Asymmetric Price Transmission: A Survey

Jochen Meyer and Stephan von Cramon-Taubadel[1]

Department of Agricultural Economics, Göttingen, Germany

E-Mail: mail@jochenmeyer.de and scramon@gwdg.de

Abstract:

Asymmetric price transmission has been the subject of considerable attention in agricultural economics. Asymmetric price transmission is not only important because it may point to gaps in economic theory, but also because its presence is often considered for policy purposes to be evidence of market failure.

In this paper we survey the literature on asymmetric price transmission. A wide variety of often conflicting theories of and empirical tests for asymmetry co-exist in this literature. We classify the different types and causes of asymmetric price transmission and describe the econometric techniques used to quantify it. We also briefly review the results of empirical applications. Outstanding methodological problems and suggestions for future research are discussed. Our main conclusion is that the existing literature is far from being unified or conclusive, and that it has often been largely method-driven, with little attention devoted to theoretical underpinnings and the plausible interpretation of results. Hence, much interesting theoretical and empirical work remains to be done.

Keywords: Price transmission, asymmetry, market integration

[1] Jochen Meyer is Ph.D. student and Prof. Dr. Stephan von Cramon-Taubadel is Professor at the Department of Agricultural Economics, Georg-August University of Göttingen, Germany

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1. Introduction

Price theory plays a key role in neo-classical economics. Within this paradigm, flexible prices are responsible for efficient resource allocation, and price transmission integrates markets vertically and horizontally. Economists who study market efficiency are therefore concerned about price transmission processes. Of special interest are those processes that are referred to as asymmetric, i.e. for which transmission differs according to whether prices are increasing or decreasing. In an extensive study of 282 products resp. product categories, including 120 agricultural and food products, Peltzman (2000) finds asymmetric price transmission to be the rule rather than the exception.[2] This leads him to the strong conclusion that the standard economic theory of markets is wrong, because it does not predict or explain the prevalence of asymmetric price adjustment (Peltzman 2000, pp. 493). On the other hand, authors such as Gauthier & Zapata (2001) and v. Cramon-Taubadel & Meyer (2000) recommend caution due to methodological problems associated with empirical tests for asymmetry. They point out that standard tests (such as the test applied by Peltzman) can lead to excessive rejection of the null hypothesis of symmetry under common conditions.

The possible existence – and perhaps prevalence – of asymmetric price transmission (APT) is of considerable importance. First, because, as Peltzman (2000) points out, APT may point to gaps in economic theory. After all, if APT is the rule, then it is difficult to be satisfied with a body of economic theory that treats it as an exception. Second, because APT could have important welfare and, hence, policy implications. APT implies that some group is not benefiting from a price reduction (buyers) or increase (sellers) that would, under conditions of symmetry, have taken place sooner and/or have been of a greater magnitude than observed. Hence, APT implies a different distribution of welfare than would obtain under symmetry, because it alters the timing and/or the size of the welfare changes that are associated with price changes. Furthermore, if APT is, as is commonly hypothesised, a manifestation of market failure (for example the exercise of market power by monopolistic middlemen), then it will also signal, in addition to redistribution, the associated net welfare losses.

[2] Peltzman uses three different samples. The first two samples consist of monthly price indices for producer and consumer goods at the national level in the US. The third sample includes individual item prices of packaged goods from one supermarket chain (Peltzman 2000 pp. 469f.). Hence, Peltzman's analysis includes, but is not restricted to food products.

Both redistribution and net welfare loss provide a *prima facie* case for policy intervention. In recent years, public institutions in the EU (for example, the EU Commission and DEFRA in the UK) have contracted studies to look into possible APT on agri-food markets, motivated at least in part by concerns that consumers may not benefit as much as expected from liberal agricultural policy reforms if processors and retailers do not pass on the associated price reductions.

Given this interest in APT and its possible ramifications, it is imperative that economists think carefully about the theories they use to explain APT. In addition, the tests, which are utilised to measure APT, should be reliable and precise. Equally important, especially from a policy perspective, tests should ideally enable us not only to determine whether APT is present in the statistical sense, but also whether it is economically relevant and which of the many possible causes underlies it. To date, much of the substantial literature on APT – the lion's share of which has been produced by agricultural economists – has concentrated on statistical issues, while neglecting economic relevance and underlying causes. A wide variety of often conflicting theories of and empirical tests for APT co-exist in the literature. While there has been progress made in the sense of statistical and analytical sophistication, it is by no means the case that newer methods have completely supplanted older ones. Existing tests describe the nature of price adjustment but most are not discerning in the sense that they make it possible to differentiate between competing underlying causes on the basis of empirical results. Furthermore, authors rarely attempt to translate their statistical results into practical economic terms, for example by calculating just how much processors have actually benefited from what appears to be a failure to pass on input price reductions as quickly as they pass on input price increases. Therefore a considerable need for further research remains, and it would appear premature to draw far-reaching conclusions for theory and policy on the basis of work to date.

In this paper we survey the literature on APT and attempt to add value by organising often discordant studies into a consistent framework, by evaluating their strengths and weaknesses, and by seeking to identify promising methods and approaches for future research. After classifying the different types of APT in section 2, in section 3 we describe the explanations for APT that have been proposed in the literature. In section 4 we focus on the econometric techniques used to test for APT. After a review of empirical applications and a discussion of outstanding methodological problems in section 5, we conclude with suggestions for future research in section 6.

2. Types of asymmetry

Asymmetry in the context of price transmission[3] can be classified according to three criteria. The first criterion refers to whether it is the speed or the magnitude of price transmission that is asymmetric. The distinction between these two types of APT is depicted in diagram 1, where a price (p^{out}) is assumed to depend on another price (p^{in}) that either increases or decreases at a specific point in time.

(Diagram 1 about here)

In diagram 1a, the magnitude of the response to a change in p^{in} depends on the direction of this change; in diagram 1b it is the speed of the response that depends. Clearly, combinations of these two fundamental types of asymmetry are conceiveable. In diagram 1c, price transmission is asymmetric with respect to both speed and magnitude because an increase in p^{in} takes two periods (t_1 and t_2) to be fully transmitted to p^{out}, while a decrease in p^{in} requires three periods (t_1, t_2 and t_3) and is not fully transmitted.

The welfare effects associated with these two types of APT are depicted schematically as shaded areas in diagram 1. Interpretation is eased by assuming a constant, unchanging volume of transactions over time, i.e. completely price inelastic demand for the output good. Asymmetry with respect to the speed of price transmission leads to a temporary transfer of welfare – in this case from buyers of the output good to sellers – the size of which depends on the length of the time interval between t_1 and t_{1+n} as well as the price changes and transaction volumes involved (diagram 1b). Asymmetry with respect to the magnitude of price transmission leads to a permanent transfer of welfare (diagram 1a), the size of which depends solely on the price changes and transaction volumes involved. Diagram 1c shows that asymmetry with respect to speed and magnitude leads to a combination of temporary and permanent welfare transfers. Which type of welfare transfer is of greater concern cannot be determined *a priori*; depending on the numbers involved, a large temporary transfer could outweigh the present value of smaller permanent transfer. If the APT in question results from the exercise of market power (see section 3 below), then asymmetry with respect to magnitude, perhaps accumulated over a number of episodes, could be used as a way of

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[3] Asymmetry is closely related to the issue of price rigidity or 'stickiness' (Means, 1935). Blinder et al. (1998) offer an extensive overview of different explanations for rigidity. Note as well that asymmetry is not only of interest with regard to price transmission. Traill et al. (1978) and Young (1980) study asymmetric supply responses, and Farrel (1952) studies asymmetric demand functions while vande Kamp & Kaiser (1999) and Granger & Teräsvirta (1993) consider asymmetric advertising-demand response functions and business cycles, respectively.

surreptitiously imposing or 'easing in' oligopoly or monopoly pricing. In this case, as noted above, APT will imply not only welfare transfers but also net welfare losses.[4]

A second criterion, following a convention employed by Peltzman, allows APT to be classified as either positive or negative. If p^{out} reacts more fully or rapidly to an increase in p^{in} than to a decrease, the asymmetry is termed 'positive' (diagram 2a). Correspondingly, 'negative' asymmetry denotes a situation in which p^{out} reacts more fully or rapidly to a decrease in p^{in} than to an increase (diagram 2b). This convention can be misleading if interpreted in a normative fashion; if p^{in} and p^{out} represent farm gate and retail prices for a commodity, respectively, 'negative' asymmetry is 'good' for the consumer, while 'positive' asymmetry is 'bad' in the sense that the former (latter) is associated with welfare gains (losses). At the same time, however, this highlights the importance of the distinction between positive and negative asymmetry, as it determines the direction of welfare transfers due to APT.

(Diagram 2 about here)

Note that price transmission does not have to flow from input to output prices as has been assumed so far. It is also possible that changes in output prices, caused for example by demand shifts, be transmitted to input prices. In this context it still makes sense to distinguish between the speed and magnitude of APT.[5] However, the distinction between positive and negative APT – defined above with respect to how p^{out} reacts to a change in p^{in} – must be generalised. We propose that positive APT be defined as a set of reactions according to which any price movement that squeezes the margin (i.e. an increase in p^{in} or a fall in p^{out}) is transmitted more rapidly and/or completely (to p^{out} or p^{in}, respectively) than the equivalent movement that stretches the margin. Conversely, APT is negative when price movements that stretch the margin are transmitted more rapidly and/or completely than movements that squeeze it.

The third criterion for classifying APT refers to whether it affects vertical or spatial price transmission. As an example of vertical APT, farmers and consumers often complain that increases in farm prices are more fully and rapidly transmitted to the wholesale and retail levels than equivalent decreases in farm prices. The discussion in this paper so far has dealt

[4] Note that this requires that we abandon the assumption of a constant, unchanging transaction volume (i.e. perfectly inelastic demand).

[5] This could be done using diagrams analogous to diagrams 1a, b and c. We omit these in the interest of brevity.

with APT exclusively in a vertical context. An example of spatial APT would be a rise in the US export price for wheat causing a more pronounced reaction in the Canadian export price than a corresponding reduction of the same magnitude. Spatial APT, like vertical APT, can be classified according to speed and magnitude, and according to whether it is positive or negative.

3. What causes asymmetric price transmission?

In this section we review the explanations for APT that have been proposed in the literature. The focus is on vertical APT, i.e. on asymmetry in price transmission between different stages of a marketing chain. At the end of the section we briefly consider whether the proposed explanations for vertical APT can also apply to spatial APT. Two main proposed causes of APT dominate the literature: non-competitive markets and adjustment costs. Other causes such as political intervention, asymmetric information and inventory management have also been proposed and are considered below under 'miscellaneous'.

3.1 Market power

Most publications on APT refer to non-competitive market structures as an explanation for asymmetry. Especially in agriculture, farmers at the beginning and consumers at the end of the marketing chain often suspect that imperfect competition in processing and retailing allows middlemen to (ab)use market power.[6] It is generally expected that this will result in positive APT. Hence, it is expected that margin-squeezing increases in input prices (or decreases in output prices) will be transmitted faster and/or more completely than the corresponding margin-stretching price changes.[7]

In most cases, however, this conjecture is presented as essentially self-evident, without rigorous theoretical underpinning.[8] In fact, the case for positive APT is not so clear-cut. Ward (1982) suggests that market power can lead to negative APT if oligopolists are reluctant to risk losing market share by increasing output prices. In a similar vein, Bailey & Brorsen (1989) consider firms facing a kinked demand curve that is either convex or concave to the origin. If a firm believes that no competitor will match a price increase but all will match a

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[6] See, for example, Kinnucan & Forker (1987); Miller & Hayenga (2001); McCorriston (2002); Lloyd et al. (2003).

[7] See Boyd & Brorsen (1988); Karrenbrock (1991); Appel (1992); Griffith & Piggott (1994); Mohanty, Peterson & Kruse (1995)

[8] McCorriston et al. (1998, 2001) and Lloyd et al. (2003) develop a framework to model the impact of market power at the intermediate stage on price transmission in the food sector and show, without considering asymmetry directly, that market power can lead to imperfect price transmission.

price cut (concave), negative asymmetry will result. Otherwise if the firm conjectures that all firms will match an increase but none will match a price cut (convex), positive asymmetry will result. Hence it is not clear *a priori* whether market power will lead to positive or negative asymmetry (Bailey & Brorsen 1989, pp. 247).

Several studies of market power and asymmetry that focus on specific markets deserve mention. Borenstein et al. (1997) study vertical price transmission from crude oil to gasoline prices, and conclude that downward stickiness of retail prices for gasoline in an oligopolistic environment will lead to positive asymmetry. They assume that in the presence of imperfect information about the prices charged by other firms, the old output price offers a natural focal point following changes in the input price. While increases in the price of crude oil will lead to an immediate increase in gasoline prices, because margins are squeezed, cost decreases won't lead to immediate output price decreases because firms will maintain prices above the competitive level as long as their sales remain above a threshold level (Borenstein et al. 1997 pp. 324f). Related to this, Balke et al. (1998) and Brown & Yücel (2000) consider oligopolistic firms that engage in unspoken collusion to maintain higher profits. Because of the importance of reputation under such conditions, APT can arise. For example, in the presence of input price increases, all firms will quickly adjust output prices upwards to signal their competitors that collusion will be maintained. However, if input prices fall, firms will wait to lower output prices to avoid signalling an undermining of the unspoken agreement.

Several papers that analyse the impact of market power consider APT that is driven not by input price changes but rather by shifts in output demand. In a paper on imperfect information in a competitive duopoly, Damania & Yang (1998) stress potential punishment as a cause of asymmetry. In their model demand is assumed to fluctuate randomly between high and low states. Punishment occurs if a firm believes that its competitor is undermining a collusive price. Given the possibility of punishment, firms facing low demand eschew a price reduction, while prices can be increased without fear of punishment following a switch to the high demand situation. Kovenock & Widdows (1998) develop a model of duopolistic competition without collusion but with price leadership. Explicit collusion is assumed to be impossible, so the leader-follower price, which is lower than the potential collusive price, prevails. In the case of an upward demand shock, the price leader adjusts prices accordingly, because otherwise the deviation of the old leader-follower price from the new potential collusive price would grow. For some range of downward demand shock, however, no reaction occurs because the old leader-follower price is automatically closer to the new potential collusive price.

In summary, many authors have suggested that market power can lead to APT. Most predict that market power will lead to positive APT. In a pure monopoly context this would appear to be reasonable. However, in the more common oligopoly context, both positive and negative APT are conceivable, depending on market structure and conduct.

To date only few attempts have been made to test the link between market power and APT empirically. For the banking sector, Neumark & Sharpe (1992) find support for the hypothesis that market concentration leads to asymmetric rigidities. In his study, Peltzman (2000) uses two proxies for market power: the number of competitors as well as market concentration, measured by the Herfindahl-Hirschman index. Interestingly, these proxies have conflicting impacts on APT: While asymmetry increases as the number of enterprises falls, it decreases with increasing concentration.

Generally, attempts to test the link between APT and market power must deal with two major difficulties. First, most empirical studies of APT deal with only one product/market using time series data (see section 4). Unless important changes in market power are known to have occurred within the study period, this sort of analysis provides no basis for comparing price transmission under conditions of more and less market power because there is no variation in the 'treatment variable'. One way of circumventing this problem is that followed by Peltzman (2000) in his unique study of a broad cross-section of different products in the US. Studies of this nature could also exploit the fact that market power in various food processing industries or at the retail level varies considerably from country to country within Europe and elsewhere (McCorriston 2002).[9] This is where the second major difficulty arises, which is that of finding a proxy for market power that goes beyond numbers of firms or concentrations, and effectively captures the behaviour – i.e. exercise of market power – that is hypothesised to cause APT (see also section 3.4). The conflicting results reported by Peltzman (2000) may be a manifestation of our lack of such proxies.

An alternative to Peltzman's approach to testing whether there is a link between market power and APT would be to subject the existing studies of APT to a meta analysis. Market power is likely to vary significantly across the many products/markets covered by past studies. This approach is unlikely to prove fruitful, however. First, market power is not the only variable that varies across existing studies. Of particular concern, the empirical methods used to test for APT have changed over time, and there is reason to believe that the test used

[9] We are grateful to a referee for this suggestion. The EU and DEFRA studies on price transmission in the agri-food sector mentioned in the Introduction are of this nature. To our knowledge, however, the results of these studies have not been published, and neither systematically tests the link between market power and asymmetry.

influences the likelihood of finding APT.[10] Separating the effects of variation in market power across studies from the effects of variation in empirical method is likely to prove difficult. Second, market power is not an issue in all past studies of APT, and even where it is, not all authors provide the sort of data that could be used to extract a uniform measure of market power for use in a quantitative meta analysis. Finally, the problem mentioned above of finding a suitable proxy for market power remains.

3.2 Adjustment and menu costs

Another major explanation for APT is provided by adjustment costs that arise when firms change the quantities and/or prices of inputs and/or outputs. If these costs are asymmetric with respect to increases or decreases in quantities and/or prices, APT can result. In the case of price changes, adjustment costs are also called menu costs. Levy et al. (1997) and Dutta et al. (1999) provide recent quantifications of menu costs in US retail markets, demonstrating that they are relevant and on average account for 27 % to 35 % of net profit margins.

For the US beef market, Bailey & Brorsen (1989) show that packers, unlike feedlots, face significant fixed costs. In the short run, margins may thus be reduced in an attempt to keep a plant operating at or near capacity. Therefore, as a result of competition between different packers, farm prices may be bid up more quickly than they are bid down (negative APT). In contrast to Bailey & Brorsen, Peltzman (2000) makes a case for positive APT, arguing that it is easier for a firm to disemploy inputs in the case of an output reduction than it is to recruit new inputs to increase output. This recruitment of inputs will lead to search costs and price premia in increasing phases.

Ward (1982) suggests that retailers of perishable products might hesitate to raise prices for fear of reduced sales leading to spoilage. This would lead to negative APT. Ward's explanation is challenged by Heien (1980), who argues that changing prices is less of a problem for perishable products than it is for those with a long shelf life, because for the latter changing prices incurs higher time costs and losses of goodwill. Heien's argument echoes to the so-called menu cost hypothesis originally proposed by Barro (1972). Here a change in nominal prices induces costs (for example the reprinting of price lists or catalogues and the costs of informing market partners). Ball & Mankiw (1994) develop a model based on menu cost in combination with inflation that leads to asymmetry. In this model, positive nominal input price shocks are more likely to lead to output price adjustment than negative price

[10] We present evidence of this in section 5 below.

shocks. This is because in the presence of inflation, some of the adjustment made necessary by an input price reduction is automatically carried out by inflation, which reduces the real value of the margin[11]. Buckle & Carlson (2000) find some evidence to support this hypothesis using a business survey in New Zealand. Peltzman (2000) finds no evidence of a relationship between menu costs and APT, but he does report evidence of greater asymmetries in more fragmented supply chains where one might expect menu costs to be higher.

Inventory management can be an important element of a firm's adjustment to exogenous shocks and is sometimes proposed as a possible cause of APT. For example, Balke et al. (1998) show that accounting methods such as FIFO (first in first out) can lead to APT. Blinder (1982) develops a model in which the non-negative inventory constraint generates positive asymmetry. Reagan & Weitzman (1982) argue that in periods of low demand firms will adjust the quantity produced and increase inventory rather than decrease output prices. In periods of high demand, on the other hand, firms will increase prices. Combined with asymmetric perceived costs of low and high inventory stocks due to an aversion to stockouts, this will generate positive APT.

In summary, as was the case for the explanations of APT based on market power, attempts to explain APT based on adjustments costs lead to ambiguous and sometimes contradictory results, with some authors providing arguments for positive APT, and others for negative. One difference between market power and adjustment costs is that while both can produce asymmetries in the speed of price transmission, only market power would appear to be capable of leading to long lasting asymmetries in the magnitude of adjustment. Another important difference is that to the extent that adjustment costs are real, any APT that they cause will not lead to welfare transfers that might provide a justification for policy intervention. It is therefore not surprising that firms accused of market power-based APT often argue that adjustment costs are really responsible.

3.3 Miscellaneous

A number of additional explanations for APT have been proposed that cannot be subsumed directly under market power or adjustment costs. In the following we review the most important of these.

Especially in agriculture, price support, often in the form of floor prices, is quite common. Kinnucan & Forker (1987) argue that such political intervention can lead to APT if it leads wholesalers or retailers to believe that a reduction in farm prices will only be

[11] See also Kuran (1983), who shows how asymmetry arises if a monopolistic firm expects inflation.

temporary because it will trigger government intervention, while an increase in farm prices is more likely to be permanent. Psychological pricing points, as suggested by Blinder et al. (1998), could have an analogous influence on price transmission.

Kinnucan & Forker (1987) and v. Cramon-Taubadel (1998) consider APT in the framework of the marketing margin model developed by Gardner (1975). In this model, the farm-retail price spread depends on shifts in both retail-level demand and farm-level supply. Under conditions of perfect competition and constant returns to scale, Gardner deduces a stronger impact of retail-level demand shifts than of farm-level supply shifts on the farm-retail price spread. Kinnucan & Forker (1987) argue that this differential impact could lead to APT. Von Cramon-Taubadel (1998), however, points out that APT will only appear to arise[12] if one type of shift is predominantly positive or negative, i.e. if the distribution of demand and/or supply shifts is skewed. Otherwise there will be equally many episodes of larger demand-driven (and smaller supply driven) transmission in each direction. A case in point might be beef markets in Europe, where large negative shifts in retail demand due to food crises have been common in recent years. In the framework of Gardner's model, the result would be a preponderance of episodes of strong transmission of downward price movements.

If larger firms benefit from economies of size in information gathering, asymmetric information between competing firms can be the result. Bailey & Brorsen (1989) argue that APT can arise due to such asymmetric information. They also point out that asymmetries in price series data can be the result of a distorted price reporting process. Bailey & Brorsen (1989) refer to an example from the US broiler market and cite a spokesman for a large buyer of broilers who claims that price decreases are not reported as quickly as price increases. A similar 'artificial' APT might arise under institutional arrangements whereby reference or indicative, for example wholesale prices are determined and quoted on a regular basis by committees of observers, often industry representatives who have vested interests.[13]

While this list of miscellaneous explanations for asymmetry is not exhaustive, it adds to the general impression of a bouquet of often casual explanations, each of which is able to produce a wide range of asymmetric behaviour. Two of the explanations mentioned in this section (the non-equivalence of demand- vs. supply-side shocks in the Granger model, and distorted price reporting processes) create what might be considered spurious APT that is not a characteristic of price transmission *per se*. The other explanation (based on expected

[12] A referee has pointed out that it is important to stress the 'appearance' of APT, since reactions to a common source of shock are actually symmetric in Gardner's model.
[13] It is claimed that some of Germany's so-called 'Notierungskommissionen' (price-quoting commissions) have produced price quotes that are biased for this reason (von Cramon-Taubadel et al. 1995).

government intervention) generates true APT by which the same shock leads to different responses depending on whether it is positive or negative. In common with APT caused by adjustment costs, it can be expected to generate asymmetry with respect to the speed of transmission, but not with respect to the magnitude.

3.4 Explanations for spatial APT

The discussion so far in this section has focused on explanations for vertical APT, but most of these explanations can be extended to spatial APT. Spatial APT occurs when p^{in} and p^{out} refer to prices not at different levels of the marketing chain but rather to prices for the same product at different locations. Bailey & Brorsen (1989) suggest that spatial price transmission may be asymmetric for four reasons: asymmetric adjustment costs, asymmetric information, market power and asymmetric price reporting. All of these explanations have been proposed in connection with vertical APT and discussed above. In the following we concentrate on several aspects of these explanations that are specific to the spatial context.

In a spatial context, adjustment costs can include the costs of transporting goods. Spatial APT might arise if the costs of transportation vary with the direction of trade. For example, transportation infrastructure and handling facilities may be geared to trade in one particular direction (Goodwin & Piggott, 2001) for historical reasons (e.g. Ukrainian grain trading infrastructure may be more geared to importing for the Soviet Union than to exporting to the rest of the world), or speed and costs of transportation might be asymmetric due to natural conditions (e.g. if it costs more to move goods up-hill or up-river than in the other direction). However, APT due to asymmetric transportation costs would be spurious in the sense suggested above. If two locations are separated by asymmetric transportation, then price transmission will only appear to be asymmetric if trade flows do indeed reverse from time to time and price movements originating in one or both of these locations are predominantly positive or negative. If price movements are distributed evenly at both locations, then both faster (down-stream) and slower (up-stream) transmission will be distributed evenly as well.

Market power as a potential source of APT gains an interesting dimension in the spatial context. A firm will possess local market power to the extent that there are no competitors within a certain radius: as a result of search costs, partners will not react to changes in the prices charged or offered by such a firm, up to a certain threshold. A firm that enjoys such local market power may use it to ensure that price changes that squeeze its margin are passed on more rapidly than changes that stretch it. The result will be vertical APT that is due to spatial market power. Unless this vertical APT is somehow synchronised across space (for example, because all of the locally monopolistic processors in a region are affected by the same exogenous factor at the same time), it may not be detected in tests that are based on spatially aggregated price data. Furthermore, local market power can arise in industries that, viewed at a national or regional level, do not appear to be candidates for market power using conventional proxies such as concentration indices. Hence, attempts to test for a link between market power and APT using spatially aggregated prices and proxies for market power in cross section across industries or products could be mis-specified; local market power might be causing APT in industries in which conventional proxies indicate that market power is not present.

Spatial APT could result as firms with local market power compete for market share in a region. To defend against 'encroachment', a firm at one location might quickly respond to a price reduction by its competitor at another; a corresponding price increase by the competitor, however, may be seen as an opportunity to expand sales, eliciting a slower price reaction or perhaps none at all. The result would be positive, spatial APT. As is the case with vertical APT, however, it is conceivable that behaviour based on market power could also lead to negative, spatial APT.

A further cause of spatial APT that is often cited in the context of developing countries is that of asymmetric flows of information between central (hub) and peripheral (spoke) markets (Abdulai, 2000). Prices at a central market, by virtue of its size and the fact that it is at the centre of a network of information, may tend to be less responsive to price changes in individual peripheral markets than vice versa.

4. Identifying asymmetric price transmission

Explaining what causes APT is not the only challenge facing researchers. Another challenge is that of devising appropriate tests for the presence of APT and measuring its extent. In the following we discuss the methods that have been developed to date and discuss the relationship between these methods and the theory discussed above.

Besides agricultural markets, especially those for gasoline and financial products (interest rates) have been tested for APT. Nevertheless, a defining characteristic of the literature on APT and especially estimation techniques is the strong focus on agricultural markets. More than other fields, agricultural economics is characterised by a long running interest in testing for APT. Oddly enough, however, this extensive literature appears to have had little impact on research in other areas of economics. Bacon (1991) reports a study for the UK Monopolies and Mergers Commission in which it is mentioned that researchers have been unable to find a rigorous way of testing for APT in the gasoline market. In this study, no mention is made of the extensive agricultural economic literature. In his otherwise comprehensive empirical analysis of APT, Peltzman (2000) also makes no reference to the agricultural economic literature.

4.1 Pre-cointegration approaches to testing for APT

Different authors use different notations, making it difficult to compare approaches. In the following, p_t^{out} is a firm's output price in period t. Furthermore, we assume that p_t^{out} is caused by p_t^{in}, the input price in t. Assuming symmetric and linear price transmission, the following equation can be used: [14]

$$p_t^{out} = \alpha + \beta_1 p_t^{in} + \mu_t . \quad (1)$$

There is a long history of estimating asymmetric adjustment in the broader sense of irreversibility. Farrell (1952) is the first to investigate irreversibility empirically, focusing on the estimation of irreversible demand functions.[15] In agriculture, Tweeten & Quance (1969) use a dummy variable technique to estimate irreversible supply functions. Equation (2) is a translation of their original equation for supply analysis into the context of APT using our notation:

$$p_t^{out} = \alpha + \beta_1^+ D_t^+ p_t^{in} + \beta_1^- D_t^- p_t^{in} + \varepsilon_t , \quad (2)$$

where D_t^+ and D_t^- are dummy variables with: $D_t^+ = 1$ if $p_t^{in} \geq p_{t-1}^{in}$ and $D_t^+ = 0$ otherwise; $D_t^- = 1$ if $p_t^{in} < p_{t-1}^{in}$ and $D_t^- = 0$ otherwise. By means of these dummy variables, the input price is split into one variable that includes only increasing input prices and another that includes only decreasing input prices. As a result, two input price adjustment coefficients are estimated, not one as in equation (1); these are β_1^+ for the increasing input price phases and β_1^- for the decreasing input price phases. Symmetric price transmission is rejected if β_1^+ and β_1^- are significantly different from one another, which can be evaluated using an F-test.

In the ensuing years, Tweeten & Quance's technique was adapted to the study of APT. As a reaction to Tweeten & Quance, Wolffram (1971) proposes another variable splitting technique that explicitly includes first differences in the equation to be estimated:

[14] If logarithms of prices are used (e.g. Peltzman, 2000; Goodwin & Piggott, 2001), a constant relative rather than a constant absolute margin is assumed.
[15] Marshall (1936) mentions the possibility of irreversible demand response. See also footnote 2 above.

$$p_t^{out} = \alpha + \beta_1^+ (p_0^{in} + \sum_{t=1}^{T} D^+ \Delta p_t^{in}) + \beta_1^- (p_0^{in} - \sum_{t=1}^{T} D^- \Delta p_t^{in}) + \varepsilon_t , \quad (3)$$

where Δ is the first difference operator. In (3), recursive sums of all positive and all negative changes in the input price are included as explanatory variables.[16]

Houck (1977) proposes a specification (4) that is similar to Wolffram's, but operationally clearer. Unlike (3), this specification does not take initial observations into account, because when considering differential effects the level of the first observation will have no independent explanatory power. Hence, the dependent variable changes to p_t^{out*} which is defined as $p_t^{out} - p_0^{out}$:

$$p_t^{out*} = \alpha t + \beta_1^+ \sum_{t=1}^{T} D^+ \Delta p_t^{in} + \beta_1^- \sum_{t=1}^{T} D^- \Delta p_t^{in} + \varepsilon_t \quad (4)$$

Houck also proposes a specification that includes only first differences of the increasing and decreasing phases of p_t^{in} without summing these as in equation (3):[17]

$$\Delta p_t^{out} = \alpha + \beta_1^+ D^+ \Delta p_t^{in} + \beta_1^- D^- \Delta p_t^{in} + \gamma_t . \quad (5)$$

Ward (1982) extends Houck's specifications by including lags of the exogenous variables:

$$p_t^{out*} = \alpha t + \sum_{j=1}^{K} (\beta_j^+ \sum_{t=1}^{T} D^+ \Delta p_{t-j+1}^{in}) + \sum_{j=1}^{L} (\beta_j^- \sum_{t=1}^{T} D^- \Delta p_{t-j+1}^{in}) + \varepsilon_t \quad (6)$$

$$\Delta p_t^{out} = \alpha + \sum_{j=1}^{K} (\beta_j^+ D^+ \Delta p_{t-j+1}^{in}) + \sum_{j=1}^{L} (\beta_j^- D^- \Delta p_{t-j+1}^{in}) + \gamma_t . \quad (7)$$

The lags-lengths *K* and *L* in equations (6) and (7) can differ, because there is no *a priori* reason to expect equal lag-lengths for the increasing and decreasing phases of price transmission. Boyd and Brorsen (1988) are the first to use lags to differentiate between the magnitude and the speed of transmission. Based on comparisons of individual β–coefficients in (6) and (7) they analyse the speed of price transmission in specific periods, and based on the sums of these coefficients they analyse its magnitude. Hahn (1990) attempts to generalise all of the approaches discussed so far (for reasons which will become clear immediately, these can be referred to as the 'pre-cointegration' approaches). He proposes a Generalised Switching Model, which, however, has had little impact on the ensuing literature.

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[16] Wolffram (1971) argues that the Tweeten & Quance technique will lead to non-constant estimates of α and biased estimates of β_1^+ and β_1^-. A modern interpretation would be that (1) and (2) are mis-specified if p_t^{out} and p_t^{in} are not cointegrated (see below).

[17] Gollnick (1972) points out that the assumption of a non-zero α in (5) implies the presence of a trend in (4), as the latter is essentially a summation of the former. This is also mentioned by Houck (1977). Some authors recognise this (e.g. Kinnucan and Forker, 1987; Zhang et al., 1995) and others do not (e.g. Mohanty et al., 1995).

4.2 Tests for APT based on cointegration analysis

In a celebrated Monte Carlo experiment, Granger & Newbold (1974) demonstrate that regressions between randomly and independently generated non-stationary or highly autocorrelated stationary time series lead to rejection of the null hypothesis that the slope coefficient equals 0 at the 5% level of significance in far more than the expected 5% of a series of repeated experiments. In other words, regressions involving non-stationary variables – or variables that display similar behaviour[18] – often produce results that are spuriously significant, suggesting the existence of relationships that do not, in fact, exist. Since then, econometricians have developed tests for non-stationarity and methods for avoiding spurious regression that are generally known under the heading 'cointegration analysis'. These methods are germane to the study of (asymmetric) price transmission because many price series appear to be non-stationary and, hence, are susceptible to spurious regression.

The first attempt to draw on cointegration techniques in testing for APT is von Cramon-Taubadel & Fahlbusch (1994), later elaborated by von Cramon-Taubadel & Loy (1996) and von Cramon-Taubadel (1998). V. Cramon-Taubadel & Fahlbusch point out the potential for spurious regression in the case of asymmetry tests based on equations such as (2), (3), (4) and (6) if these are estimated without regard to the possible non-stationarity of price series.[19] They suggest that in the case of cointegration between non-stationary series p_t^{in} and p_t^{out}, an error correction model (ECM), extended by the incorporation of asymmetric adjustment terms[20], provides a more appropriate specification for testing APT.

According to this approach, first equation (1) is estimated. If tests prove that (1) is not a spurious regression, then p_t^{in} and p_t^{out} are referred to as being cointegrated and (1) can be considered an estimate of the long-term equilibrium relationship between them. In a second step, an ECM that relates changes in p_t^{out} to changes in p_t^{in} as well as the so-called error correction term (ECT) – the lagged residuals from the estimation of (1) – is estimated. The ECT measures deviations from the long run equilibrium between p_t^{in} and p_t^{out}, so including it in the ECM allows p_t^{out} not only to respond to changes in p_t^{in} but also to 'correct' any

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[18] A (weakly) stationary time series has a constant mean, variance and set of covariances. In practical terms, this means that the time series has constant properties and does not, for example, drift off systematically in any direction or display phases of increased volatility.

[19] The first-order autocorrelation that often characterises the estimates of these regressions is probably a symptom of this problem. See the Appendix.

[20] This is first proposed by Granger & Lee (1989).

deviations from the long run equilibrium that may be left over from previous periods. Splitting the ECT into positive and negative components (i.e. positive and negative deviations from the long-term equilibrium – ECT$^+$ and ECT$^-$) makes it possible to test for APT. The ECM, including lagged changes in p_t^{in} takes the following form:

$$\Delta p_t^{out} = \alpha + \sum_{j=1}^{K} \beta_j \Delta p_{t-j+1}^{in} + \phi^+ ECT_{t-1}^+ + \phi^- ECT_{t-1}^- + \gamma_t \tag{8}$$

Von Cramon-Taubadel & Loy (1996) suggest that the Δp^{in} in (8) can also be split into positive and negative components to allow for more complex dynamic effects:

$$\Delta p_t^{out} = \alpha + \sum_{j=1}^{K} (\beta_j^+ D^+ \Delta p_{t-j+1}^{in}) + \sum_{j=1}^{L} (\beta_j^- D^- \Delta p_{t-j+1}^{in}) + \phi^+ ECT_{t-1}^+ + \phi^- ECT_{t-1}^- + \gamma_t \tag{9}$$

Von Cramon-Taubadel & Fahlbusch (1994) use (8) to test for vertical APT between producer and wholesale markets for pork in Northern Germany, and von Cramon-Taubadel & Loy (1996) use (9) to study spatial APT on world wheat markets. Scholnick (1996) also uses an error correction model to test for asymmetric adjustment of interest rates, while Borenstein et al. (1997) employ a specification similar to (9) in which the ECT is not segmented. Balke et al. (1998) and Frost & Bowden (1999) also employ variants of the asymmetric error correction model.

Three points should be made with regard to specifications such as (8) and (9). First, cointegration and the ECM are based on the idea of a long run equilibrium, which prevents p_t^{in} and p_t^{out} from drifting apart. Hence, in the framework of equations such as (8) and (9) it is only possible to consider asymmetry with respect to the speed of price transmission, not the magnitude. APT with respect to magnitude means that there is a permanent difference between positive and negative episodes of transmission; this will, in the long run, ratchet the prices in question apart, with the result that they cannot be cointegrated.

Second, Enders & Granger (1998) and Enders & Siklos (2001) modify the standard cointegrating Dickey-Fuller test to allow for asymmetric adjustment. This makes it possible to test for cointegration without maintaining the hypothesis of symmetric adjustment to the long run equilibrium. This corrects a potential inconsistency (invalid inference) in the two-step approach developed by von Cramon-Taubadel & Fahlbusch (1994), because failure to find that p_t^{in} and p_t^{out} are cointegrated in the first step – estimation of (1) – may actually be due to the fact that the standard Dickey-Fuller test is based on the assumption of symmetric adjustment. Abdulai (2000, 2002) studies Swiss pork markets using the Enders & Granger framework.

Third, both (8) and (9) are based on linear error correction (i.e. constant parameters ϕ^+ and ϕ^-) whereby a constant proportion of any deviation from the long-run equilibrium is corrected, regardless of the size of this deviation.[21] Von Cramon-Taubadel (1996) investigates possible non-linearity in price transmission by allowing higher order polynomials of ECT to enter into the ECM. Using these *ad hoc* formulations he finds significant evidence of non-linear error correction in spatial price transmission of pork markets in the EU, and in particular that smaller values of the ECT are associated with smaller values of ϕ – i.e. trigger less response in p_t^{in} – than larger values.

Following the threshold approach introduced by Tong (1983), it is possible to consider an intuitively appealing type of ECM in which deviations from the long-run equilibrium between p_t^{in} and p_t^{out} will only lead to price responses if they exceed a specific threshold level. In diagram 3, a threshold error correction scheme is compared with asymmetric but linear error correction and quadratic error correction. The thresholds are given by c_1 and c_2, and whenever the ECT lies on the interval $[c_1, c_2]$, no error correction takes place. Azzam (1999) suggests that threshold error correction is plausible in the presence of adjustment costs. The interval $[c_1, c_2]$ can be interpreted as containing those deviations from the long-term equilibrium, which are, compared to adjustment costs, so small that they will not lead to a price adjustment. Goodwin & Piggott (2001) call this interval the 'neutral band'.

(Diagram 3 about here)

Note that the threshold scheme nests standard linear error correction when $c_1 = c_2 = 0$. Note as well that the threshold model allows for two types of asymmetry, one of which has not been considered so far. The first type refers to price transmission when ECT lies outside the interval $[c_1, c_2]$. In this case, the slopes of the corresponding line segments can differ (as they do in diagram 3), reflecting a difference between ϕ^+ and ϕ^- or, as discussed above, asymmetry with respect to the speed of transmission. The second type of asymmetry refers to the fact that $|c_1|$ need not equal $|c_2|$, in other words that the interval $[c_1, c_2]$ need not be symmetric about the origin. If this type of asymmetry holds, then deviations in the positive and negative directions must reach different magnitudes before a response in p_t^{out} is

[21] Strictly speaking, the error correction in (8) and (9) is also non-linear, if ϕ^+ and ϕ^- differ from one another significantly, i.e. if APT holds. The following discussion focuses on non-linearity with respect not to the sign of the deviation from long run equilibrium, but rather with respect to its magnitude, given its sign.

triggered. In a vertical context this might hold if adjustment costs are asymmetric, as was discussed in section 3.2 above. In a spatial context, this might reflect a situation in which the transaction costs associated with trade between two markets differ according to the direction in which trade flows between them.

Based on methods proposed by Balke & Fomby (1997) and Tsay (1989), Goodwin & Holt (1999), Goodwin & Harper (2000) and Goodwin & Piggott (2001) test for thresholds such as those depicted in diagram 3. Equation (10) shows how threshold cointegration of this type can be specified and estimated:[22]

$$\Delta p_t^{out} = \begin{cases} \alpha_1 + \sum_{j=1}^{K} (\beta_{1,j} \Delta p_{t-j+1}^{in}) + \phi_1 ECT_{t-1} + \gamma_t \text{ if } ECT_{t-1} < c_1 \\ \alpha_2 + \sum_{j=1}^{K} (\beta_{2,j} \Delta p_{t-j+1}^{in}) + \phi_2 ECT_{t-1} + \gamma_t \text{ if } c_1 \le ECT_{t-1} \le c_2 \\ \alpha_3 + \sum_{j=1}^{K} (\beta_{3,j} \Delta p_{t-j+1}^{in}) + \phi_3 ECT_{t-1} + \gamma_t \text{ if } ECT_{t-1} > c_2. \end{cases} \quad (10)$$

In the case of non-zero adjustment costs, the estimation of threshold models can improve the analysis of APT. But is also raises new questions. How many thresholds should be included in an analysis and how can the significance of these thresholds be tested?[23] In practice, estimation of (10) requires imposing a restriction of the minimum share of observations to be included in the neutral band. What impact does this restriction have on the results of such estimation? Since price adjustment outside the neutral band is still assumed to be linear in threshold models, would it be useful to combine thresholds with other forms of non-linear adjustment? Finally, while applications of the threshold approach are no longer rare, we are aware of no application in which estimated thresholds are interpreted in an economic sense. Given what is known about the markets in question (in a spatial context, for example, transport costs between markets A and B and the size of standard consignments), are the estimated thresholds plausible in the sense that they correspond to the minimum incentives required to elicit price adjustments (i.e. trade between A and B)? The consideration of

[22] Goodwin and his co-authors use a grid search strategy to find optimal thresholds. Obstfeld & Taylor (1997) suggest an alternate method.

[23] Hansen & Seo (2002) develop a test for the significance of a single threshold in an error correction model. In the case of single threshold, the ECT is segmented not according to whether it is greater or less than 0 but rather according to whether it is greater or less than a threshold value that might differ from 0. It is difficult to think of applications to price transmission in which a specification of this nature would make much sense. We are not aware of any extension of or alternative to Hansen & Seo's approach that makes it possible to test the significance of more than one threshold. Meyer (2003) uses the framework of Hansen & Seo and also includes a 'neutral band'.

threshold effects certainly adds to the methods available for studying APT, but it is relatively new and there are probably a number of refinements in the research pipeline.

4.3 Miscellaneous methods

Outside of agricultural economics, a number of eclectic approaches to testing for asymmetry can be found. Carlton (1986), for example, bases his test for APT on a purely descriptive analysis. He claims that in the case of negative APT, the smallest positive price change should be smaller than the smallest negative price change. Recent studies of asymmetric adjustment in the banking sector include more sophisticated tests based on rational distributed lag and partial adjustment models. Examples are Hannan & Berger (1991), Neumark & Sharpe (1992) and Jackson (1997).

All of the techniques mentioned so far continue to be used in papers on APT; there is little sense of methodological progress based on a broad consensus among practitioners. For example some quite recent publications have made use of 'pre-cointegration' test methods (e.g. Schertz Willett et al. 1997; Peltzman 2000; Aguiar & Santana 2002).[24] While the incorporation of time series concepts such as cointegration and threshold effects certainly represents refinement, there is no consensus agreement that other approaches have become obsolete and should be discarded.

5. A review of empirical applications and outstanding issues

In the following we briefly review the existing empirical applications of the methods for testing APT outlined above and discuss a number of outstanding issues related to the links between theory and empirical applications in the APT literature. Our review of empirical applications is based on a thorough literature search and our own keeping track of conferences in agricultural economics over the last decade. We cannot claim to have an exhaustive overview, however; publication bias implies that we will not be aware of studies that have been rejected by journals or conferences, or perhaps produced for consulting purposes and not published.

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[24] Peltzman (2000) applies a pre-cointegration test that is identical to one proposed by Gollnick in 1971. He also applies a test which includes a type of ECT. However, this ECT is not based on estimated deviations from a long-run equilibrium but, rather, is calculated as the simple difference between output and input price indices.

5.1 Empirical applications to date

To date there have been 40 publications in major journals on the estimation of APT, 27 of which have appeared in the last decade. An overview of these publications can be found in the Appendix. 27 of 40 applications deal with agricultural products, 12 of these with meat. Additionally, there have been 7 publications on interest rates, 4 publications on fuel/gasoline products and 2 publications on samples of different products. Two-thirds of the published papers focus on US markets; 7 deal with spatial and 33 with vertical APT. Most applications are based on monthly and weekly price data (24 and 11 studies, respectively), while daily, fortnightly and quarterly data are each used once.

Nearly half of the tests for APT make use of some type of 'pre-cointegration' approach (19 of 40). ECM and threshold are employed in 11 papers (4 ECM / 7 threshold). 7 studies, primarily based on non-agricultural markets, apply a variety of other approaches.

Is there a link between the estimation method and the results obtained? Table 1 presents results of a qualitative meta-analysis based on the results of all of the individual tests that have been published to date. Since several papers cover more than one product, the 40 publications yield 205 individual tests of APT. Of these, 93 apply a pre-cointegration test based on first differences (equations (5) and (7)), 53 apply a pre-cointegration approach based on recursive sums of first differences (equations (3), (4) and (6)), 31 apply an asymmetric error correction model (equation (8) and (9)) and 28 apply either threshold or other techniques.

(Table 1 about here)

Note that Peltzman's (2000) tests are not included in table 1, because his 282 individual tests would 'swamp' the rest. However, Peltzman's results can be compared with those that are based on pre-cointegration methods using first differences (the third column in table 1), as he applies one of these methods. Furthermore, his results resemble these quite closely; Peltzman finds evidence of asymmetry in roughly two-thirds of all cases, while on average all other authors who use a similar test find APT in 68% of their cases. Over the entire sample of literature covered by table 1, symmetry is rejected in nearly one-half of all cases. Pre-cointegration methods based on first difference and threshold methods lead to considerably higher shares of rejection of symmetry (68 and 80%, respectively), while pre-cointegration methods based on the recursive summation of first differences and ECM-based methods lead to lower shares (25 and 45%, respectively). The category 'miscellaneous methods' leads to rejection of symmetry in only 6% of all applications, but there is little replication of the many different methods within this category.

5.2 Further methodological issues

Since different methods appear to lead to different rates of rejection of the null hypothesis of symmetry, the fact that the literature to date contains no rigorous comparison and analysis of the strengths and weaknesses of the available methods is worrisome. It is clear that the available methods are not all simply reparametrisations of one another and that they can therefore not all be equally appropriate in all cases. Von Cramon-Taubadel & Loy (1999) take a first stab at proposing a comprehensive testing procedure based on tests of the time series characteristics of the available price data and their implications for the choice of testing methods. However, this work is preliminary and in need of refinement. In the following we note a number of additional methodological issues that have received attention in recent years.

First, the problem of multicollinearity when applying certain asymmetry tests was first addressed by Houck (1977) who pointed out that "when a variable is segmented into increasing and decreasing components, it is possible that the two segments will be highly correlated with each other" (p. 571). This problem arises when the recursive sums of positive and negative price changes - essentially step functions - are included on the right hand side of a test regression (see equations (3), (4) and (6)), as the former (latter) follows a clear positive (negative) trend. Gauthier & Zapata (2001) confirm this result using Monte Carlo analysis. Since multicollinearity influences the stability of the parameter estimates that are used to test the null of symmetry, this could have important implications for the reliability of pre-cointegration methods that are based on recursive sums of price differences (note that these methods are comparatively unlikely to reject symmetry, see table 1).

Second, the behaviour of the different tests for APT in the presence of data anomalies warrants attention. Von Cramon-Taubadel & Meyer (2000) study the behaviour of tests for APT in the presence of structural breaks in the underlying price series using a Monte Carlo experiment. They find that all methods lead to significant over-rejection – albeit to differing degrees – of the null hypothesis of symmetry in the presence of structural breaks. Since there are many indications that structural breaks are common in price and other economic series, the authors recommend that tests for structural breaks be employed prior to tests for asymmetry to improve the reliability of inference regarding APT. The problem with structural breaks may be related to our own casual observation (based for example on recursive estimation and repeated estimation using a 'moving window' of data) that relatively small episodes in price data often have a strong impact on the result of APT tests. We are not able to propose an explanation for either this phenomenon or the impact of structural breaks on tests for APT; (part of) the answer may lie in determining why different test approaches are susceptible to differing degrees, which is the topic of ongoing research.

A third important issue is that of data frequency. It was mentioned above that 24 of 40 tests for APT in the literature are based on monthly data. Only two papers specifically address the issue of data frequency; von Cramon-Taubadel & Loy (1996) contrast the results of using weekly and monthly data, while Borenstein et al. (1997) work with weekly and fortnightly data. Von Cramon-Taubadel & Loy (1996) point out that any empirical attempt to quantify dynamic relationships such as APT requires data with a frequency that exceeds the frequency of the adjustment process (for example, the arbitrage transactions that integrate markets). If, as might be expected in many cases, price transmission takes place within days or weeks, monthly and even lower frequency price data will too 'blunt' an instrument (see also Boyd & Brorsen 1988). Von Cramon-Taubadel, Loy & Musfeldt (1995) demonstrate this using weekly slaughter pig prices from different regions in the EU which they aggregate to generate corresponding monthly and quarterly time series; as the frequency of the employed data decreases, ECMs estimated using these data become simpler as lagged terms lose significance, and the coefficients of the remaining terms (contemporary price changes and the ECT) approach 1. The ECMs estimated with quarterly data simply reflect the fact that at this level of temporal aggregation, prices in different regions are highly correlated, and provide no basis for tests of APT. The lack of attention to this issue in the literature on APT is notable, and it may be that some studies fail to find evidence of APT simply because they are based on low-frequency data. Clearly, what data frequency is appropriate will depend on the characteristics of the products and markets in question.

Miller & Hayenga (2001) suggest that data frequency can help distinguish between different possible causes of APT. They argue that some causes will lead to APT exclusively in the low- (or high-) frequency cycles of observed prices. Hence, if for example APT is found in the low-frequency cycles, causes that are only consistent with APT in the high-frequency cycles can be eliminated. Miller & Hayenga suggest, for example, that the APT that is due to search costs and local market power will be found high-frequency cycles, but not in low-frequency cycles because the longer a price change lasts, the more likely it is that partners (consumers in the case of locally monopolistic retailers, for example) will search for and find better prices. Therefore, if APT in a given setting is found to exist exclusively in low-frequency cycles, explanations based on local market power and search costs can be eliminated and attention focused on explanations that are consistent with APT in low-frequency cycles. These include, according to the authors, explanations based on inventory behaviour, which firms will only adjust in response to low-frequency price changes. Miller & Hayenga suggest that empirically testing for APT in different ranges of the frequency domain (see below) can be used to at least narrow down the set of possible explanations in a given setting, and they propose using band spectrum regression to do so.[25]

Fourth, we have pointed out above that authors rarely attempt to distinguish between APT that is statistically significant and APT that is economically meaningful. Given that tests are being carried out using increasingly long data sets, it is conceivable that statistical and economic criteria will diverge. This could be relevant to the search for links between test methods and causes of APT. Adjustment costs might conceivably lead to artificial APT that is statistically significant but economically negligible. However, it would be reasonable to expect any APT that is caused by the conscious use of market power to be economically meaningful, i.e. to produce a significant increase in economic profits. Only in this case would APT have any meaningful welfare implications.

Finally, only few studies explicitly attempt to link empirical confirmation of APT to the factors that have been proposed as possible causes of asymmetry in the theoretical literature. Azzam (1999, p. 525) argues succinctly that "… so far asymmetry tests are more useful in describing how markets look than how they work."

As outlined above, Miller & Hayenga (2001) propose testing for APT in low- and high-frequency ranges of the frequency domain as a means of linking cause and effect. As the authors point out themselves, however, it will generally only be possible to narrow down the set of possible explanations using this approach, not to identify a unique explanation. Furthermore, price behaviour in an oligopoly setting can lead to APT in both low- and high-frequency cycles. Finally, Miller & Hayenga's approach is based on the assumption that firms are able to discern, *a priori*, between low- and high-frequency price changes, something that may not be plausible in all settings.

Peltzman (2000) measures the correlation between the degree of observed asymmetry and variables that reflect market concentration, cost shares etc., but he admits that he is "fishing" (p. 468). Possible methods of testing the link between APT and market power, and the associated difficulties, were discussed in section 3 above. In general, all attempts to distinguish between different causes of APT empirically will have to deal with the likelihood that many possible causes will often coincide. Many agricultural markets, for example, will combine elements of market power with inventory and adjustment costs and government

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[25] In the final analysis Miller & Hayenga (2001) estimate a VAR in differences - essentially a pre-cointegration approach - for different frequency-domain subsets of their data on US pork prices.

intervention. Furthermore, while many explanations for generic APT have been proposed, there is little in the literature that could serve as a basis for empirical tests that distinguish between these explanations. Granted, a firm with market power, for example, might be able to behave in a way that produces APT, but what exact quantitative expression or pattern of APT (positive, negative, with respect to magnitude or speed), if any, would represent the optimal use of this firm's power? Similarly, while inventory management can produce APT, we are aware of no study that quantitatively links observed APT to actual inventory management practices and costs in a concrete context.

To break this impasse, progress is required in several areas. As is often the case, deductive and inductive approaches can play complementary roles. Deductive, theoretical work could provide a better indication of the conditions under which APT would indeed represent a rational use of market power or response to adjustment costs, and exactly what form this APT could be expected to take. Inductively, cross-sectional studies – coupled with improved empirical tests (see section 4 above) – could attempt to exploit differences in factors that might cause APT – for example market power – across products and/or countries. Additionally, in-depth case studies of the structure and institutional features of specific marketing chains would be helpful. Especially interesting would be 'smoking gun' case studies whereby, perhaps in cooperation with anti-trust authorities, known cases of collusion could be studied to see whether they have led to APT, and if so, what form it has taken.

6. Conclusions

The main results of this survey of the literature on APT are sobering. The two main strands of this literature – the theoretical strand that discusses possible causes for APT and the methodological strand that discusses empirical tests – each present a broad range of results. However, there is little sense of progress towards a unified theory or set of testing procedures. Furthermore, these two strands of the literature are poorly integrated as existing tests have not been refined to the point where they can help distinguish between different possible causes of APT. An additional fault line in the literature that cuts across both the theoretical and methodological strands separates agricultural economics from related disciplines. Agricultural economics has been responsible for the majority of publications on the topic of APT to date, and for a number of interesting innovations. Researchers in other fields of economics seem to have taken little notice of this work, however.

In future empirical work, it would be helpful if researchers paid more attention to the data that they employ to test for APT (frequency, possible anomalies), and went beyond simply finding APT (or not) to put more emphasis on interpreting their results (economic significance, interpretation – for example of estimated thresholds, possible causes, relation to the structural and institutional features of the market being studied). It would also be helpful if studies based on applying new testing procedures would compare results with those attained using older methods, or would apply the new procedures to data that has been analysed using other methods in the past. There is reason to believe that journals, to the extent that they lean towards publishing 'flashy' new methods, have generated a literature in which most studies apply new methods to new data, limiting the basis for comparisons that could provide a basis for progress.

The good news, of course, is that a great deal of interesting research beckons. Given the potential implications of APT for both economic theory and economic policy, this research promises to continue to combine the 'academic' and the 'practical' in a most enticing manner.

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Appendix I

applications of asymmetric price transmission tests													
				method			*data*					*results*	
no	***author***	***year***	***Journal***	***test***	***causality***	***time series***	***product***	***ver./spat.***	***region***	***frequency***	***period***	***asym./sym.***	***problems***
1	Heien	1980	AJAE	level	x	-	food prod.	vertical	usa	monthly	1960:1-1975:12	mixed	
2	Ward	1982	AJAE	level	x	-	vegetables	vertical	usa	monthly		mixed	
3	Freebairn	1984	RMAE	diff.	x	-	food prod.	vertical	australia	monthly	1971-1982	symmetry	
4	Carlon	1986	AER	diff.	-	-	diff.	vertical	usa	monthly	1957:1-1966:12	symmetry	only test for neg. asym
5	Kinnucan & Forker	1987	AJAE	level	-	-	milk products	vertical	usa	monthly	1971:1-1981:12	asymmetry	autocorrelation
6	Boyd & Brorsen	1988	NCJAE	level / delta	-	-	pork	vertical	usa	weekly	1974-1981	symmetry	autocorrelation
7	Schroeder	1988	AB	level	x	-	pork	vertical	usa	weekly	1983-1986	mixed	
8	Bailey & Brorsen	1989	WJAE	delta	x	-	cattle	spatial	usa	weekly	1979:6-1986:4	mixed	no autocorrelation
9	Hahn	1990	JAER	diff.	-	-	meat	vertical	usa	weekly/monthly	1980:1-1987:3	asymmetry	
10	Pick, Karrenbrock & Carman	1990	AB	level	-	-	fruit	vertical	usa	weekly	1985:2-1987:6	mixed	autocorrelation
11	Karrenbrock	1991	FRBoSL	delta	-	-	gasoline	vertical	usa	monthly	1983:1-1990:12	mixed	
12	Punyawadee, Boyd & Faminow	1991	CJAE	delta	-	-	pork	spatial	canada	weekly	1965:1-1989:12	symmetry	autocorrelation
13	Bacon	1991	EE	diff.	-	-	gasoline	vertical	uk	semimonthly	1982:6-1990:1	asymmetry	
14	Hannan & Berger	1991	AER	diff.	-	-	interest rates	vertical	usa	monthly	1983:9-1986:12	asymmetry	
15	Appel	1992	AW/S	level	-	-	chicken	vertical	germany	monthly	1973:1-1989:12	asymmetry	autocorrelation
16	Hansmire & Willet	1992		level	-	-	apples	vertical	usa	monthly	1980-1990		autocorrelation
17	Neumark & Sharpe	1992	QJE	diff.	-	-	interest rates	vertical	usa	monthly	1983:10-1987:11	asymmetry	
18	Griffith & Piggott	1994	AE	level	-	-	meat	vertical	australia	monthly	1971:1-1988:12	mixed	autocorrelation
19	Zhang, Fletcher & Carley	1995	AB	level	x	-	peanut	vertical	usa	monthly	1984:1-1992:7	mixed	autocorrelation
20	Mohanty, Peterson & Kruse	1995	CJAE	level	x	-	wheat	spatial	world	monthly	1980:1-1990:6	asymmetry	autocorrelation
21	v. Cramon & Loy	1996	CJAE	ecm	x	x	wheat	spatial	world	monthly/weekly	1980:1-1991:6	symmetry	
22	Scholnick	1996	JIMF	ecm	-	x	interest rates	vertical	asia	monthly	1983:1-1992:11	mixed	
23	Bernard & Willet	1996	JAAE	level	x	-	broiler	vertical	usa	monthly	1983:1-1992:12	mixed	autocorrelation
24	Borenstein, Cameron & Gilbert	1997	QJE	ecm / level	-	x	gasoline	vertical	usa	weekly/semimonthly	1986:3-1992:12	mixed	
25	Jackson	1997	RIO	diff.	-	-	interest rates	vertical	usa	monthly	1983:12-1985:11	asymmetry	
26	Schertz Willet et al.	1997	AB	delta	x	-	apples	vertical	usa	monthly	1975-1990	mixed	
27	Enders & Granger	1998	JBES	threshold	-	x	interest rates	vertical	usa	quarterly	1958:Q1-1994:Q1	mixed	
28	v. Cramon	1998	ERAE	ecm	-	x	pork	vertical	germany	weekly	1990:1-1993:10	asymmetry	heteroskedasticity
29	Balke, Brown & Yücel	1998	FRBoD	level / ecm	x	(x)	gasoline	vertical	usa	weekly	1987:1-1996:8	mixed	
30	v. Cramon & Loy	1999	JfNuS	ecm / level	-	x	wheat	spatial	world	weekly	1980:1-1996:3	symmetry	
31	Goodwin & Holt	1999	AJAE	threshold	-	x	beef	vertical	usa	weekly	1981:1-1998:3	symmetry	
32	Frost & Bowden	1999	JBES	ecm	-	x	interest rates	vertical	new zealand	monthly	1985:9-1996:4	asymmetry	
33	Goodwin & Harper	2000	JAAE	threshold	-	x	pork	vertical	usa	weekly	1987:1-1999:1	mixed	structural changes
34	Peltzman	2000	JPE	delta	-	-	diff.	vertical	usa	monthly	1978-1996	mixed	
35	Abdulai	2000	JDE	threshold	-	x	maize	spatial	ghana	monthly	1980:5-1997:10	asymmetry	
36	Enders & Siklos	2001	JBES	threshold	-	x	interest rates	vertical	usa	monthly	1964:1-1998:12	mixed	
37	Goodwin & Piggott	2001	AJAE	threshold	-	x	corn / soybeans	spatial	usa	daily	1992:1-1999-3	mixed	
38	Abdulai	2002	AE	threshold	-	x	pork	vertical	switzerland	monthly	1988:1-1997:9	asymmetry	
39	Aguiar & Santana	2002	AB	level	x	x	diff.	vertical	brazil	monthly	1987:1-1998:6	mixed	autocorrelation
40	Romain, Doyon & Frigon	2002	AB	level	-	-	milk	vertical	usa	monthly	1980-1997	mixed	autocorrelation

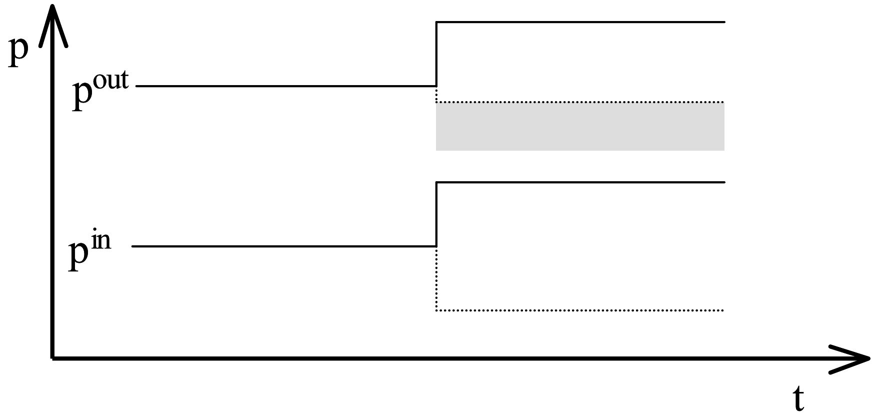
Journals: AJAE = American Journal of Agricultural Economics RMAE = Review of Marketing and Agricultural Economics AER = The American Economic Review NCJAE = North Central Journal of Agricultural Economics AB = Agribusiness WJAE = Western Journal of Agricultural Economics JAER = The Journal of Agricultural Economics Research FRBoSL = Federal Reserve Bank of St. Louis Review CJAE = Canadian Journal of Agricultural Economics EE = Energy Economics AW/S = Agrarwirtschaft Sonderheft QJE = Quarterly Journal of Economics AE = Agricultural Economics JIMF = Journal of International Money and Finance JAAE = Journal of Agricultural and Applied Economics RIO = Review of Industrial Organization JBES = Journal of Business & Economic Statistics ERAE = European Review of Agricultural Economics FRBoD = Federal Reserve Bank of Dallas, Economic Review JfNuS = Jahrbücher für Nationalökonomie und Statistik JPE = Journal of Political Economy JDE = Journal of Development Economics

causality: X = Test for Causality is calculated - = Test for Causality is not calculated

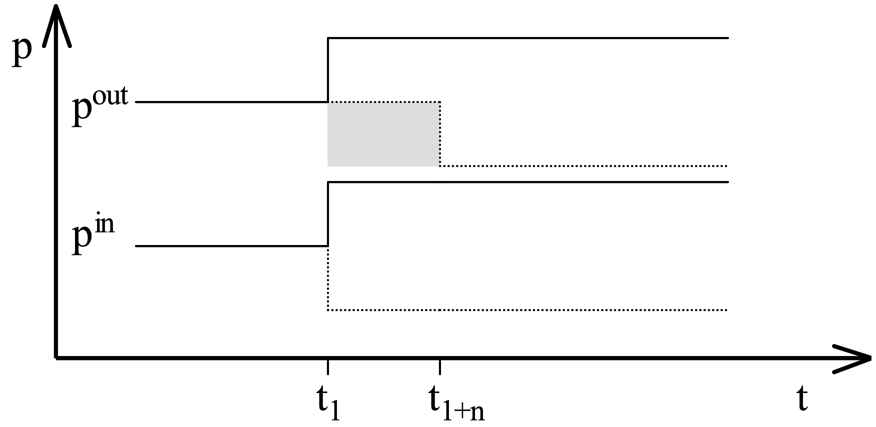
time series: X = unit-root test is calculated - = unit-root test is not calculated

Source: own

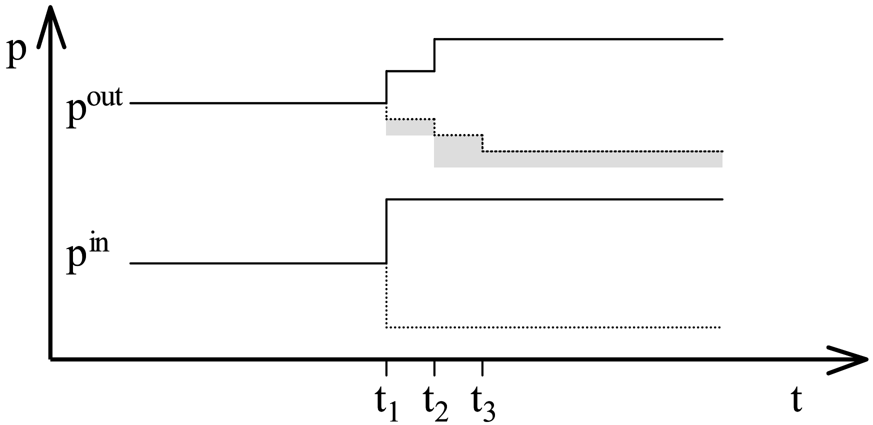
Dia. 1a: asym. price transmission (magnitude)



Dia. 1b: asym. price transmission (speed)

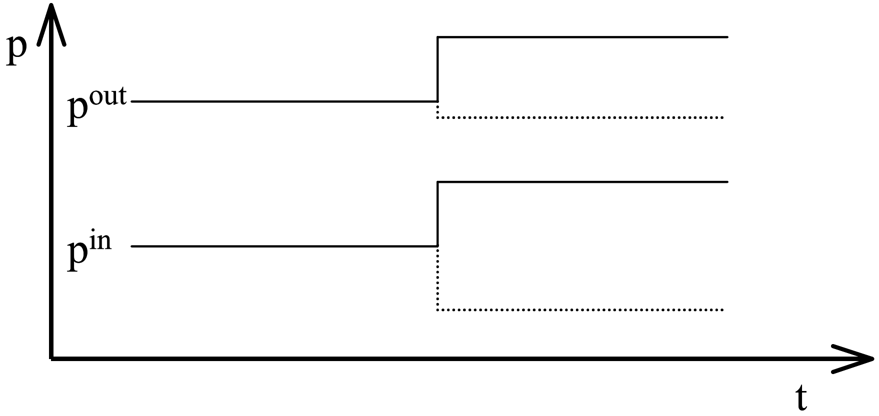


Dia. 1c: asym. price transmission (speed and magnitude)



Source: own

Dia. 2a: positive asym. price transmission



Dia. 2b: negative asym. price transmission

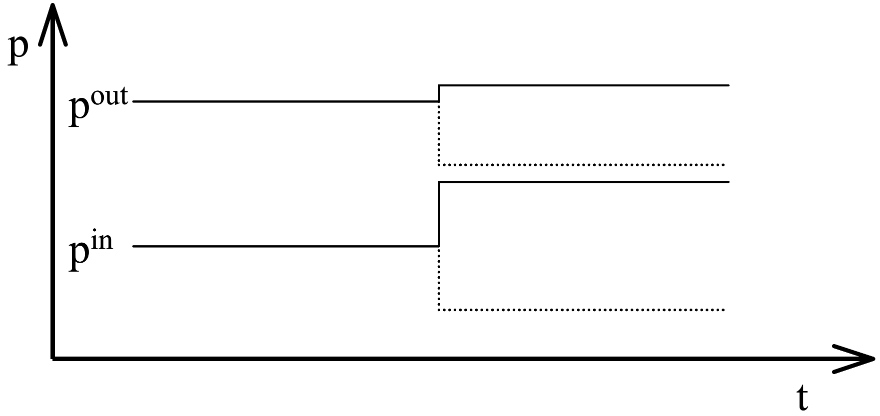
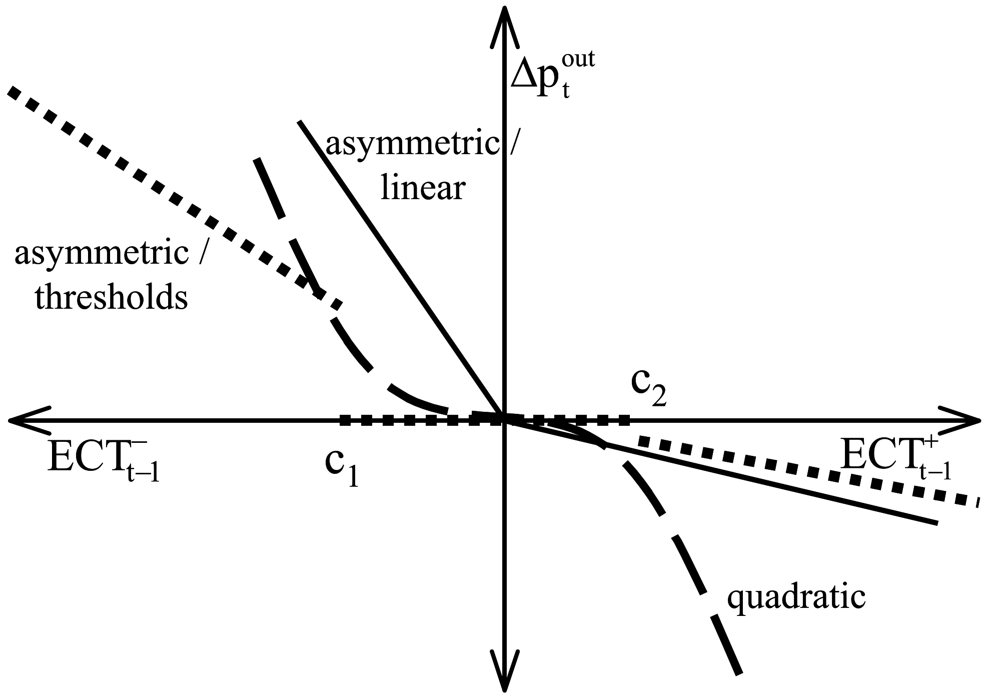


Diagram 3: types of error correction



Source: own

Table 1: Results of the application of different asymmetry tests

	Test method					
	All methods	Methods using first differences	Methods using summed differences	ECM methods	Threshold methods	Misc. methods
Total cases, of which	205	93	53	31	10	18
Symmetry maintained	106	30	40	17	2	17
Symmetry rejected	99	63	13	14	8	1
Symmetry rejected (%)	48	68	25	45	80	6

Source: own - see Appendix