to find a cointegrating relation between the price pair in only rare cases.

Given that it is misspecified as it stands now, Wohlgenant and Haidacher (1989) and Wohlgenant (1999) (see 7.5.1) have suggested that the price equation in (8.2) be reformulated to allow for industry-wide demand, supply and marketing shocks as explanatory variables, as:

$$P_{xt} = \alpha + \beta_1 P_{at} + \beta_2 Z_t + \beta_3 W_t + \beta_4 S_t \tag{8.13}$$

where, Z_t, W_t and S_t are denote the demand, marketing and supply shocks respectively.

In the empirical chapter that follows, we run two sets of tests for cointegration using 11 price pairs from the UK food and energy industries. In the first set, we undertake a test using only information related to the price pair. If we find cointegration, then that means the price pair by themselves provide adequate information for a test suggesting that (8.2) above is well specified. If we do not find cointegration on the basis of information provided by the price alone, then this means the price pair by themselves do not provide adequate information for a test suggesting that (8.2) is misspecified. Thus in the second set, we run a cointegration test based on (8.13) using not only information relating to the price pair but also information relating to industry-wide shocks.

Chapter 9

A Test for co-integration: the case of price series from the UK food and energy sectors

9.1 Background

As we have shown in our empirical literature review, in recent years establishing a relationship between two or more price pairs in vertically related markets using co-integration analysis has become widespread. This has been motivated by the realization that when estimating a coefficient for a price pair early models of vertical price transmission regression were prone to the spurious regression problem such that they established a correlation between the price pair when in fact there was none (Granger and Newbold, *op cit.*). They suffered from this problem because they made a prior assumption that there was a long-run economic relationship between the price pair without first investigating the time series properties of the pair.

Applying the concept of co-integration when estimating price transmission coefficients is believed to free any regressions that involve two or more series from the spurious regression problem because prior to estimating the long-run regression equation, it ensures, unlike the practice followed by the early models, that the price pair which enter the price transmission regression are tied to each other in a long-run economic relationship.

As we have made evident in our review of the literature, studies for different countries have shown that many price pairs in the food and energy sectors are co-integrated, such that, over time, a movement in one price series triggers a movement in the other such that both series move in the direction of a new equilibrium once the original has been disturbed. The presence of cointegration implies that there is a constant linear relationship between the two variables. But as predictions from the existing models of price transmission suggest, by themselves time series of final product and farm input prices in vertically related markets do not in general have a constant linear relationship except under highly restrictive assumptions. These assumptions are that (*i*) the given markets operate with constant returns to scale; (*ii*) that their downstream and upstream sectors are perfectly competitive, or if they are not, they operate with a constant elasticity demand function and (or constant elasticity farm supply function) so that the price mark-up and the price mark-down are constant ; and (*iii*) that the cost share of the farm input is unity.

This chapter will test empirically the hypothesis that a time series of farm input and retail product prices will co-integrate by themselves. To test the validity of this hypothesis, the Johansen maximum likelihood test for co-integration is applied to a time series of eleven price pairs in the UK food and energy sectors. These price pairs represent the retail and producer prices (or price indices where appropriate) for **milk, fresh fruits, sugar, potato, eggs, coffee, beef, pork, lamb, chicken and petrol.**

9.2 Empirical Strategy

As might be recalled, the chapter dealing with the empirical literature review has dwelt at length on the concept of co-integration and its empirical implementation. We do not therefore repeat it here. Our plans for the remaining part of the chapter are as follows.

First, we describe the sources and nature of our data. Next, we present a graphical description of the data. We then finally examine the time series properties of the data. This task will involve testing each price series for stationarity using the ADF unit-root test and then testing them for co-integration using the Johansen FIML procedure.

9.3 Sources and nature of data

For the purpose of our analysis, we use 11 pairs of price series relating to the UK food and oil industries. These series represent monthly retail and producer level prices for **milk, fresh fruits, sugar, potato, eggs, coffee, beef, pork, lamb, chicken and petrol.**

The price series for fresh fruits, sugar (sugar beet and retail granule sugar), potato and eggs represent monthly retail and producer price indices over the period, 1988.1-1998.12 as extracted from the Monthly Digest of Statistics published by the UK Office for National Statistics.

The farm-gate prices for milk represent monthly prices paid to farmers in pence per litre of fresh milk while the retail prices represent the milk equivalent of cheese in pence per litre[1] charged by supermarkets. They cover the period, 1995.1-2000.12. The retail and farm-gate prices are extracted from various issues of the Annul Report of the UK Dairy Council and of the Annual report of Agricultural Prices issued by the UK Department of Environment, Fisheries and Rural Affairs (DEFRA) respectively.

The monthly series for retail instant coffee price and those for imported green bean coffee price over the period, 1996.1-2000.8 are made available to us by the Office of National Statistics and DEFRA respectively. The series for instant coffee price are measured in pence per 200 gram pure instant coffee jar, while those for imported green bean coffee

[1]The conversion factor for the milk equivalent of cheese is kindly provided to us by the Food Standards Agency. The equivalence is arrived at by assuming 2 million litres of fresh milk makes 196 tonnes of hard cheese.

price are measured in pence per 200 gram jar of instant coffee equivalent. The equivalence is worked out using a conversion factor as stipulated in Annex 1 of the International Coffee Agreement, 2001 (International Coffee Organization); i.e., 1kg instant=2.6 kg of green bean coffee. The average coffee retail price series are derived from the UK Retail Price Index (RPI). As such, they represent an average of prices that are charged by all retail outlets covered by the RPI, which include supermarket multiples and a number of small stores. They represent purchase prices as apply to consumers in retail outlets thus are inclusive of tax and a profit margin. They also include special promotions and discounts (e.g offers of 50 pence off an item). However, they do not include 'three for the price of two' type of offers. It is worthy of note here that average prices derived from the RPI are calculated on the basis of actual prices charged in January which are then updated each month using the relevant item index. The monthly average price series for green coffee bean imports reflect the CIF value of such imports. They are sourced from HM Customs and Excise and prepared by DEFRA.

The monthly price series for crude oil and motor spirit for the UK over the period, 1982.1-1995.6 have been provided to us by Dr Robert Witt of Surrey University. The monthly price series for motor spirit expressed in pence per litre constitute the net monthly average price of four-star leaded petrol paid at the pump by consumers on approximately the 15th day of the month[2]. The average is worked out on the basis of information collected from major oil companies by the Department of Trade and Industry (DTI) and published in the Monthly Digest of Energy Statistics. The monthly crude oil price series, expressed in pence per litre, reflect the monthly average price of Brent crude oil originating from the UK continental Shelf[3].

The retail and producer price series for beef, pork, lamb and chicken cover the period 1990.1-2000.12 and are provided by the Meat and Livestock Commission (MLC). The

[2]The net petrol price is arrived at by subtracting from the gross retail price of four-star leaded petrol excise duty and value added tax. The value added tax has been either 15% or 17% of gross retail price whereas excise duty is revised annually with the budget.

[3]The price of Brent crude oil for each month in pence per litre has been arrived at by multiplying the price in US cents by the sterling-US dollar exchange rate for that month.

producer price for each category is derived from a survey of auctions and abattoirs in Great Britain and reflects the farm-gate price. All live prices are converted to carcass weight equivalent (CWE) using the proportion of carcass meat in the live animal. The retail prices for all meat categories reflect a representative retail price for each meat as charged by supermarkets, by butchers and regional meat retailers. They are constructed by aggregating over prices recorded for individual cuts according to the share they have in the MLC's basket which in turn reflects the proportions of the meat cuts obtained from the carcase. Retail prices do not account for discounts such as buy-one-get-one free and exclude loyalty card bonuses and other effective discounts. Both the producer and retail price series are expressed in real terms by adjusting the nominal prices for the Retail Price Index (all items)[4].

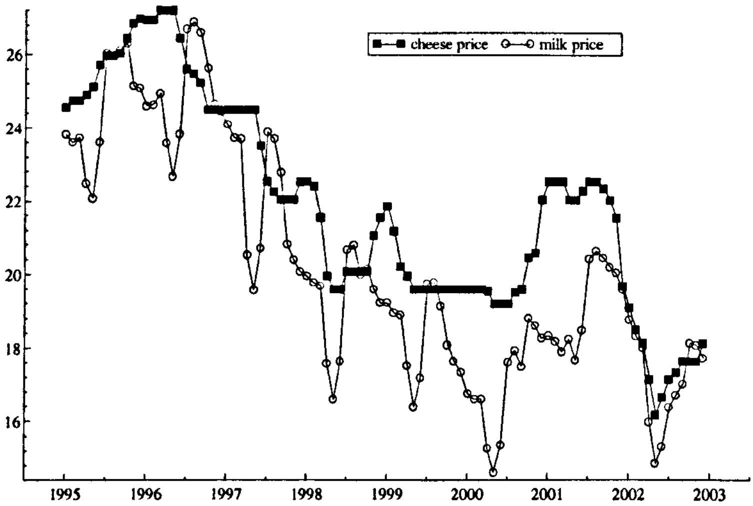
9.4 Graphical description of the data

In the following, we describe graphically the temporal behavior followed by each of the selected price pairs. Figure 9.1 plots the monthly prices of fresh milk and cheese over the period, 1995.1-2000.12. As the plot clearly indicates, over the sample period, both price series have followed a general downward trend. But this trend has not been so smooth as both series have shown marked fluctuations over the period. As is evident from the plot, this fluctuation has been more marked for the milk price series. The plot also clearly shows that fresh milk prices have been at their all-time low in the first half of 2000 while they have been at their all-time high in the second half of 1996. On the other hand, cheese prices have been at their all-time low in the first half of 2002 while they have been at their all-time high in the first half of 1996. The plot also seems to suggest that, over the sample period, both price series have moved together over time.

Figure 9.2 plots the retail to producer price spread for UK milk over the reference period. As the plot makes evident, the fluctuations observed for the raw price series have

[4]For details of the construction of the price series and their characterstics, refer to MAFF (1999): Supply of Groceries from Multiple Stores

Figure 9-1: UK retail and producer milk prices , 1995.1-2000.12



been reflected in a price spread which seems to be highly unstable.

Figure 9.3 plots the monthly retail and producer price indices for UK fresh fruits over the period 1988.1-1998.12. As the plot clearly illustrates, there has been a general upward trend in the retail and producer price indices for the UK fresh fruits. Despite this general trend, nevertheless, both indices have exhibited fluctuations over the reference period. The graphical evidence seems to suggest that the UK retail and producer price indices for fresh fruit have moved together over the reference period.

Figure 9.4 plots the retail to producer price spread for UK fresh fruits over the reference period. As shown by the plot, the price spread for this period has been characterized by structural break.

Figure 9.5 plots the monthly retail and producer price indices for granulated sugar and sugar beet respectively over the period 1994.1-1999.7. As the plot clearly indicates, over the sample period, both price indices have followed different patterns. The pattern exhibited by the retail price index has been one of decline in the first half of 1994, of a recovery in the second half of the same year, of a persistent rise into mid-1996 and then of a persistent decline afterwards. On the other hand, the pattern of the producer price

Figure 9-2: The price spread: UK milk prices, 1995.1-2000.12

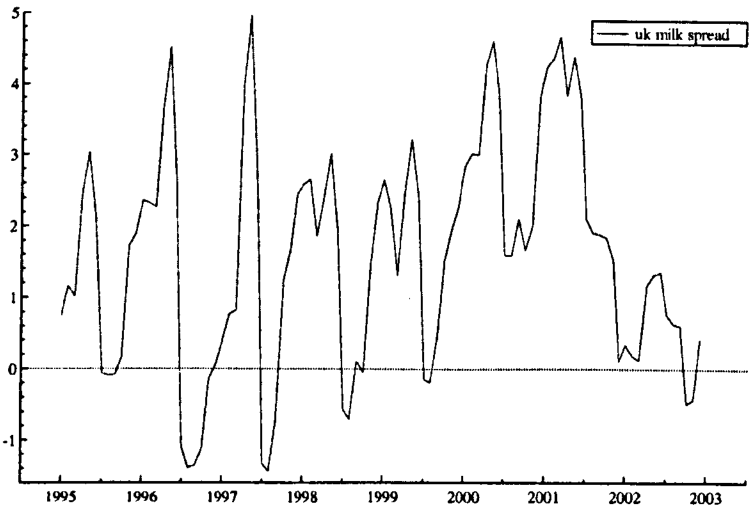


Figure 9-3: Retail and producer price indices: UK fruits, 1988.1-1998.12

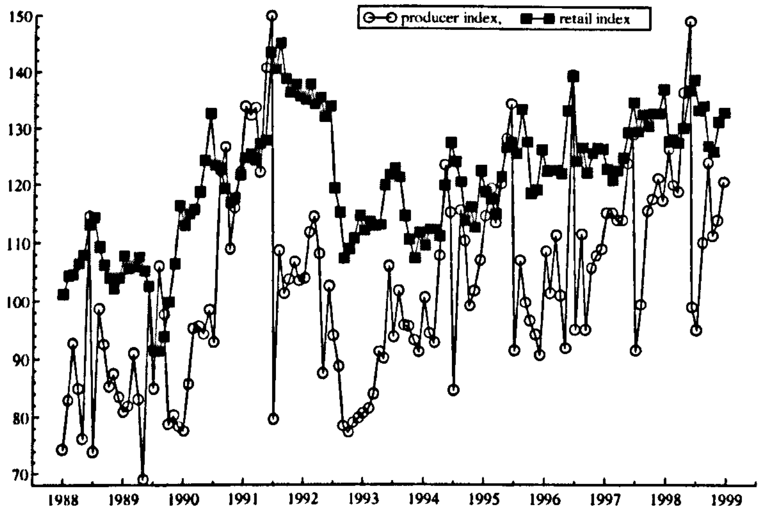
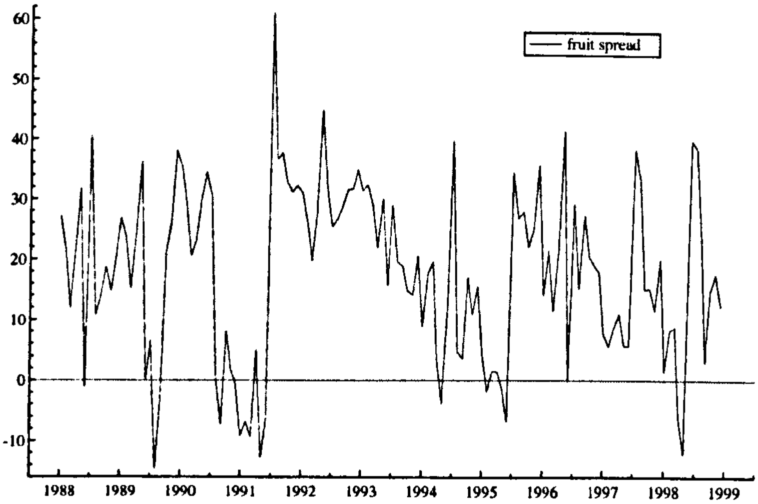


Figure 9-4: The price spread, UK fresh fruit prices, 1988.1-1998.12



index has been one of a step-wise rise until the second half of 1996, of a step-wise decline until the second half of 1998 and then of a recovery afterwards. There thus seems to exist no indication of the price indices moving together.

Figure 9.6 plots the retail to producer price spread for sugar over the reference period. Over the sample period, the spread has generally shown an upward trend . But this trend has not been smooth. As the plot clearly indicates, it fluctuates between 1994 and the second half of 1996 then suddenly rises in a step-wise fashion until the late second half of 1997 only to fall afterwards.

Figure 9.7 plots the monthly retail and producer price indices for UK potato over the period 1988-1998. As the plot clearly indicates, the most prominent characteristic of both price indices through out the period seems to have been random fluctuation. But this characteristic seems to have been more prominent during the period into 1994, during which time the fluctuations occurred at short intervals, than in the subsequent period when these fluctuations occurred at long intervals. This being the general observation, in mid-1995 the retail price index plummeted to its all-time low while the producer price index shot to its all-time high. But as the plot makes evident, there seems to be an

Figure 9-5: Retail and producer price indices: UK sugar, 1994.1-1999.7

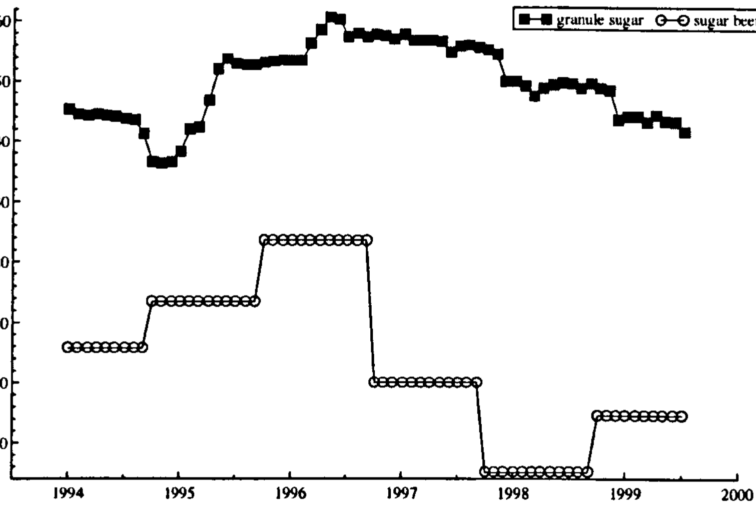


Figure 9-6: The price spread: UK sugar prices, 1994.1-1999.7

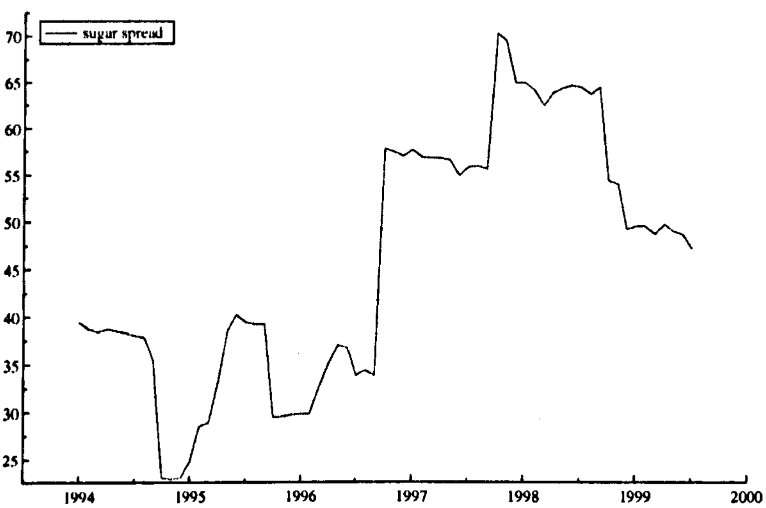
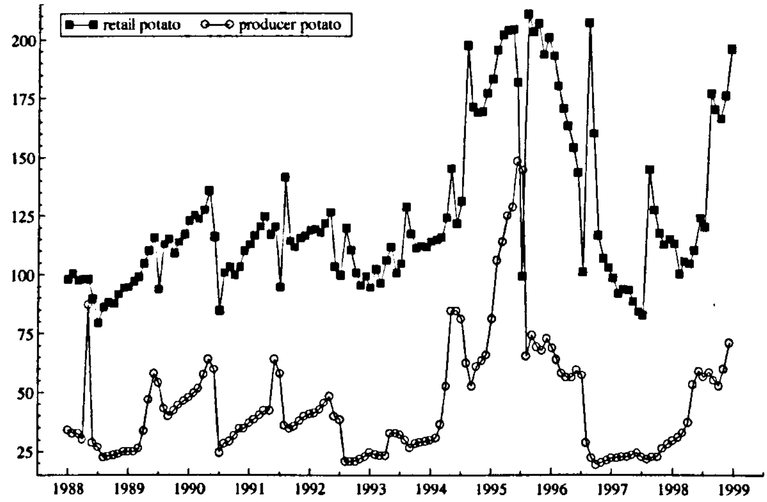


Figure 9-7: UK retail and producer potato prices, 1988.1-1998.12



indication that both price indices have co-moved over time over the reference period.

Figure 9.8 plots the retail to producer price spread for UK potato for the reference period. As the plot clearly shows, the spread has been characterized by random fluctuations, obviously reflecting the observed fluctuations in both price indices during the reference period. It might be worth noting that the sudden dip in the retail price index observed in mid-1995 comes out prominent in the plot of the price spread as well.

Figure 9.9 plots the UK monthly retail and producer price indices for eggs for the period, 1988-1998. As the plot clearly shows, while the retail price index has followed a general upward trend over the reference period, the producer price index does not seem to have followed such a trend; it rather has fluctuated at long intervals. Therefore except for the short interval between 1990 and late second half of 1991, both retail and producer price indices have generally drifted apart.

Figure 9.10 plots the retail to producer price spread for UK eggs for the reference period. As the plot illustrates, even though generally the price spread has followed an upward trend over the period, it has been characterized by a mix of trends. Evidently, the period 1988-1990 witnessed a general decline in the spread with the next two years

Figure 9-8: The price spread: UK potato prices, 1988.1-1998.12

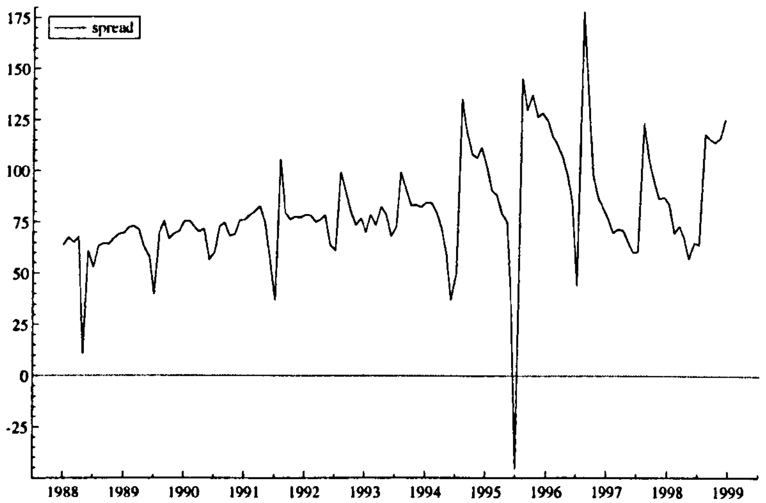


Figure 9-9: UK retail and producer egg prices, 1988.1-1998.12

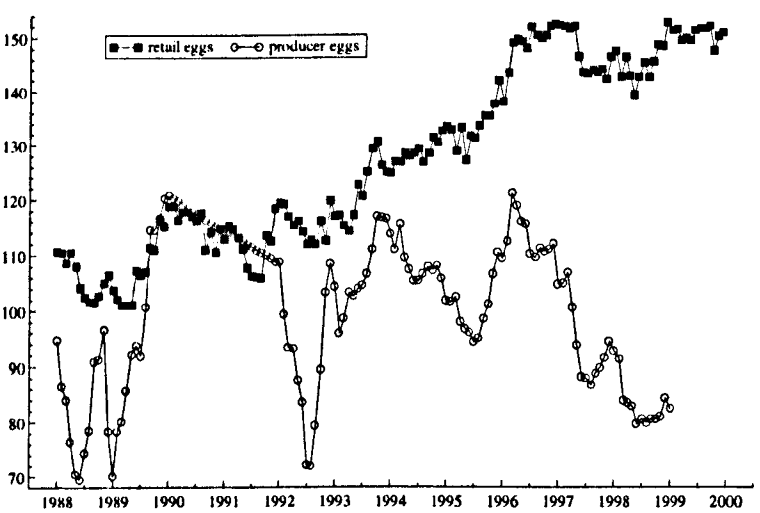
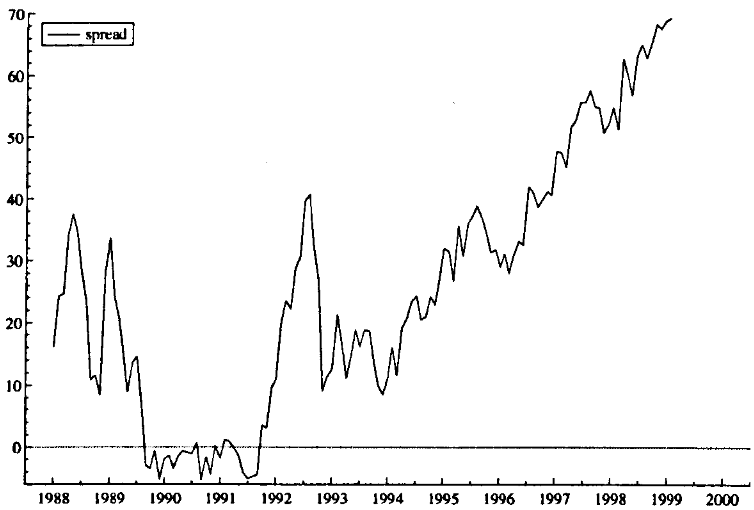


Figure 9-10: The price spread: UK eggs, 1988.1-1998.12

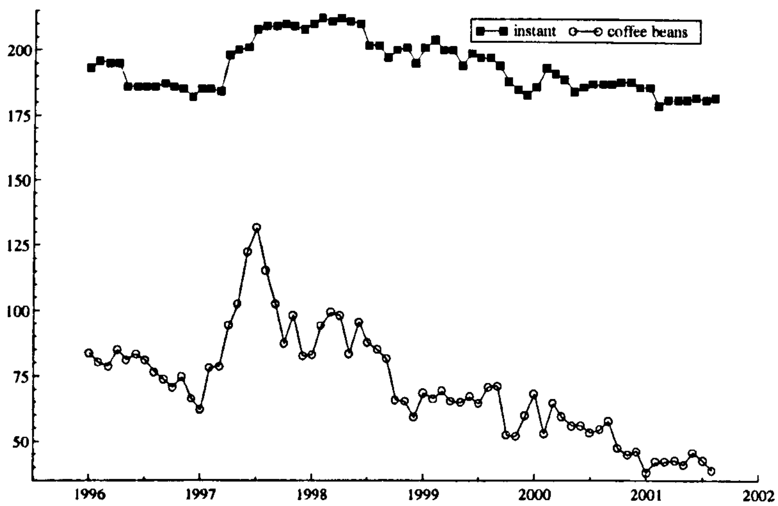


witnessing a relative stability in the spread which was only interrupted by the sudden spike in mid-1992. The period beginning 1994, however, has been characterized by uninterrupted widening of the spread.

Figure 9.11 plots the average monthly prices of both instant coffee and imported green coffee beans over the period, 1996.1-2000.8. As the plot makes evident, over the sample period, both price series seem to have followed a general downward trend. But this seems to have been a particularly characteristic feature of the price series for imported coffee beans. The plot also shows that the price series for coffee beans have shown more frequent fluctuations than those for retail instant coffee, which seem to have remained relatively stable, and this because they are subject to the vagaries of nature and to fluctuations in the international market.

But it is quite clear that both series seem to have followed paths which are typified by swings. For instance, over the period into 1997, the retail price series for instant coffee remain stable, rise to a peak in the first quarter of 1997, then stabilize until mid-1999 only to fall afterwards. The price series for coffee beans, on the other hand, decline in the first two years of the sample period, rise to a new peak in the first quarter of 1997

Figure 9-11: UK instant and green coffee beans prices, 1996.1-2000.8

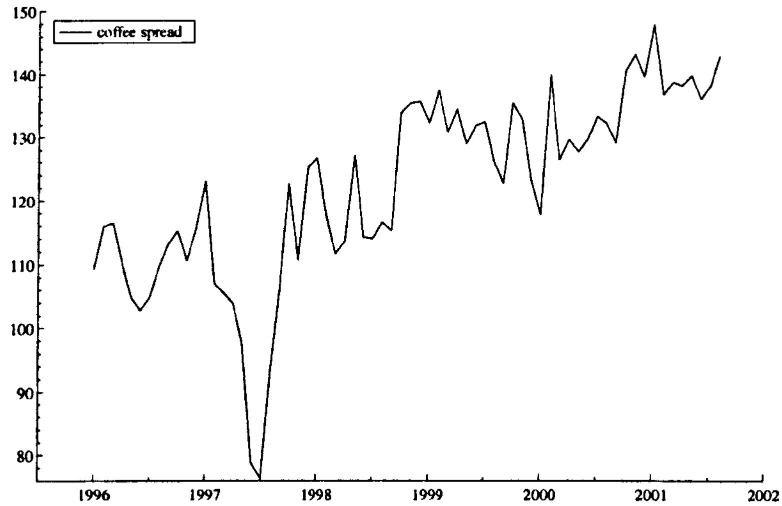


then suddenly plummet to a new level in mid-1997 and further decline afterwards with frequent swings along the way. Generally, however, judging from the plot, there is a rough indication that the retail and producer price series have moved together over the sample period.

Figure 9.12 plots the retail to producer price spread for UK coffee. Mirroring the erratic behavior of both price series, the price spread has been volatile over the reference period. In general, it has followed an upward trend. But the trend's path has been characterized by frequent swings reflecting the fluctuations observed in the price series for imported coffee beans.

Figure 9.13 plots the average monthly real beef and cattle prices for the UK over the period 1990.1-2000.12. As the plot clearly indicates, over the reference period, the prices of beef and cattle have shown a general downward trend. But this downward trend has been more prominent for real cattle prices than for beef prices. The exceptions are the sudden peaks observed in mid-1993 and during the first half of 1996 and the sudden dip in the real producer price observed during the second half of 1998. The peak observed during the first half of 1996 is associated with the announcement of the link between BSE

Figure 9-12: The price spread: UK instant and green coffee bean prices, 1996.1-2000.8



and new variant CJD. At the most preliminary level, the plot suggests that the retail and producer price levels have co-moved over the reference period.

Figure 9.14 plots the retail to producer price spread for UK beef. As the plot makes evident, the retail to producer price spread has generally shown a rising trend over the reference period. This reflects the relatively rapid decline in real prices for cattle observed for this period. The plot also shows that the widening of the spread has been step-wise mirroring the relative stability in the price series during 1990-1993 and the general downward trend in the series afterwards.

Figure 9.15 plots the monthly averages of the UK real pork prices over the period, 1990.1-2000.12. The plot shows that over the reference period, the retail and producer prices of pork have followed a downward trend. The exceptions are the spike observed for both series in mid-1996 and the dip observed in late 1998. But evidently, relative to the trend observed for beef prices, the real prices for pork seem to have shown more volatility. But judging from the plot, there is a strong suggestion that both the retail and producer price series have moved together over time.

Figure 9.16 plots the retail to producer price spread for UK pork. The plot clearly

Figure 9-13: UK retail and producer beef prices: 1990.1-2000.12

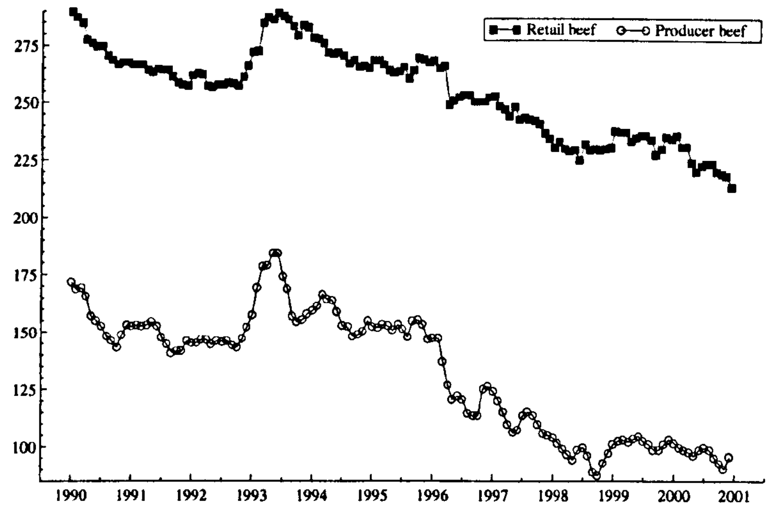


Figure 9-14: The price spread: UK beef prices, 1990.1-2000.12

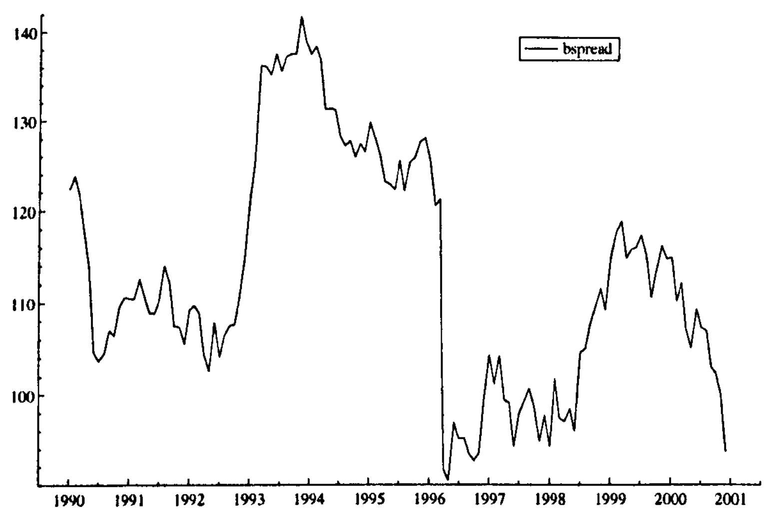
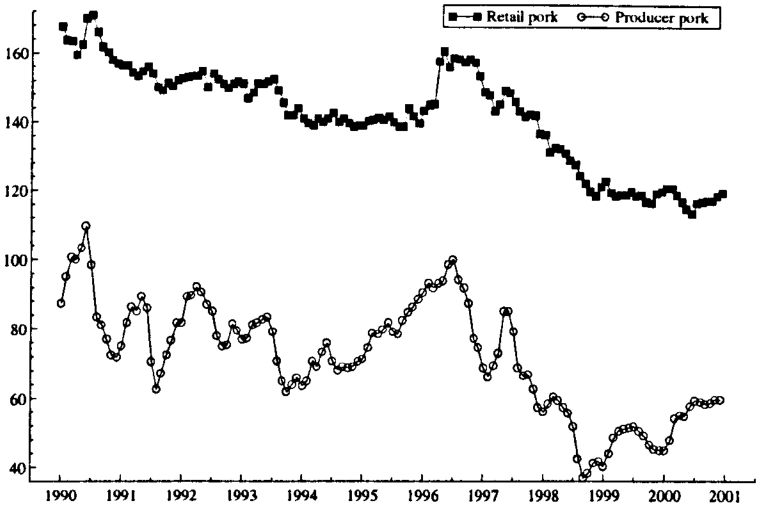


Figure 9-15: UK retail and producer pork prices, 1990.1-2000.12



indicates that, over the reference period, the spread for this meat category has been volatile.

Figure 9.17 plots the monthly average real retail and producer lamb prices for the UK over the period 1990.1-2000.12. As the plot clearly indicates, the lamb market is characterized by frequent seasonal fluctuations. This reflects the fact that in this market prices peak in the spring and plummet in the autumn. However, beginning in 1997, the fluctuation in the real producer price of lamb has followed a downward trend while that in the real retail price has remained relatively stable. From the plot, however, there seems to be an indication that, over the sample period, the price series have co-moved.

Figure 9.18 plots the retail to producer price spread for lamb meat over the reference period. As illustrated by the plot, over the reference period, the price spread seems to have exhibited fluctuations around a time trend. But clearly, the mean of the price spread seems to have grown over the period around a time trend.

Figure 9.19 plots the average monthly retail and producer prices of chicken meat for the UK over the period 1990.1-2000.12. As the plot clearly shows, while the producer price has generally declined, the retail price has consistently remained volatile. But

Figure 9-16: The price spread: UK pork prices, 1990.1-2000.12

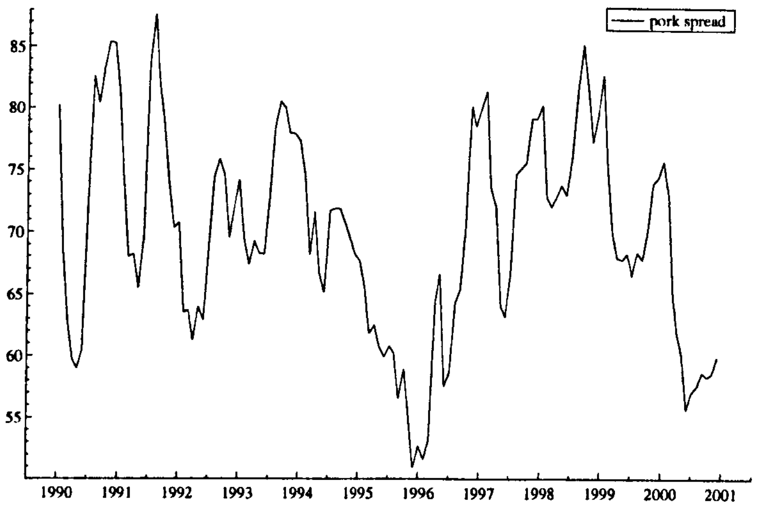


Figure 9-17: UK retail and producer lamb prices, 1990.1-2000.12

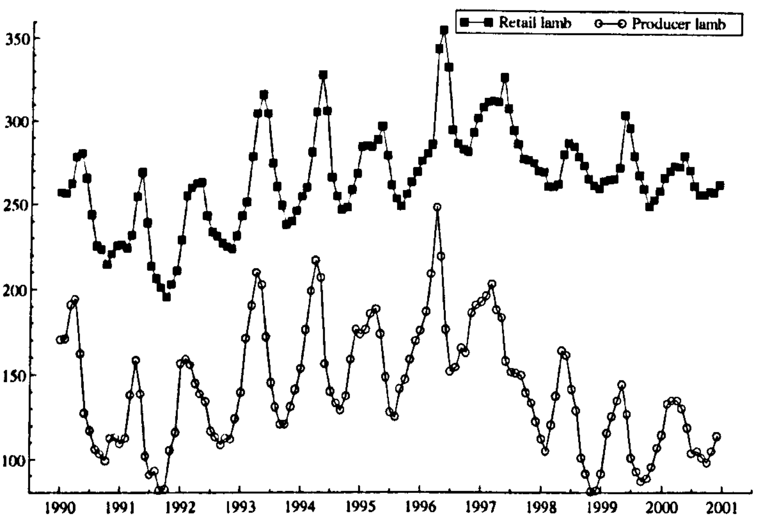
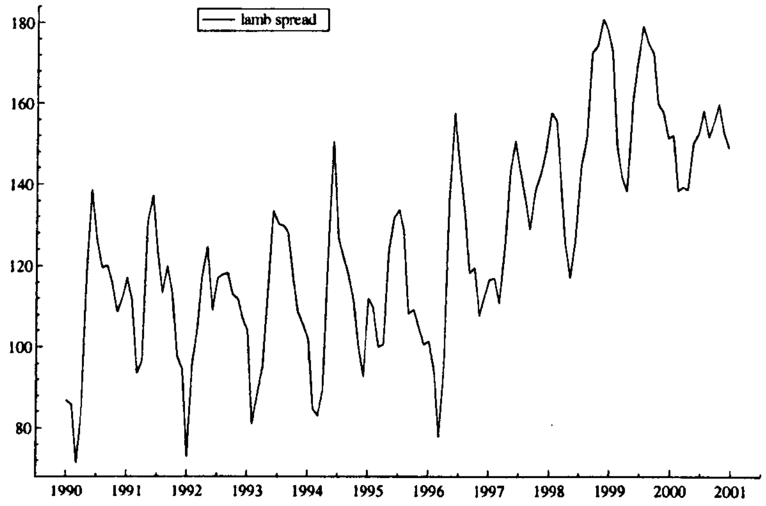


Figure 9-18: The price spread: UK lamb prices, 1990.1-2000.12



beginning in the second half of 1996, while retail price levels have increased slightly, the decline in producer price has been more dramatic. A cursory look at the plot shows that the retail and producer price series have drifted apart over the sample period.

Figure 9.20 plots the retail to producer price spread for chicken meat over the reference period. While generally, the spread has been volatile, it has grown since mid-1996 reflecting the growth in retail price levels during this period. It is quite evident that over the reference period the spread has trended upwards.

Figure 9.21 plots the monthly average series for UK crude oil and four-star petrol prices over the period 1982.1-1995.12. As the plot makes evident, over the reference period, both price series have been subject to severe short-term fluctuations (or volatilities). Their behavior follows no set pattern. It rather varies for different time periods. Evidently, the first five years witness a general upward trend in the price series while the subsequent years witness mixed trends with the spike observed in the first half of 1990 and the sudden dip observed in the first half of 1986 being the exceptions. Despite these peculiarities, the price series seem to have moved together over the reference period.

Figure 9.22 plots the retail to producer price spread for the UK four-star petrol over

Figure 9-19: UK retail and producer chicken prices.

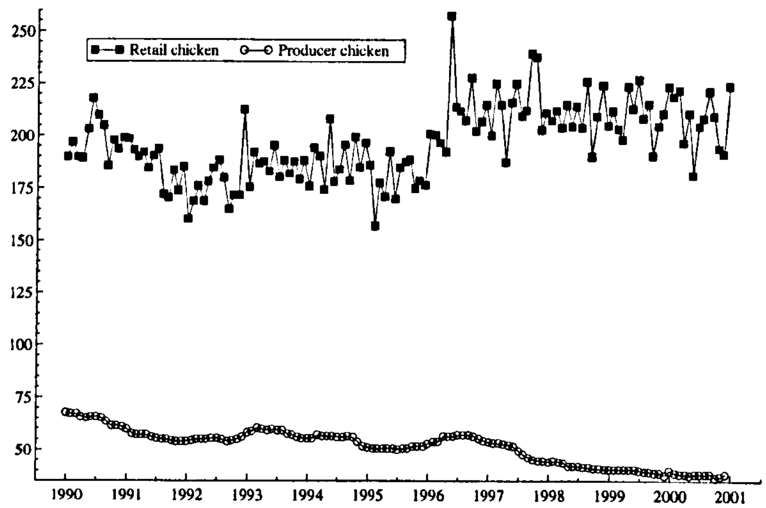


Figure 9-20: The price spread: UK chicken prices, 1990.1-2000.12

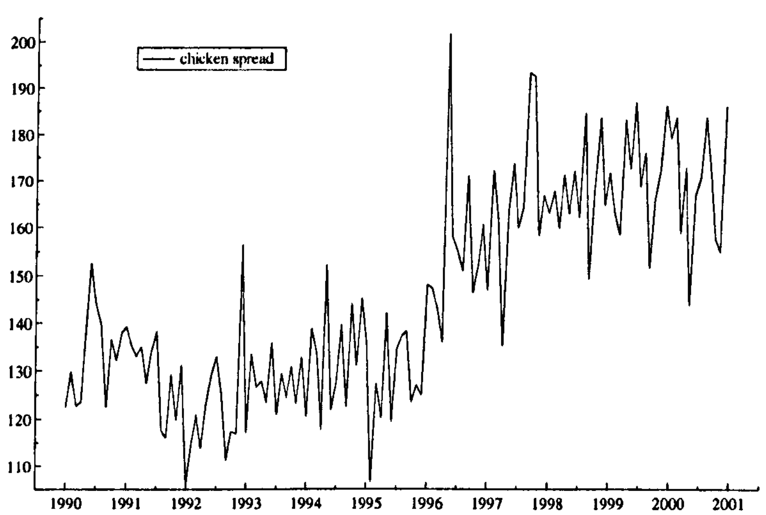
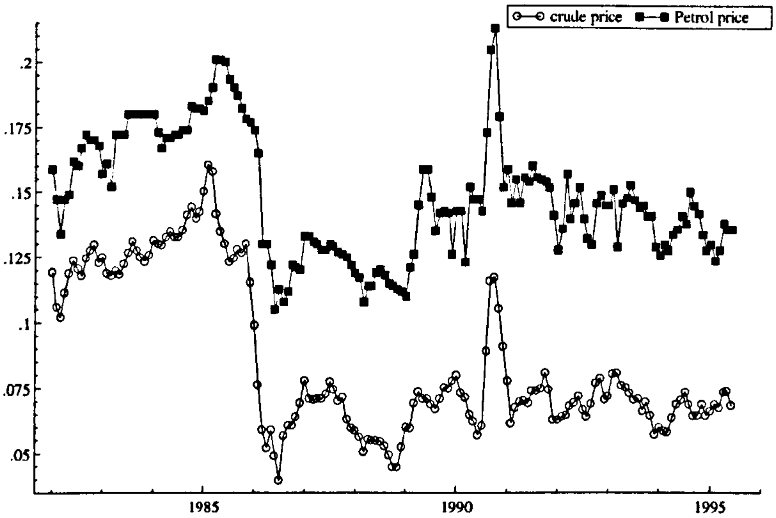


Figure 9-21: UK crude and petrol prices, 1982.1-1995.12

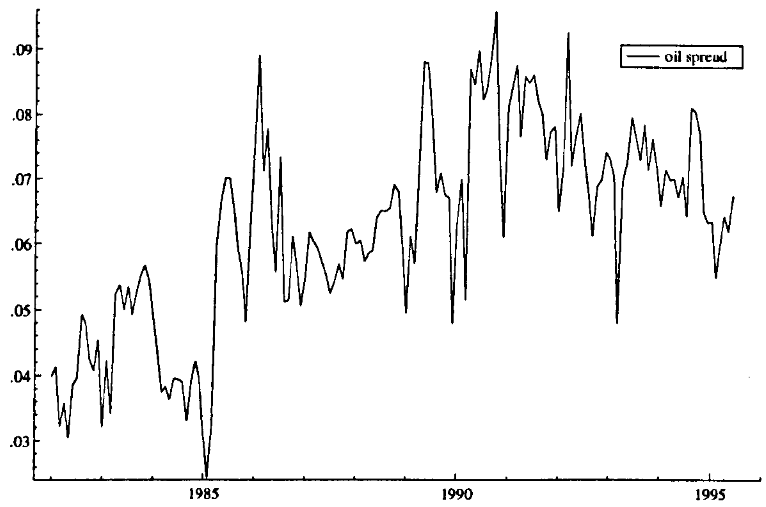


the reference period. As the plot clearly shows, the price spread for this industry has trended upwards over the sample period in a step-wise fashion. This is an indication that, over the sample period, the mean for the price spread has been variable.

9.4.1 Graphical description of data: a brief summary

As the graphical description has shown, apart from the price pairs for sugar and eggs, the most important characteristic of all other price pairs seems to be the apparent co-movement of the pairs. This might be a pointer to the potential existence of a co-integrating relationship between each of the price series in the pairs. However, as we will show in the following section, the fact that two price series have co-moved over time does not mean that, by themselves, the price series co-integrate. In fact, the apparent co-movement might have been due to variables which relate to each series independently but about which we have no information available at the moment. Therefore the co-movement suggested by the plots for many price pairs should not be taken for any guide to inferences about a co-integrating relationship between the price series in a pair as the nature of this relationship can only be picked out by investigating the time series

Figure 9-22: The price spread: UK oil prices, 1982.1-1995.12



properties of the series. In the following section therefore, we undertake a formal test to evaluate whether the above price pairs are co-integrated by themselves.

9.5 Time series properties of the price pairs

9.5.1 Stationarity

As has been pointed out elsewhere, the first step in the test for co-integration involves the test for unit-roots in the levels of the price series. The test for unit-roots helps one to evaluate whether, as they appear in their raw form, any two price pairs are stationary or non-stationary. As is very well known, if the unit-root test confirms that the series are stationary, then it follows that ordinary OLS estimation can be applied to establish a relationship between the two series. However, this relationship is short run. If, on the other hand, the test confirms that both price series are non-stationary, then whilst this allows for a possible long run relationship the most appropriate tool to apply in such circumstances is rather co-integration.

In the following, we apply the Augmented Dickey-Fuller (ADF) unit-root test to evaluate whether the selected price pairs are stationary. The statistical package we use to run this test is PcGive 9 (see Doornik and Hendry, 2000). Prior to undertaking this test we select the most appropriate lag length using the Akaike information criterion which is readily run by the statistical package. For all price series, we start from a lag length of 13, which the package uses as a default for monthly series and then choose that length of lag which corresponds to the smallest value of this information criterion. The ADF regression relating to the price in levels includes a constant, a trend and seasonals while such a regression for the differences includes a constant and seasonals but not a trend. Table 9.1 summarizes the results for the choice of lag length and for a unit-root test. Whereas double asterisk indicates rejection at the 99% significance, a single asterisk indicates rejection at the 95% level of significance.

As results in Table 9.1 show, all prices are non-stationary I(1) in levels while they are stationary, I(0) in first differences at the 1% significance level of the test. This suggests that co-integration is the most appropriate tool for studying the nature of long-run economic relationship between the price series in the selected pairs. As we have explained elsewhere, if any two price pair are co-integrated by themselves, then this means that, on grounds of the information provided by the price pair alone, and without the need for any other information, one can establish a long-run economic relationship between the series in the pair. If, on the other hand, one cannot establish a co-integrating relationship between a price pair based on information provided by the price pair alone, then this means that either the price pair do not co-integrate at all, or, if they do, they do so in the presence of other relevant information. In this particular instance, the analyst needs to look for a list of variables that are not only related to each of the price pair independently but also are of the same degree of integration as the price pair themselves. This is not an easy task unless the analyst has prior knowledge of this 'extra marital' relationship between the price series and this other information.

Table 9.1: ADF Unit Root Tests: Assorted UK product prices,

Price variable	In levels	Lag	In first differences	Lag	Order of integration
raw milk	-2.2384	6	-6.1024**	8	I(1)
cheese	-2.1338	1	-5.1599**	0	I(1)
farm fresh fruits	-2.3485	3	-9.5022**	2	I(1)
retail fresh fruits	-2.4283	1	-8.9955**	0	I(1)
sugar beet	-1.5011	0	-6.2450**	0	I(1)
granule sugar	-2.4246	0	-3.0106*	1	I(1)
raw potato	-1.8916	0	-10.211**	0	I(1)
retail potato	-1.9299	1	-12.376**	0	I(1)
raw eggs	-4.0054	11	-3.380*	12	I(1)
retail eggs	-2.4554	3	-13.072*	0	I(1)
green coffee beans	-4.0432	0	-6.6058**	0	I(1)
instant coffee	-3.8995	0	-5.7063**	0	I(1)
farm beef	-2.4051	1	-5.1256**	2	I(1)
retail beef	-1.5549	0	-6.4519**	1	I(1)
farm pork	-2.1955	1	-6.5742**	1	I(1)
retail pork	-1.4470	0	-9.2744**	0	I(1)
farm lamb	-1.5027	6	-6.9143**	5	I(1)
retail lamb	-2.2695	3	-6.6684**	3	I(1)
farm chicken	-2.1198	2	-4.7656**	1	I(1)
retail chicken	-3.1534	10	-3.3720*	11	I(1)
crude oil	-1.8066	4	-6.6761**	3	I(1)
petrol	-2.4112	0	-11.262**	0	I(1)

Table 9.2: Common lag length: VAR of UK beef prices, 1990.1-2000.12

Common lag length	SBC	HQ	AIC
0	10.668	10.335	10.107
1	5.5686	5.1802	4.9147
2	5.3545	4.9107	4.6072
3	5.4918	4.9925	4.6511

9.5.2 Co-integration test in the absence of shocks

As the above unit-root test results indicate, all the price series are non-stationary I(1) in levels. This suggests that co-integration is the most appropriate tool for investigating a long-run economic relationship between a price pair. In the following therefore, we apply the Johansen Maximum Likelihood test for co-integration to each of the 11 selected price pairs and test whether, on grounds of information provided by the retail and producer prices alone, one can establish a co-integrating relationship between prices in any pair. This test is carried out on the basis of a multivariate Vector Autoregressive (VAR) model in levels allowing for a constant, seasonal dummies but not for a time trend. Our rationale for excluding the time trend from the VAR is to ensure that only information provided by the retail and producer price information enter the VAR and not any other information that can be proxied by the time trend. It is possible that a deterministic trend term in a VAR may proxy for omitted I(1) variables and thereby lead to the conclusion that the price pair are co-integrated by themselves when they are not.

The UK beef price pair

As we have pointed out earlier, the test for co-integration between a price pair requires that a common lag length be identified for the VAR of prices. As Table 9.2 shows, on counts of the SBC, HQ and AIC selection criteria, the most appropriate lag length chosen for the UK VAR of beef price pair is 2. This is because, as perusal of the results reveals, the selected information criteria attain their smallest value for 2 lags.

To ensure that the chosen lag length produces vector error terms that are white noise,

Table 9.3: Serial correlation test: VAR of UK beef prices, 1990.1-2000.12

Common lag length	Test for serial correlation, Chi^2(4), AR 1-1
2	2.49 [0.6464]

Table 9.4: Co-integration test: VAR of UK beef prices, 1990.1-2000.12

H_0: rank=p	λ_{trace}	95%	λ_{max}	95%
p==0	9.667	15.4	9.245	14.1
p<=1	0.4226	3.8	0.4226	3.8

we next test the VAR errors for serial correlation. The results are presented in Table 9.3. Clearly, the null hypothesis of no serial correlation cannot be rejected for a VAR with a common lag length of 2. This is because for the given lag length the probability with which the null can be accepted is reasonably high. Hence, a VAR(2) is a congruent approximation of the data and we perform the test for co-integration on this basis.

Table 9.4 summarizes the co-integration test results. Clearly, on grounds of our VAR specification for this pair, the null hypothesis of no co-integration cannot be rejected in favor of the alternative of co-integration on counts of both λ_{trace} and λ_{max} statistics This implies that given information provided by the price pair alone, no long-run economic relationship can be established for this pair.

The UK pork price pair Table 9.5 presents the results for the choice of common lag length for the VAR of UK pork price pair on the basis of our selected information criteria. As the results clearly show, the SBC and HQ criteria choose 2 lags. But the AIC chooses 3 lags.

To evaluate whether the chosen lag lengths produce VAR error terms that are white

Table 9.5: Common lag length: VAR of UK pork prices, 1990.1-2000.12

Common lag length	SBC	HQ	AIC
0	10.139	9.8059	9.5783
1	4.6316	4.2432	3.9777
2	4.5969	4.1530	3.8496
3	4.6816	4.1823	3.8409

Table 9.6: Serial correlation test: VAR of UK pork prices, 1990.1-2000.12

Common lag length	Test for serial correlation, Chi^2(4), AR 1-1
2	4.4076 [0.3536]
3	3.3118 [0.5071]

Table 9.7: Co-integration test: VAR of UK pork prices, 1990.1-2000.12

H_0: rank=p	λ_{trace}	95%	$\lambda_{\max}$	95%
p==0	30.53**	15.4	27.13**	14.1
p<=1	3.402	3.8	3.402	3.8

noise, we undertake a diagnostic test for serial correlation for each chosen lag length. The results are summarized in Table 9.6. Evidently, for both lag lengths, the null hypothesis of no serial correlation cannot be rejected. However, the probability of accepting the null when it is true is greater for a lag length of 3 than that for a lag length of 2. We therefore undertake the co-integration test based on a lag length of 2[5].

The co-integration test results are presented in Table 9.7. As the λ_{trace} and $\lambda_{\max}$ statistics clearly show, for the pork price pair, the null hypothesis of no-co-integration is rejected at 1% significance in favor of the alternative of co-integration. Furthermore, the null of a single co-integrating vector against the alternative of more than one such vector cannot be rejected. This suggests that on the basis of information provided by this price pair alone, and without recourse to any other information, one can establish a long-run economic relationship for this pair.

The UK lamb price pair Table 9.8 presents results for the choice of a common lag length for the VAR of UK lamb price pair based on the aforementioned information criteria. As a look at the results reveals, the SBC chooses 2 lags while the HQ and AIC choose 3 lags.

To see whether choice of these lag lengths is supported by the data, we undertake a diagnostic test for serial correlation for different lags. The test results are summarized in Table 9.9. As the results clearly show, the null hypothesis of no serial correlation is not

[5]A lag length of 2 also confirms a co-integrating relation between the pair.

Table 9.8: Common lag length: VAR of UK lamb prices, 1990.1-2000.12

Common lag length	SBC	HQ	AIC
0	13.542	13.209	12.981
1	9.5792	9.1908	8.9253
2	9.1829	8.7390	8.4356
3	9.2221	8.7227	8.3813
4	9.3713	8.8165	8.4372

Table 9.9: Serial correlation test: VAR of UK lamb prices, 1990.1-2000.12

Common lag length	Test for serial correlation, Chi^2(4), AR 1-1
2	4.4076 [0.3536]
3	2.6249 [0.6224]

rejected for the lag lengths selected by the information criteria. But the probability of accepting the null when it is true is higher for a lag length of 3 than it is for a lag length of 2. On this count, we proceed to test for cointegration assuming a common lag length of 3, VAR(3). [6]. The test results are presented in Table 9.10.

As the results clearly show, for the lamb price pair, the null hypothesis of no co-integration cannot be rejected for the chosen VAR specification against the alternative of co-integration. This suggests that, as they stand now, the price pair do not co-integrate. This implies that on counts of information provided by the price pair alone, it is not possible to establish a long-run economic relation for the price pair. This might imply that the price series in the pair do not co-integrate at all, or, if they do, they do on the proviso that other relevant information are provided.

[6]Running the test on the basis of a lag length of two does not produce a a co-integrating relation either.

Table 9.10: Co-integration test: VAR of UK lamb prices, 1990.1-2000.12

H_0: rank=p	λ_{trace}	95%	$\lambda_{\max}$	95%
p==0	8.369	15.4	5.299	14.1
p<=1	3.07	3.8	3.07	3.8

Table 9.11: Common lag length: VAR of UK chicken prices, 1990.1-2000.12

Common lag length	SBC	HQ	AIC
0	10.452	10.119	9.8914
1	5.7119	5.3236	5.0580
2	5.5120	5.0682	4.7647
3	5.5730	5.0737	4.7323
4	5.6253	5.0705	4.6911

Table 9.12: Serial correlation test: VAR of UK chicken prices, 1990.1-2000.12

Common lag length	Test for serial correlation, Chi^2(4), AR 1-1
2	8.6603 [0.0702]
4	6.2771 [0.1794]

The UK chicken price pair Table 9.11 presents the choice of common lag length for the VAR of UK chicken price pair on the basis of the above information criteria. As the results clearly show, while the SBC and HQ choose 2 lags, the AIC chooses 4 lags.

To see whether the choice of common lag length on counts of both categories of information criteria is admitted by the data, we run a diagnostic test for serial correlation assuming different lags. The test results are presented in Table 9.12. As the table clearly shows, the null hypothesis of no-serial correlation cannot be rejected for both choices of lag length. However, the probability of accepting the null when it is true is higher for a lag length of 4 than it is for a lag length of 2. On counts of a higher probability of acceptance of the null of no serial correlation therefore we conduct the test for cointegration assuming a common lag length of 4 .

Table 9.13 presents the co-integration test results for the chicken price pair. As the results clearly show, the null hypothesis of no co-integration cannot be rejected against the alternative of co-integration. This means that, as they stand now, the chicken price pair are not co-integrated. This suggests that either the price pair do not co-integrate inherently, or, if they do, they do so conditional on the availability of other relevant variables that are related to each of the prices in the pair independently. Hence, on grounds of information provided by the price pair alone, no long-run economic relationship can be established for the pair.

Table 9.13: Co-integration test: VAR of UK chicken prices, 1990.1-2000.12

H_0: rank=p	λ_{trace}	95%	$\lambda_{\max}$	95%
p==0	14.8	15.4	14.08	14.1
p<=1	0.719	3.8	0.719	3.8

Table 9.14: Common lag length: VAR of UK fresh fruit prices, 1988.1-1998.12

Common lag length	SBC	HQ	AIC
0	10.813	10.480	10.253
1	8.3496	7.9612	7.6956
2	8.4024	7.9585	7.6550
3	8.5003	8.0009	7.6595

The UK fresh fruits price pair Table 9.14 presents results for the choice of a common lag length for the VAR of UK fruit price pair on counts of information criteria. As the results clearly indicate, on counts of HQ and AIC, the chosen common lag length is 2 while on counts of SBC the chosen lag length is 1.

To evaluate whether the lag lengths chosen on the basis of the two information criteria are admitted by the data, we conduct a diagnostic test for serial correlation corresponding to each choice. The results are presented in Table 9.15. As the results clearly indicate, the null hypothesis of no serial correlation cannot be rejected for both lag lengths against the alternative of serial correlation. But evidently, the probability of accepting the null when it is true is smaller for 2 lags than it is for 1 lag. On this ground therefore we undertake the test for co-integration assuming a common lag length for the VAR of 1.

Table 9.16 presents the co-integration test results for this price pair. The results show that at the 1% significance level, the null of no co-integration is rejected in favor of co-integration on counts of both the λ_{trace} and $\lambda_{\max}$ statistics. On the other hand, the null of a single co-integration vector against the alternative of more than one co-integration

Table 9.15: Serial correlation test: VAR of UK fresh fruit prices, 1988.1-1998.12

Common lag length	Test for serial correlation, Chi^2(4), AR 1-1
1	8.0186 [0.0909]
2	8.692 [0.0693]

Table 9.16: Co-integration test: VAR of UK fresh fruit prices, 1988.1-1998.12

H_0: rank=p	λ_{trace}	95%	$\lambda_{\max}$	95%
p==0	37.57**	15.4	33.72**	14.1
p<=1	4.357	3.8	4.425	3.8

Table 9.17: Common lag length: VAR of UK potato prices, 1988.1-1998.12

Common lag length	SBC	HQ	AIC
0	13.300	12.968	12.740
1	10.605	10.216	9.9506
2	10.661	10.217	9.9136
3	10.816	10.316	9.9748

vector is not rejected. This implies that the price pair for fresh fruit the information provided by the price pair is enough to establish a long-run economic relationship for the pair.

The UK potato price pair Table 9.17 presents the choice of common length for the VAR of UK potato price pair based on the three information criteria. As the results clearly show, the SBC and HQ select a common lag length of 1 while the AIC selects a common lag length of 2. To see if the lag lengths suggested by the information criteria produce vector error terms that are white noise, we undertake a diagnostic test for serial correlation for the respective lag lengths.

The test results are presented in Table 9.18. As the results clearly show, even though the null hypothesis of no serial correlation cannot be rejected for both lag lengths, the probability with which the null is accepted is higher for 2 lags than it is for 1 lag. On counts of a higher probability of rejecting the null of no serial correlation therefore we undertake the test for cointegration between the pair assuming a common lag length of 2[7].

Table 9.19 summarizes the co-integration test results for the potato price pair. As the test results show, the null hypothesis of no co-integration between the potato price

[7] A lag length of 1 also produces a co-integrating relation between the price pair.

Table 9.18: Serial correlation test: VAR of UK potato prices, 1988.1-1998.12

Common lag length	Test for serial correlation, Chi^2(4), AR 1-1
1	5.7058 [0.2222]
2	4.7658 [0.3122]

Table 9.19: Co-integration test: VAR of UK potato prices, 1988.1-1998.12

H_0: rank=p	λ_{trace}	95%	λ_{max}	95%
p==0	27.35**	15.4	25.44**	14.1
p<=1	1.912	3.8	1.912	3.8

pair is rejected against the alternative of co-integration. On the other hand, the null of a single co-integrating relation between the pair cannot be rejected in favor of more than one co-integrating vector. This suggests that as they stand now, the potato price pair are co-integrated. This implies that on counts of information provided by the price pair alone, and without recourse to any other information, it is possible to establish a long-run economic relationship for the pair.

UK milk price pair Table 19.20 presents results for the choice of lag length for the VAR of UK milk price pair based on information criteria. Clearly, all the information criteria choose a common lag length of 2. To see whether the chosen lag length is admitted by the data, we conduct a diagnostic test to check for serial correlation in the vector error terms.

The test results are presented in Table 9.21. Clearly, for a lag length of 2, the null hypothesis of no serial correlation cannot be rejected. And given this lag length, the probability with which the null cannot be rejected is quite high. This suggests that for

Table 9.20: Choice of common lag length: VAR of UK milk prices, 1995.1-2000.12

Common lag length	SBC	HQ	AIC
0	3.5103	3.0919	2.8109
1	-1.6332	-2.1214	-2.4492
2	-1.7029	-2.2609	-2.6355
3	-1.5307	-2.1584	-2.5798

Table 9.21: Serial correlation test: VAR of UK milk prices, 1995.1-2000.12

Common lag length	Test for serial correlation, Chi^2(4), AR 1-1
2	3.0755(0.5453)

Table 9.22: Co-integration test: VAR of UK milk prices, 1995.1-2000.12

H_0: rank=p	λ_{trace}	95%	$\lambda_{\max}$	95%
p==0	21.88**	15.4	20.95**	14.1
p<=1	0.9265	3.8	0.9265	3.8

2 lags, the vector error terms are white noise. The test for co-integration between the milk price pair is thus based on the assumption of 2 lags for the VAR.

Table 9.22 presents the co-integration test results for the milk price pair. As the results show, the null hypothesis of no co-integration can be rejected in favor of the alternative of co-integration at the 1% significance level. This implies that, as they stand now, the milk price pair are co-integrated. This suggests that, given information provided by the price pair alone, it is possible to establish a long-run economic relation for the pair.

The UK egg price pair Table 9.23 presents results for the choice of lag length for formulating the VAR of UK egg price pair using the three information criteria. As the results clearly show, all three information criteria choose a common lag length of 2 for the VAR. Having chosen a common lag length for the VAR, the next step is to evaluate whether this choice is compatible with white noise vector errors. To this end, we undertake a diagnostic test for serial correlation of the vector errors.

The test results are presented in Table 9.24. As the results clearly show, the null

Table 9.23: Common lag length: VAR of UK egg prices, 1988.1-1998.12

Common lag length	SBC	HQ	AIC
0	11.375	11.043	10.815
1	5.4220	5.0336	4.7681
2	5.3194	4.8755	4.5721
3	5.4288	4.9294	4.5880

Table 9.24: Serail correlation test: VAR of UK egg prices, 1988.1-1998.12

Common lag length	Test for serial correlation, Chi^2, AR 1-1
2	3.8292 [0.4296]

Table 9.25: Co-integration test: VAR of UK egg prices, 1994.1-1999.7

H_0: rank=p	λ_{trace}	95%	$\lambda_{\max}$	95%
p==0	8.574	15.4	8.514	14.1
p<=1	0.05959	3.8	0.05959	3.8

hypothesis of serial correlation cannot be rejected for the vector errors assuming 2 lags. Indeed, the probability of not rejecting the null seems to be very high for this choice of lag. This suggests that VAR(2) is a good approximation of the data. In undertaking a co-integration test for this pair therefore a lag length of 2 is assumed.

Table 9.25 summarizes the co-integration test results for the egg price pair. As the results clearly indicate, the null hypothesis of no co-integration cannot be rejected in favor of the alternative of co-integration. This suggests that, as they stand now, the price pair do not co-integrate. This might be either because the price pair do not co-integrate at all or there are factors that relate to each of the prices in the pair independently but which are not included in the VAR. Therefore it appears that on counts of information provided by the price pair alone, it is not possible to establish a long-run economic relationship between the pair.

The UK sugar price pair Table 9.26 summarizes results for the choice of lag length for the VAR of UK sugar price pair based on the three information selection criteria. As the results clearly show, on counts of the three information criteria, the most appropriate common lag length chosen for the VAR is 1. To ensure that this choice of lag length is admitted by the data, we run a diagnostic test for serial correlation in the vector errors.

Table 9.27 summarizes the diagnostic test results. As the results clearly show, the null hypothesis of no serial correlation in the VAR errors cannot be rejected for the given lag length. We therefore undertake our test for co-integration assuming 1 common lag for the VAR.

Table 9.26: Common lag length: VAR of UK sugar prices, 1994.1-1999.7

Common lag length	SBC	HQ	AIC
0	10.060	9.5168	9.1759
1	5.1100	4.4764	4.0787
2	5.3355	4.6114	4.1569

Table 9.27: Serial correaltion test: VAR of UK sugar prices, 1994.1-1999.7

Common lag length	Test for serial correlation, Chi^2, AR 1-1
1	6.9716 [0.1374]

Table 9.28 summarizes the co-integration test results for the UK sugar price pair. As the results clearly show, for the chosen lag, the null hypothesis of no co-integration cannot be rejected for the price pair. This suggests that, as they stand now, the price pair are not co-integrated. The explanation might be that either the price series in the pair do not co-integrate at all, or, if and when they do, they do because of the presence of other variables, which, being integrated of the same order as the price series themselves relate to each series independently. The implication of this result is that on counts of the information provided by the price pair alone, a long-run economic relationship cannot be established for the pair.

The UK oil price pair Table 9.29 summarizes results for the choice of a common lag length for the VAR of UK oil price pair based on the three information criteria. The results show that two of the information criteria, i.e., the SBC and HQ choose a maximum lag length of 2 for the VAR while the AIC information criterion chooses a lag length of 3. To see whether these lag lengths are congruent with the data, we undertake a diagnostic test for serial correlation in the vector errors.

Table 9.30 presents these diagnostic test results. As the results clearly show, the null

Table 9.28: Co-integration test: VAR of UK sugar prices, 1994.1-1999.7

H_0: rank=p	λ_{trace}	95%	$\lambda_{\max}$	95%
p==0	13.21	15.4	10.64	14.1
p<=1	2.569	3.8	2.569	3.8

Table 9.29: Common lag length: VAR of UK oil prices, 1982.1-1995.6

Common lag length	SBC	HQ	AIC
0	-15.219	-15.506	-15.703
1	-18.977	-19.312	-19.542
2	-19.111	-19.494	-19.757
3	-19.052	-19.483	-19.778

Table 9.30: Serial correlation test: VAR of UK oil prices, 1982.1-1995.6

Common lag length	Test for serial correlation, Chi^2, AR 1-1
2	13.767 [0.0081] **
3	3.1317 [0.5360]

hypothesis of no serial correlation in the vector errors is rejected for a lag length of 2 while it is not for a lag length of 3. This suggests that a lag length of 3 for the VAR is a better approximation of the data. When conducting the test for co-integration therefore we assume a common lag length of 3 for the VAR.

Table 9.31 summarizes the co-integration test results for the oil price pair. On counts of the λ_{trace} statistic, , the null hypothesis of no co-integration is rejected in favor of the alternative of at least a single cointegration for the pair at the 5% significance. However, on counts of the $\lambda_{\max}$, the null of no cointegration cannot be rejected in favor of the alternative of a single cointegration. This apparent contradiction is not uncommon in cointegration analysis and should not be cause for concern since the λ_{trace} statistic accepts the null of a single cointegration vector against the alternative of two cointegrating vectors. Therefore one should take the results as suggesting that, as they stand now, the oil price pair are cointegrated. This means that on the basis of information provided by the pair alone, one can establish a long-run economic relationship between the price pair.

Table 9.31: Co-integration test: VAR of UK oil prices, 1982.1-1995.6

H_0: rank=p	λ_{trace}	95%	$\lambda_{\max}$	95%
p==0	17.41*	15.4	14.0	14.1
p<=1	3.403	3.8	3.403	3.8

Table 9.32: Common lag length: VAR of UK coffee prices, 1996.1-2000.8

Common lag length	SBC	HQ	AIC
0	11.398	10.860	10.522
1	7.9121	7.2853	6.8902
2	8.1544	7.4381	6.9865
13	8.7981	7.0970	6.0244

Table 9.33: Serial correlation test: VAR of UK coffee prices, 1996.1-2000.8

Common lag length	Test for serial correlation, Chi^2, AR 1-1
1	3.1006 [0.5411]
13	9.7557 [0.0448]*

The UK coffee price pair Table 9.32 presents results for the choice of a common lag length for the VAR of the UK coffee price pair based on the three information criteria. As the results clearly show, two of the information criteria, i.e., the HQ and the AIC select a common lag length of 13 while the SBC selects a common lag length of 1. To see whether these lag lengths are supported by the data, we conduct a diagnostic test for serial correlation in the vector errors assuming lags of 1 and 13.

Table 9.33 summarizes the diagnostic test results. As a cursory look at the results reveals, while the null of no serial correlation in the vector errors cannot be rejected by the data for a lag length of 1, such is rejected for a lag length of 13. This suggests that the choice of VAR(1) is more congruent with the data. In testing for co-integration between the series in the price pair therefore we assume a lag length of 1.

Table 9.34 summarizes the co-integration test results for the coffee price pair. As the results clearly indicate, the null of no co-integration against the alternative of co-integration between the series cannot be rejected. This suggests that, by themselves, the UK instant and imported coffee bean prices do not co-integrate. The implication is that, on the basis of information provided by the price pair alone, no meaningful long-run economic relation can be established. But this should not be taken to mean that, inherently, the price pair do not co-integrate. However, if at all any evidence of co-integration can be established, then, it can be established with the availability of

Table 9.34: Co-integration test: VAR of UK coffee prices, 1996.1-2000.8

H_0: rank=p	λ_{trace}	95%	$\lambda_{\max}$	95%
p==0	12.44	15.4	10.81	14.1
p<=1	1.632	3.8	1.632	3.8

information about variables that are not only integrated of the same order as the price series themselves but also are independently related to each of the price pair.

Summary

The foregoing analysis of the time series properties of the selected price pairs brings out two major characteristics. The first major characteristic is that all price pairs are non-stationary in the levels and stationary in their first differences. The second major important characteristic that has been brought out is that, of the 11 selected price pairs, in only 5 pairs, namely, potato, fresh fruits, milk pork and oil do we find co-integration on the basis of information provided by the price pairs alone. For the remaining 6 pairs, namely, sugar, coffee, eggs, beef, lamb and chicken, we find no co-integration given the price information at hand. For the latter category of price pairs, the explanation for the absence of co-integration might be that either the price pairs do not co-integrate at all, or if they do, they do with the inclusion in the VAR of several other variables which not only relate independently to each of the price series in the pair, but also are of the same degree of integration as the price series themselves.

As might be recalled, the theoretical price transmission models predict that, given only information provided by a pair of prices in a vertical market, co-integration arises as a special case rather than in general. Apart from the assumptions of perfectly competitive markets and constant returns to scale, these models predict that it arises under the assumption of an industry whereby the cost share of the farm input is unity. Given these restrictive assumptions, it follows that co-integration arises when the average price spread remains constant over time[8]. This being the case, it might be of interest to know whether

[8]Recalling from chapter 2, for a retail shock, the price spread in a perfectly competitive industry

the price pairs for which we have found co-integration based on the price information at hand have been characterized by an average constant spread over the sample period.

Evaluating whether the mean of the spread has remained constant over time is tantamount to evaluating whether the spread has been stationary in the levels. In the following therefore we apply the ADF unit-root test to the retail to producer price spread corresponding to each of the 11 price pairs. We then see whether the null of non-stationarity for the spread in levels can be rejected for the 5 price pairs for which we have found co-integration using the FIML procedure and cannot be rejected for the remaining 6 price pairs for which we have not found co-integration using the same procedure. The regression used to test for stationarity includes unrestricted constant and seasonals but not a trend term. The exclusion of the trend term from the regression is done with the view to controlling for the effects of non-price information.

Table 9.35 summarizes the ADF unit-root test results. As the results clearly show, at reasonable significance levels, the null of a unit-root (non-stationarity) in the price spread can be rejected for fresh fruits, for potato, for milk and for oil while it cannot be rejected for the remaining 7 price pairs. This suggests that, on counts of the ADF unit-root test, it is only for these price pairs that we can establish co-integration given information provided by the pairs alone.

Evidently, for 4 price pairs, i.e., for fresh fruits, potato, milk and oil we find co-integration both on counts of the FIML procedure and on counts of the ADF unit-root test. It is quite striking that fresh fruits and potatoes are products which are sold in supermarkets as they appear in their raw form. Therefore it is reasonable to expect the cost of processing for these products to be minimal, and, consequently, the cost share of the farm input in total industry cost to be very high.

However, we find one anomalous result. This relates to the pork price pair. Whereas,

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operating with constant returns to scale is given by:

$dP_x^* - dP_a^* |_{dN} = \frac{\eta_N S_b (e_a - e_b)}{D}$, which, for $S_b = 0$, equals zero, implying a constant spread. On the other hand, for a primary input shock, the price spread, given these assumptions is given by:

$dP_x^* - dP_a^* |_{dW} = -\frac{e_W e_a e_b S_b}{D}$, which, again for $S_b = 0$, equals zero.

Table 9.35: ADF unit-root test on the price spread, UK food and oil prices

Price spread	constant and seasonals
milk	-3.2970 (1)*
fresh fruits	-5.2218** (0)
sugar	-1.5164 (0)
potato	-5.2019** (0)
eggs	0.11514 (0)
coffee	-0.63873 (0)
beef	-1.1577 (12)
pork	-2.7340 (1)
lamb	-0.58906 (7)
chicken	-0.82964 (10)
oil	-3.3071** (0)

on counts of the FIML procedure, we find co-integration for this pair, on counts of the ADF unit-root test, we do not find co-integration.

In general, from the above analysis, it appears that for 10 price pairs out of 11, i.e., with the exception of the pork price pairs, the ADF and Johansen co-integration test results seem to reinforce each other to support the inferences made by our theory regarding a co-integrating relation between a price pair. However, for the pork price pair, the Johansen and ADF co-integration test results are at variance suggesting that, for this product, the validity of our *a priori* inferences cannot be evaluated.

9.5.3 Cointegration test in the presence of shocks

As might be recalled, in the preceding we have established that on the basis of information related to the price pair alone, one is not able to establish a cointegrating relationship between the price pairs for UK beef, lamb, chicken, eggs, coffee, sugar and pork. Given that the theoretical models of price transmission point to the importance of shocks, this might be more a sign of misspecification of the cointegration equation than the lack of cointegration between the pairs as such. As our review of the literature has shown, changes in prices in different sectors of the vertical market are spurred by a combination of sudden shocks which strike these sectors. Intuitively, therefore, the lack of cointegration between the price pairs for the above products could possibly have resulted from the ommission of these shocks from the cointegration regression. To see if this is indeed the case, we re-run, in keeping with the suggestion of economic theory, the cointegration regression for each product allowing for sector shocks which originate in the retail, supply and marketing sectors. Prior to proceeding with this, however, we briefly discuss the exogenous shocks that we have chosen as proxy for each product. This is a task we turn to next.

The retail (demand) shock

For the meat products, the demand shock is proxied by the natural logarithm of cumulative UK monthly counts of meat scares (LnM_scare) spanning over the period, 1985.1-2003.12. These series are obtained from Euro PA Associates and represent the number of articles in the press (Times, Sunday Times, Guardian, Observer) relating to meat scares. Prior to Nov 96 these represent BSE related articles even though a small number of abattoir hygiene articles occur in the pre-1990 period. After Nov 1996, the index includes articles relating to e-coli, abattoir hygiene etc. As Lloyd et al.. (2003) have pointed out, the choice of this index as a proxy for a demand-side shock is justified by consumers' over-reaction to potential health risks associated with commercial food in general and meat-based food in particular.

For all non-meat product prices, the demand shock is proxied by the UK monthly food retail price index (FRPI) spanning the period, 1987.1 -2003.12 (1987=100). The index is sourced from the ONS Monthly Digest of Statistics. Our choice of this index to proxy for a demand-side shock for all other products is based on our intuition that exogenous factors such as a change in income and population size, few among others, put pressure on the general level of food prices by affecting the level of demand for food products.

Figures 9.23 and 9.24 plot the natural logarithm of monthly counts of meat scares and the monthly food retail price indices respectively.

Figure 9-23: Natural logarithm of cumulative monthly counts of meat scares, 1985.1-2003.12

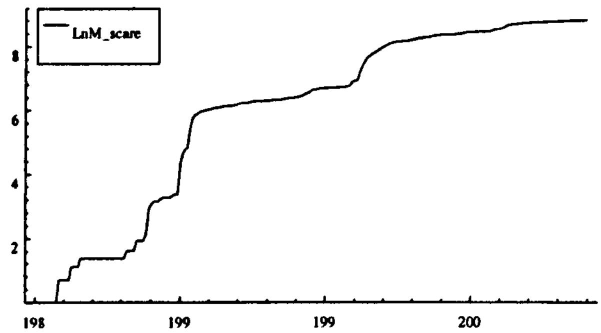


Figure 9-24: UK monthly Food Retail Price Index (FRPI), 1987.1- 2003.12

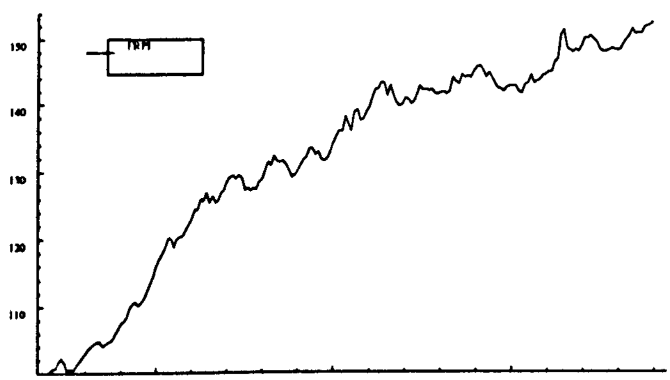
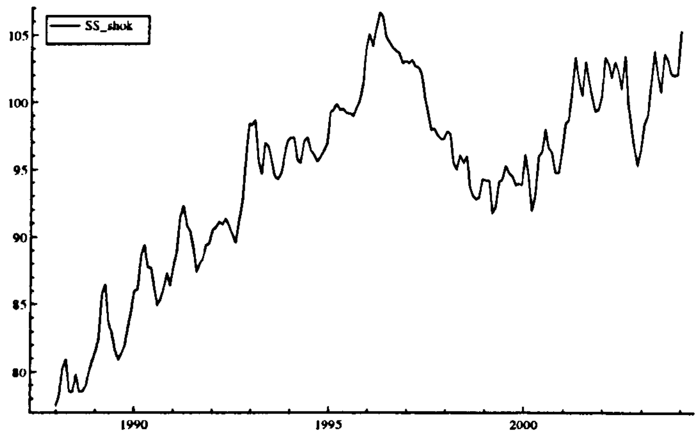


Figure 9-25: UK monthly index of the purchase prices of the means of agricultural production, 1989.1 - 2003.12

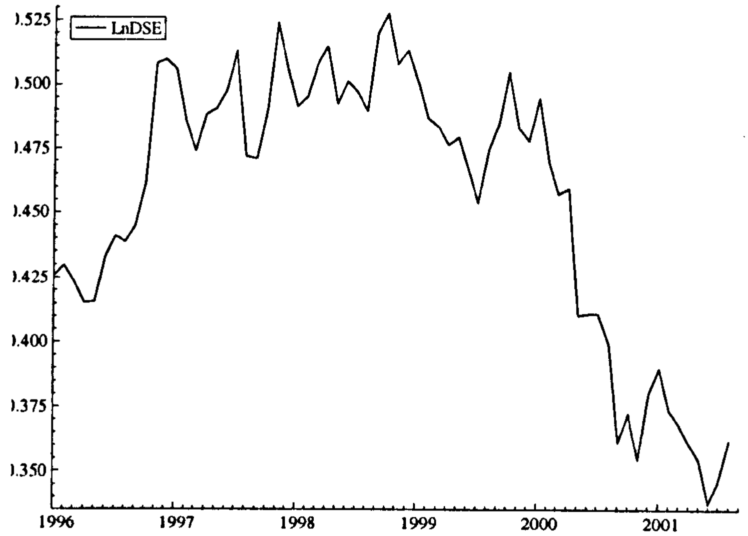


The supply shock

With respect to all agricultural products (except for coffee), the supply shock (SS_shok) is proxied by the UK monthly index of the purchase prices of the means of agricultural production as correspond to the category "Goods and services currently consumed". Spanning over the period 1989.1 - 2003.12, they are obtained from the DEFRA website. The intuition for our choice of this index as a proxy for supply-side shock is based on the observation that, for most agricultural products that are produced domestically, input costs (e.g., fertilizer, chemicals, etc.) make up a substantial proportion of their farm-gate prices. Therefore we expect any sudden change in the level of an index which measures input costs to feed through to changes in the farm gate prices of these products. Figure 9.25 presents a plot of the series over the reference period.

For coffee, the supply shock is proxied by the natural log of the monthly UK Stirling-US dollar exchange rate (abbreviated hereafter LnDSE). This series is obtained from the ONS and spans the period 1993.1-2003.12. The reason we use the Stirling-dollar exchange rate as a supply shock for this product in place of the monthly index of the purchase prices of the means of agricultural production, as we did for the other non-meat

Figure 9-26: Log of monthly Stirling-US dollar exchange rate, 1993.1-2003.12



products, is because green coffee beans are imported rather than produced domestically. This means that green coffee bean price is more likely to be prone to fluctuations in the Stirling-dollar exchange rate than to fluctuations in the cost of the means of agricultural production in the UK. Figure 9.26 plots the series over the reference period

The marketing shock

For all products, the marketing shock (M_shok) is proxied by the seasonally adjusted monthly unit wage cost index for UK manufacturing (2000=100) as sourced from the ONS. As pointed out earlier, the cost of marketing input is an amalgam of several costs of processing raw agricultural inputs for many of which publicly available information is scant. But, without doubt, changes in the general level of unit wage costs in the manufacturing industry affect directly the industry processing costs which in turn affect the level of retail prices. Figure 9.27 plots the secular trend of these series spanning the period, 1987.1 - 2003.12.

As eyeballing of the plots in Figures 9.23-9.27 suggests, except for the supply shocks,

Figure 9-27: Seasonally adjusted monthly unit wage cost index for UK manufacturing (2000=100), 1987.1- 2003.12

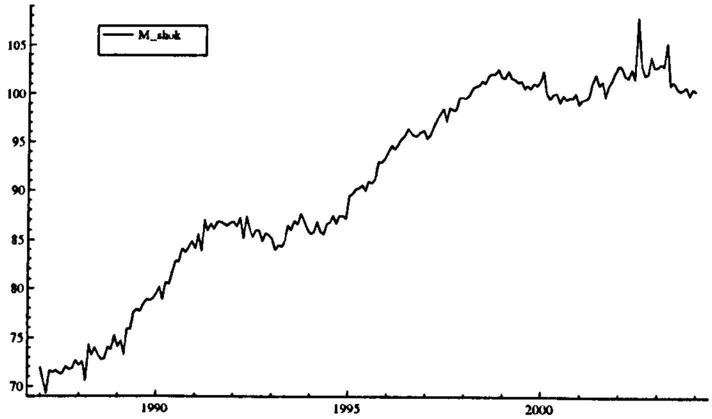


Table 9.36: ADF unit-root test: retail, supply and marketing shocks for UK agricultural products, various years

Variable	Level	lag	First-difference	lag	Order of integration
Meat scares	-1.0678	1	-10.482**	0	I(1)
FRPI	-2.1478	0	-12.888**	0	I(1)
SS_shok	-2.0681	2	-10.360**	1	I(1)
M_shok	-0.9413	1	-22.160**	0	I(1)
DSE	-1.914	0	-9.104**	0	I(1)

the demand and marketing shocks seem to show a persistent upward trend. This persistent trend is obviously a rough indication that, as they stand now, the series are non-stationary. To see if this is the case, we subject these shocks to a formal ADF unit-root test. Table 9.36 presents the test results.

As the results clearly show, whereas the null of a unit root in the levels is not rejected, the hypothesis of a unit-root in first-differences is rejected at the 1% significance level as denoted by the double asterisk. This points to all shocks being non-stationary I(1) in levels and stationary I(0) in first-differences. This suggests that re-running the cointegration regressions for the above product price pairs, for which we have not established cointegration on price information alone, allowing for these shocks is admissible as all these product pairs are also non-stationary I(1).

In the literature, there are two approaches regarding the conduct of a cointegration test allowing for I(1) random variables. The first is one advocated by Johansen (1995) which requires that all I(1) random variables enter the cointegrating space as potentially endogenous. This means, any cointegrating vectors present appear in the vector error correction model for each of the variables and the error terms for each such variable are correlated with those in the rest of the system. The second approach is that advocated by Pesaran et al.. (2000) and regards a subset of random variables which are integrated of order one I(1) as structurally exogenous (or as forcing variables). This means that any cointegrating vectors present do not appear in the sub-system vector error correction model (VECM) for these exogenous variables and the error terms in this sub-system are uncorrelated with those in the rest of the system. While the former approach gives the analyst no room for subjective judgement regarding the treatment of I(1) random variables, the second approach gives the analyst such a room for subjective judgement. In other words, in the former approach exogeneity of the variables has to be tested for, whereas in the latter it is rather assumed.

Even though intuitively, considering certain I(1) variables, such as the ones we have just described above, might be appealing, on consideration of the lack of adequate information regarding the nature of their relation with the individual product prices, treatment of these variables as potentially endogenous is more appealing. In re-running the cointegration regression for each price pair allowing for shocks, therefore, we adopt the approach advocated by Johansen. Accordingly, we implement his Maximum Likelihood cointegration test whereby we enter all the I(1) price variables and shocks into the VAR as potentially endogenous allowing for unrestricted constant, seasonal dummies but not for a time trend. Our exclusion of the trend term from the VAR is premised on the intuition that the shocks will already have taken care of its role.

Table 9.37: Co-integration test: VAR of UK beef prices inclusive of retail, supply and marketing shocks 1990.1-2000.12

rank	λ_{trace}	$\lambda_{\max}$
p==0	70.28*	30.88
p<=1	39.4	23.27
p<=2	16.13	8.237
p<=3	7.896	4.845
p<=4	3.05	3.05

VAR of UK beef prices inclusive of retail, supply and marketing shocks

To test whether the UK price pair cointegrate in the presence of shocks, we first choose a common lag length for the VAR using information criteria. We find that all information criteria choose a common lag of 2 for which the vector errors are white noise. Based on this common lag, we then undertake a cointegration test. Table 9.37 summarizes the cointegration test results.

As Table 9.37 makes evident, the λ_{trace} statistic rejects the null hypothesis of no cointegration in favor of at least a single cointegrating vector at the 5% significance. The $\lambda_{\max}$ statistic, on the other hand, fails to reject the null of no cointegration in favor of a single cointegrating vector. Evidently, however, both statistics do not reject the null of a single cointegrating vector in favor of the alternative of more than one such cointegrating vector. Despite the inconsistency of the $\lambda_{\max}$, we take this result as suggesting that there is a single cointegrating vector in the VAR of the UK beef prices and the three shocks. Indeed, a visual inspection of the plot of the cointegration vector, as shown in Figure 9.28 seems to confirm this[9].

This means that whereas, previously, in the absence of shocks in the cointegration regression we could not identify a cointegrating relation between the price pair, now, in their presence we can identify a unique cointegrating relation with a meaningful economic interpretation.

[9]Forcing the constant term to enter the cointegrating space as restricted contributes to the identification of cointegration even on counts of the $\lambda_{\max}$ statsitc. But results are not reported here.

Figure 9-28: Time series of cointegration vector, corrected for short-run dynamics, VAR of UK beef prices inclusive of retail, supply and marketing shocks, 1990.1-2000.12.

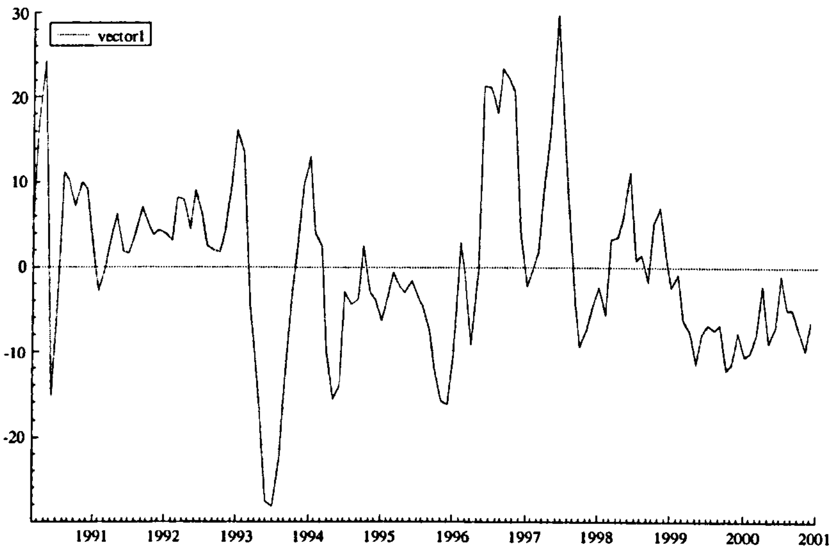


Table 9.38: Co-integration test: VAR of UK lamb prices inclusive of retail, supply and marketing shocks 1990.1-2000.12

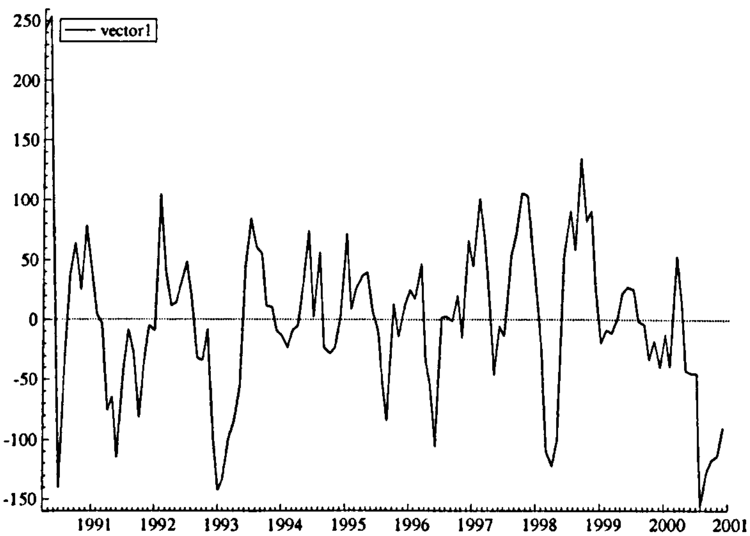
rank	λ_{trace}(prob)	$\lambda_{\max}$(prob)
p==0	109.4**	63.28**
p<=1	46.17	22
p<=2	24.17	14.69
p<=3	9.478	5.682
p<=4	3.796	3.796

VAR of UK lamb prices inclusive of retail, supply and marketing shocks

Prior to testing whether the UK lamb price pair cointegrate in the presence of the three exogenous shocks, we first choose a common lag length for the VAR. Using information criteria and applying a test for serial correlation of the vector errors, we choose a common lag of 3. On this basis, we test if we can detect any cointegrating relationship between the price pair. Table 9.38 presents the test results.

As the test results show, both the λ_{trace} and $\lambda_{\max}$ statistics reject the null of no cointegration in favor of at least a single cointegration at 1% significance. Indeed, as

Figure 9-29: Time series of cointegration vector, corrected for short-run dynamics, VAR of UK lamb prices inclusive of retail, supply and marketing shocks, 1990.1-2000.12.



both statistics show, the null of a single cointegrating vector cannot be rejected in favor of at least two cointegrating vectors Thus, clearly, the results suggest that there is a single cointegrating vector in the VAR of UK lamb prices and three shocks. As a cursory look at Figure 9.29 reveals, this seems to be confirmed by the plot of the vector errors which fluctuate around a zero mean. This means that whereas, previously, in the absence of shocks in the cointegration regression we could not identify a cointegrating relation between the lamb price pair, now, in their presence we can identify a unique cointegrating relation.

VAR of UK chicken prices inclusive of retail, supply and marketing shocks

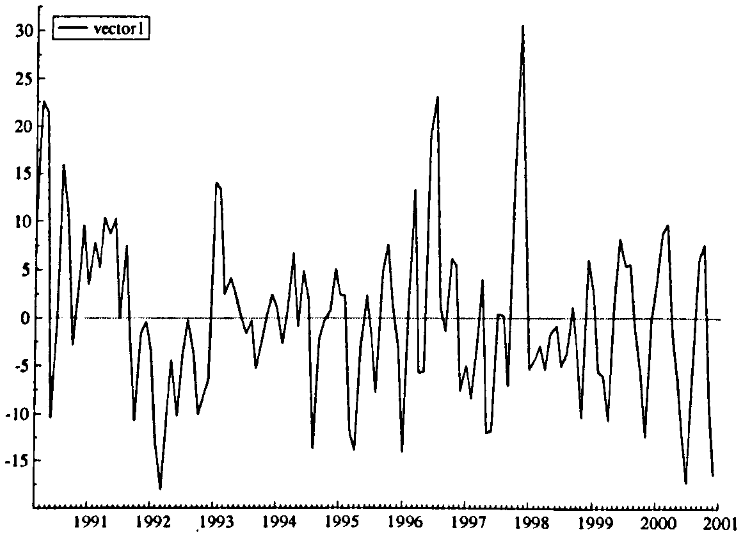
The test for cointegration between the UK chicken price pair in the presence of the three shocks proceeds on the basis of a common lag length of 2 which we have chosen using information criteria and allowing for white noise vector errors. The test results are summarized in Table 9.39.

As the results show, both the λ_{trace} and $\lambda_{\max}$ statistics reject the null of no cointe-

Table 9.39: Co-integration test: VAR of UK chicken prices inclusive of retail, supply and marketing shocks 1990.1-2000.12

rank	λ_{trace}(prob)	$\lambda_{\max}$(prob)
p==0	125.8**	69.33**
p<=1	56.47**	26.07
p<=2	30.4*	18.25
p<=3	12.15	8.587
p<=4	3.56	3.56

Figure 9-30: Time series of cointegration vector, corrected for short-run dynamics, VAR of UK chicken prices inclusive of retail, supply and marketing shocks, 1990.1-2000.12.



gration in favor of at least a single cointegrating vector at 1% significance. Indeed, as the λ_{trace} statistics indicates, the null of 3 cointegrating vectors does not seem to be rejected in favor of the alternative of 4 such vectors. However, the $\lambda_{\max}$ statistics fails to reject the null of a single cointegrating vector in favor of the alternative of two cointegrating vectors. This suggests that even though potentially, there are three cointegrating vectors, it is more likely that a single cointegrating vector is identified. In fact, a visual inspection of the cointegrating vectors points to the existence of a single cointegrating vector which has error terms that seem to be white noise. This is plotted in Figure 9.30.

Table 9.40: VAR of UK egg prices inclusive of retail, supply and marketing shocks, 1988.1-1998.12

rank	λ_{trace}(prob)	$\lambda_{\max}$(prob)
p==0	64.39[0.125]	28.19[0.211]
p<=1	36.2[0.391]	17.66[0.535]
p<=2	18.54[0.537]	11.53[0.605]
p<=3	7.01[0.583]	6.79[0.523]
p<=4	0.2197[0.639]	0.2197[0.639]

This means that whereas, previously, in the absence of shocks in the cointegration regression we could not identify a cointegrating relation between the chicken price pair, now, in their presence we do identify a unique cointegrating relation.

VAR of UK egg prices inclusive of retail, supply and marketing shocks

For this price pair, the test for cointegration in the presence of the three shocks is conducted assuming a common lag length of 2 which we have chosen using information criteria and allowing for white noise vector errors. Table 9.40 summarizes the test results.

As the results clearly indicate, on counts of both the λ_{trace} and $\lambda_{\max}$ statistics, the null of no cointegration cannot be rejected in favor of at least a single cointegration vector at 1% significance. This means that even in the presence of the three shocks, one cannot identify a unique cointegrating vector. This suggests that the UK egg price pair do not cointegrate inherently probably because the UK market for eggs is not integrated such that changes in producer price do not feed through to retail prices and *vice versa*. This result seems to be robust to the type of VAR specification.

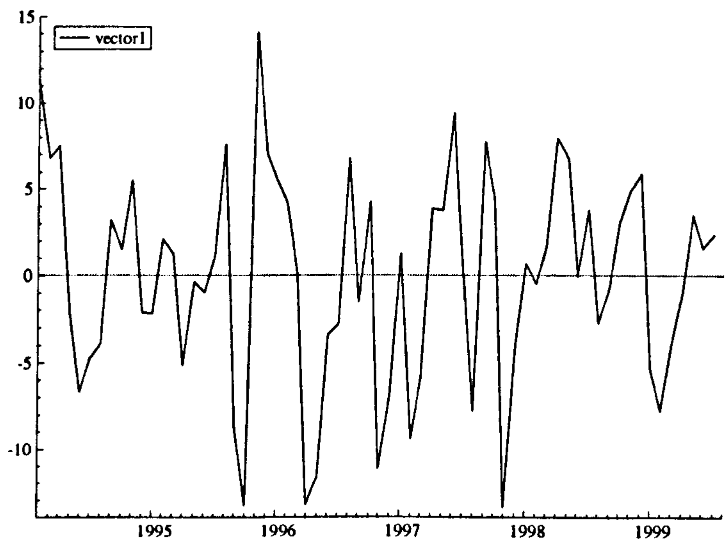
VAR of UK sugar prices inclusive of retail, supply and demand shocks

The test for cointegration between the UK sugar price pair in the presence of the three shocks is carried out assuming a common lag of 1 chosen using information criteria and allowing for vector errors that are white noise. Table 9.41 summarizes the test results.

Table 9.41: VAR of UK sugar prices inclusive of retail, supply and marketing shocks, 1994.1-1999.7

rank	λ_{trace}(prob)	$\lambda_{\max}$(prob)
p==0	86.13**	40.29**
p<=1	45.83	23.52
p<=2	22.31	14.02
p<=3	8.292	5.699
p<=4	2.593	2.593

Figure 9-31: Time series of cointegration vector, corrected for short-run dynamics, VAR of UK sugar prices inclusive of retail, supply and marketing shocks, 1994.1-1999.7.



The results clearly show that, on counts of both λ_{trace} and $\lambda_{\max}$ statistics, the null of no cointegration is rejected at 1% significance in favor of the alternative of cointegration. In fact, as both statistics clearly indicate, the null of a single vector cannot be rejected in favor of at least two cointegrating vectors. This suggests that, given this VAR specification, a single cointegrating vector can be uniquely identified. Figure 9.31 plots the residuals of the cointegrating vector which dance around a zero mean.

This means that whereas, previously, in the absence of shocks in the cointegration regression we could not identify a cointegrating relation between the sugar price pair,

Table 9.42: VAR of UK coffee prices inclusive of supply and marketing shocks, 1994.1-2001.8

rank	λ_{trace}(prob)	$\lambda_{\max}$(prob)
p==0	49.85 [0.030]*	33.12 [0.007]**
p<=1	16.72 [0.668]	11.07 [0.649]
p<=2	5.65 [0.738]	4.97 [0.745]
p<=3	0.67 [0.412]	0.67 [0.412]

now, in their presence we can identify a unique cointegrating relation.

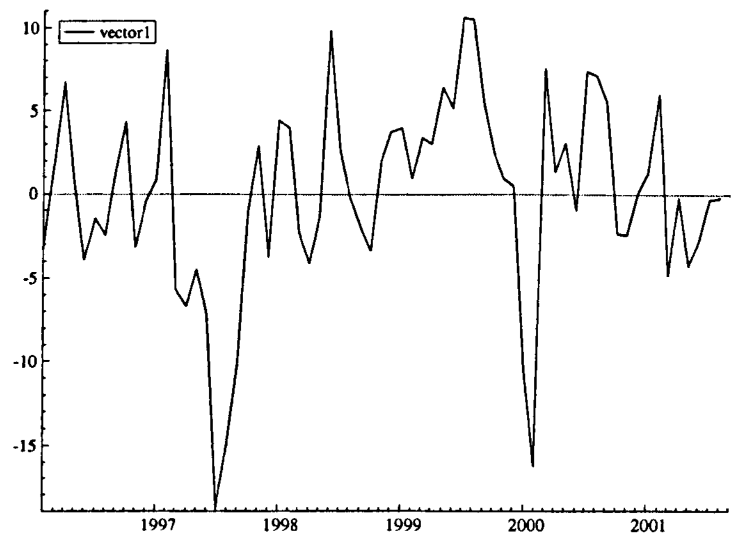
VAR of UK coffee prices inclusive of retail, supply and marketing shocks

A cointegration test for the VAR of UK coffee prices inclusive of the demand, supply and marketing shocks is undertaken assuming a common lag of 1 which is chosen using information criteria. Given this VAR specification, the test does not detect any cointegration. However, given a VAR devoid of the demand shock, the test yields a single cointegrating vector. Table 9.42 summarizes the test results for a VAR of UK coffee prices inclusive of the supply and marketing shocks.

As the results clearly show, with the given VAR specification, the null of no cointegration is rejected by both the λ_{trace} and $\lambda_{\max}$ statistics at the 5% and 1% significance levels respectively in favor of at least a single cointegration vector. In fact, the null of a single cointegrating vector cannot be rejected by both statistics in favor of more than one such cointegrating vector suggesting that there is a single cointegrating vector. Figure 9.32 plots the errors for the cointegration vector that has been uniquely identified. Except for the episodes in 1997.7 and 2000.2, the vector errors seem to be well behaved lending credence to the predictions of the test statistics.

This leads us to the conclusion that whereas in the absence of shocks in the regression we could not identify a cointegrating relation between the UK coffee price pair, now, in their presence we can identify such a cointegrating relation. This points to the fact that the UK coffee prices at the producer and retailer levels tend to co-move only in response to the supply and marketing shocks.

Figure 9-32: Time series of cointegration vector, corrected for short-run dynamics, VAR of UK coffee prices inclusive of supply and marketing shocks, 1994.1-2000.8.



In this sub-section, we have tested for cointegration for the product pairs, for which we could not find cointegration in 9.5.2, allowing for retail, supply and marketing shocks. The results suggest that for five product price pairs, i.e., beef, lamb, chicken, sugar and coffee price pairs, undertaking the test allowing for these shocks in the regression contributes to the identification of cointegration. On the other hand, for the egg price pair, undertaking the test allowing for these shocks does not contribute to the identification of cointegration suggesting that the market for eggs is not integrated.

9.6 Summary

In this chapter we set out to test the hypothesis that, given information provided by a price pair alone, a co-integrating relationship in a vertically related market arises as a very special case rather than in general, arising as it is, under highly restrictive assumptions; these being that all the vertical stages in the industry are perfectly competitive; that the industry operates with a constant returns to scale technology; and that the cost share of the raw input is unity. With the view to testing this hypothesis, we applied the Johansen maximum likelihood test for co-integration to 11 UK price pairs in the food and energy sectors. On the basis of this test, we found co-integration for 4 out of 11 price pairs; i.e., potato, fresh fruits, milk and oil. Except for oil, the processing cost for potatoes fresh fruits and milk is likely to be minimal as the raw input for these products seems to be the only input which goes into the production of the final product.

As the aforementioned hypothesis implies a constant average price spread for a pair, i.e., a stationary price spread, we also cross-checked the Johansen co-integration test results by testing for stationarity of the price spread that corresponds to each of the 11 price pairs. We did this by applying the ADF unit-root test to each of the 11 price spreads. We found that, except for results for the pork price pair, results for the remaining other price pairs are consistent with the Johansen co-integration test results. We find that the price spreads for potato, fresh fruits, milk and oil are stationary while those for the remaining other pairs are non-stationary.

We thus find that on counts of both the Johansen and ADF unit-root tests, co-integration is identified only for potato, fresh fruits, milk and oil. This result seems to support our theoretical prediction that, given information provided by a price alone, co-integration can be observed only for products for which the cost share of the raw input is unity, i.e., products for which the cost of processing is minimal. And, obviously, potatoes fresh fruits and milk are products which are sold in supermarkets as they appear in their raw form with minimum processing involved suggesting that the cost share of processing input for these products is minimal. It thus appears that on the basis of information provided by these price pairs alone, it is possible to establish a long-run economic relationship between the price series in the pairs.

For the remaining 6 price pairs[10], co-integration cannot be observed either because the price pair do not co-integrate at all (the egg price pair) or, if they do (beef, lamb,

[10]We do not categorise the pork price pair here because without the shocks the pair do cointegrate. We thus consider it as a borderline case.

chicken, sugar and coffee price pairs) they do with the inclusion of sector shocks that are not only of the same order of integration as the price series in the pair themselves but are independently related to each price series in the price pair, which is in keeping with the predictions of theory

The major implication of the above conclusion therefore appears to be that, given only information on a price pair, the test for co-integration applies to products for which the processing cost is minimal. For all other product categories, the test for co-integration has to proceed on the basis of not only information related to both the price series in the pair but also of information related to shocks, which originate in different sectors of the vertical market.

Chapter 10

Conclusion

10.1 Results

In this thesis we have made an attempt to review and evaluate the existing theoretical and empirical literatures relating to price transmission and identify the existing obvious research gaps that need filling in. To fill these research gaps we have then made our contribution to the existing literature by way of developing a theoretical model of price transmission in vertical markets assuming market power in both the farm and retail markets. We have gone further to establish a link between economic theory and co-integration.

The tasks we have accomplished in this thesis can be categorized into four. The first task which we have accomplished in chapter 2 of the thesis involved use of an intuitive (i.e., graphical) approach to explaining changes in the marketing margin, following retail demand and input supply shocks, assuming that all markets in a vertically-related industry are perfectly competitive, that inputs are combined in variable proportions, and that industry technology is characterized by constant returns to scale. We have illustrated that despite its simplicity this approach can make reasonable predictions about movements in the price spread and the degree of price transmission.

Two important conclusions that are drawn from this approach are: (1) that the signs and magnitudes of changes in the marketing margin depend on the source of the exogenous shock; and (2) that, in qualitative terms, the proportion in which inputs are combined is of secondary importance for the impact of exogenous shocks on changes in the marketing margin. As our review of the theoretical literature has shown, these conclusions are consistent with predictions that derive from a more rigorous approach which operates within the framework of multi-market equilibrium.

The second important task that we have accomplished in chapters 3, 4 and 7 of the thesis involved an exposition of the rigors involved in modelling price transmission both theoretically and empirically. This task has not only given us a deeper insight into the techniques employed by price transmission models but it has also served us a purpose as a pointer to potential research tasks that can be accomplished in the field. One such task which was pointed to as a task worth pursuing is modelling the impact of oligopsony power in the farm sector on the degree of price transmission and evaluating its interaction with oligopoly power. And this is the third task which we have accomplished in chapter 5 of our thesis.

The major conclusion drawn from this modelling exercise is that, in the presence of oligopsony power in the farm market and oligopoly power in the retail sector, the outcome for the degree of price transmission, relative to that in the perfectly competitive benchmark, cannot be determined *a priori* without knowledge of the functional forms for farm supply and retail demand. This is because the degree of price transmission predicted when oligopsony and oligopoly power interact can be identical to or different from that predicted when the market is perfectly competitive. But this should not be taken to mean that by themselves oligopoly and oligopsony power do not impinge negatively on social welfare either in isolation or in juxtaposition. It has to be noted that, even when they are behaving as if they were perfectly competitive, the welfare loss that producers often suffer as a result of their operation cannot be overemphasized. This is particularly relevant in situations where a highly concentrated industry which exercises market power both in its relation with consumers and with producers imposes on producers what are commonly known as vertical restraints, practices that have negative social welfare consequences.

The third task which we set ourselves in chapter 6 involved simulating the effects of market power on the degree of price transmission controlling for its interaction with other determining parameters. The major conclusions that are drawn from this simulation exercise can be summarized as follows. Firstly, for any given degree and form of market power, increasing cost share of the farm input and the degree of substitutability between inputs increases, *ceteris paribus,* the degree of price transmission. Secondly, for a given degree of market power, the impacts, on the degree of price transmission, of both the retail demand and marketing supply elasticities are ambiguous.

The fourth task which we have set ourselves in the eighth and nine chapters involved making inferences about a co-integrating relation between the prices of the farm input and the retail product based on the predictions of economic theory presented in chapter eight and given information provided by the price pair alone. The major inference that we have drawn from this exercise is that the price transmission coefficient implied by different models, i.e., perfect competition, oligopoly, and (or) oligopsony power will not be unique except in very special cases, as it depends on the source of the exogenous shock. In other words, it is unidentified in the co-integration relation in all cases except where (1) markets are perfectly competitive; (2) market power operates with a constant mark-up and mark-down; and (3) the cost share of the farm input is unity. Consequently, under the given assumptions, farm input and retail prices will never co-integrate in general. unless the empirical test for cointegration allows for industry-level shocks as suggested by theory.

In chapter 9, we have attempted to evaluate whether this inference is borne out in practice. Results for a cointegration test on a time series of price pairs for the UK suggest that, given only price information, a long run cointegration relation is identified only for four price pairs out of eleven. Of the pairs for which a cointegrating relation is identified, two relate to products for which the cost share of the farm input is likely to be high. For the remaining other price pairs, except for one, cointegration is identified if the price equation on which the empirical test is based allows for industry-wide shocks.

10.2 Limitations

The thesis has set out to model the impact of market power on the degree of price transmission in a vertically-related industry assuming that market power reflects only as a distortion of a perfectly competitive pricing behavior where the relationship among stages of the industry is non-contractual. As several studies have shown, however, market power can reveal itself in practices that have nothing to do with prices. These practices thrive in a market environment which is characterized by a contractual relation. As our literature survey has made evident, vertical restraints are among the most common forms of market power that thrive in such a contractual environment. If left unchecked these practices are believed to harm the interest of the public. Indeed, of the 52 practices that were identified by the UK Competition Commission as characterizing the vertical relation between retailers' and suppliers, 27 stood to operate against the public interest.

Given that market power reveals itself in such harmful practices, then it follows that the approach of modelling market power's impact on the degree of price transmission solely on the basis of price information is bound to be limited in its usefulness. To appreciate this point, say a particular industry faces constant elasticity retail demand and farm supply functions. Under the given assumption, our model predicts that the degree of price transmission for this industry is identical to that which one would obtain in a perfectly competitive industry. This is because the industry does not vary its margin in response to an exogenous shock suggesting that it behaves as if it were perfectly competitive. In such circumstances, one would expect the industry to be harmless to the public interest. Assume, now that despite the functional forms of demand and farm supply which the industry faces, the supplier-retailer relation is characterized by a contractual relation whereby vertical restraints are common. In this particular instance, the industry might be judged as operating against the public interest where on grounds of its pricing behavior it is not.

The morale of this example is that conclusions drawn about market power's impact on the degree of price transmission from a model such as we have developed in our thesis need not be taken as final. They should rather be reinforced with analysis of market power practices which such a model is not inherently capable of capturing.

A general limitation which our thesis suffers from concerns the aggregation procedure. Through out the thesis we have aggregated by market shares as others have done in the literature. But this implies that firms have different market shares, the obvious question being why? In this setting, some firms are likely to be more efficient than others, due to differences in costs. This is acceptable in most cases but in the context of price transmission, the aggregate effect will depend on how firms are affected by the supply shift which will also be contingent in their cost structure. So, for example, suppose firm A uses a high proportion of farm inputs and is the market leader compared to firm B. If there is a shift in the farm supply function, this will affect firm A more than firm B so that market shares will also change, and hence likely have an effect on price transmission. Even though the way to get around this problem is to assume a homogeneous oligopoly i.e. to aggregate by the number of firms, the implication, for price transmission, of a leader-follower type relationship among firms in an industry still remains unclear.

Issues of market power and the aggregation procedure aside, our model of price transmission is a two-stage model and as such does not treat the processing sector as a separate stage in the vertical chain of the industry. It rather treats it as part of the retail sector. The implication is that our model is not able to assess the impact of market power's presence at the processing stage. This has a strong implication for the nature of inference regarding the existence of a cointegrating relation between the prices of the farm input and the retail product that we have deduced from the model. As might be recalled, given only information relating to the price pair, our model predicts that except under highly restrictive assumptions, a cointegrating relation between the prices does not arise in general. In the absence of a model which treats the processing sector as a separate entity, our thesis is limited in its ability to answer the question whether the rarity of a cointegration relation between the price pair is due to the omission of marketing costs from the cointegration regression.

10.3 Directions for future research

As the limitations of the thesis suggest, our work in the thesis is not by any means complete. However, the limitations are also pointers to the potential areas of research that can be undertaken in the future.

One potential area of research that can be undertaken in the future is to model price transmission allowing for a contractual relation between the supply and retail stages of the vertical market. It might be of interest to know whether modelling along this line produces price transmission outcomes that are any different from those which obtain when the supplier-retailer relation is modelled based only on prices.

A second fruitful avenue of research that can be pursued in the future involves modeling price transmission in the context of a Stackelberg competition whereby firms are categorized according to whether they are leaders or followers. It will be interesting to see whether this has implications for market shares which are used for aggregating over firms.

A third potential area of further research is to model the vertical market as involving more than two stages such that the processing sector is modelled as a separate entity rather than as part of the retail sector. Of particular interest might be to assess how oligopoly power in the processing and retail stages and oligopsony power in the purchase of the farm input interact to impact on the degree of price transmission.

A fourth area of further research is to develop a structural model to see whether, given only information by a price pair alone, as inferred from our model, a cointegrating relation between the prices of the farm input and the retail product, arises only for an industry for which technology is characterized by constant returns to scale, input and output markets are perfectly competitive and the cost share of the farm input is unity.

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