Asymmetric Price Transmission: A Survey

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1. Introduction

Price theory is one of the foundations of 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 therefore investigate price transmission processes. Of special interest are those processes that are referred to as asymmetric. In an extensive study, Peltzman (2000) finds asymmetric price transmission to be more the rule than the exception. This leads him to draw the strong conclusion that the standard economic theory of markets is wrong, because asymmetric price adjustment is not its general implication (Peltzman 2000, pp. 493). On the other hand, authors such as Gauthier & Zapata (2001) and v. Cramon-Taubadel & Meyer (2000) recomment caution due to methodological problems associated with empirical tests for asymmetry. They point out that standard tests (such as that applied by Peltzman) can lead to excessive rejection of the null hypothesis of symmetry under common conditions.

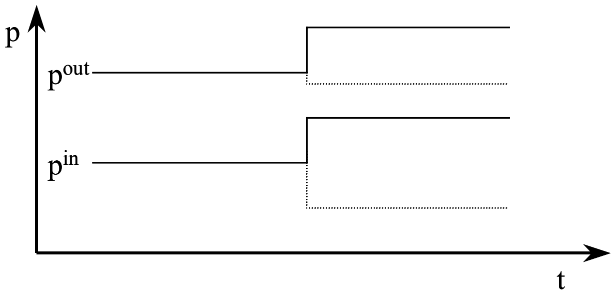
Clearly, the issue of asymmetric price transmission is of great importance. First because, as Peltzman point out, it may point to large gaps in economic theory. Second, because asymmetry can have important implications for policy. Since it is commonly assumed that asymmetric price transmission is caused by market power, empirical evidence of asymmetry is often claimed to justify intervention. Given these possible ramifications, it is obviously imperative that economists think very carefully about the theories they use to explain and the tests they use to measure asymmetric price transmission.

In this paper we survey the literature on asymmetric price transmission. This literature contains a substantial share of publications by agricultural economists. After classifying the different types of asymmetric price transmission in section 2, we describe the explanations for asymmetric price transmission that have been proposed in section 3. In section 4 we focus on the econometric techniques used to quantify asymmetry. Section 5 concludes with a discussion of outstanding methodological problems and suggestions for future research. Our main conclusion is that the existing literature is far from being unified or conclusive, and that a great deal of work remains to be done. A wide variety of often conflicting theories of and empirical tests for asymmetry co-exist in the literature. Furthermore, existing tests are not discerning in the sense that they as a rule to do not make it possible to choose between competing explanations for asymmetry on the basis of empirical results. Therefore, after more than three decades of work, 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.

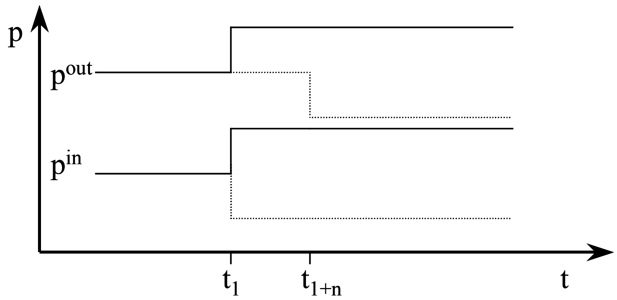
2. Types of asymmetry

Two basic types of asymmetry are depicted in diagram 1 in the context of price transmission, 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.[1] In diagram 1a, the magnitude of the response by p^{out} to a change in p^{in} depends on the direction of this change. In diagram 1b, the speed of the response by p^{out} depends on the direction of the change in p^{in}. Clearly, combinations of these two fundamental asymmetries are conceiveable. In diagram 2, an increase in p^{in} takes two periods (t_1 and t_2) to be fully transmitted to p^{out}. The corresponding transmission of a decrease in p^{in} is asymmetric with respect to both speed and magnitude because it requires three periods (t_1, t_2 and t_3) and is not full.

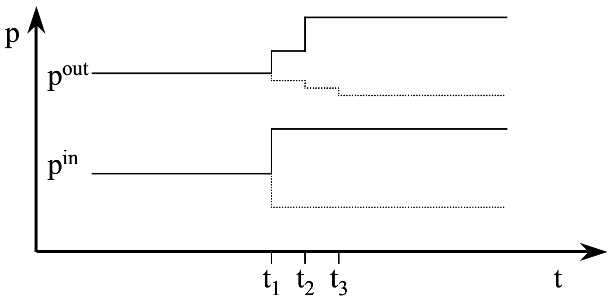
Dia. 1a: asymmetric price transmission (magnitude)



Dia. 1b: asymmetric price transmission (speed)



Dia. 2: asym. price transmission (combination)



Price transmission, and thus asymmetry, can be vertical or spatial (horizontal). As an example of vertical asymmetry, farmers and consumers often complain that increases in farm

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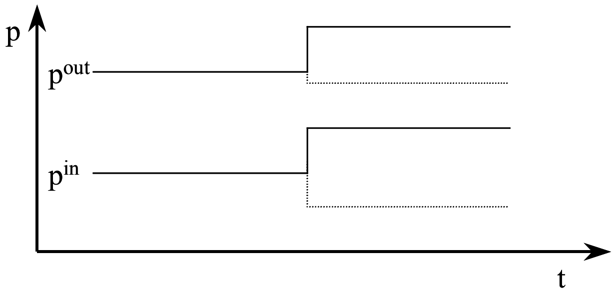
[1] Asymmetry is closely related to the issue of price rigidity or 'stickiness' (Means, 1935). Blinder et al. (1998) offer an extensive overview of different explanations for rigidity. Note as well, that asymmetry is not only of interest with regard to price transmission. Traill et al. (1978) and Young (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.

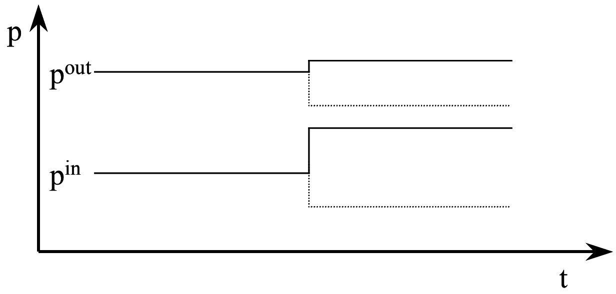
prices are more fully and rapidly transmitted to the wholesale and retail levels than similar decreases in farm prices. An example of spatial asymmetry would be a rise in the US wheat price causing a more pronounced reaction in Canadian wheat prices than a corresponding reduction of the same magnitude.

Following a convention employed by Peltzman, asymmetry can be either positive or negative.

Dia. 3a: positive asym. price transmission



Dia. 3b: negative asym. price transmission



If p^{out} reacts more fully or rapidly to an increase in p^{in} than to a decrease, the asymmetry is termed 'positive' (diagram 3a). 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 3b). This convention can be misleading if interpreted in a normative fashion; if p^{in} and p^{out} represent farm and retail prices for a commodity, respectively, 'negative' asymmetry is 'good' for the consumer, while 'positive' asymmetry is 'bad'.

3. What causes asymmetric price transmission?

Two main causes of asymmetric price transmission dominate the literature: the presence of non-competitive markets and existence of adjustment costs. Other causes such as political intervention, asymmetric information and inventory management are also reported.

3.1 Market power

The vast majority of publications on the topic of asymmetric price transmission includes considerations of non-competitive market structures. Especially in agriculture, farmers at the beginning and consumers at the end of a marketing chain often believe that less than perfect competition in the processing and retailing sectors allows middlemen to make use of market power.[2] This market power is often expected to lead to positive asymmetry. Hence,

[2] See, for example, Kinnucan & Forker (1987); Miller & Hayenga (2001).

it is expected that increases in input prices which reduce marketing margins will be transmitted faster and more completely than decreases as a result of market power.[3] In most cases, however, this conjecture is presented without rigourous theoretical underpinning. Indeed, some authors such as Ward (1982) suggest that market power can lead to negative asymmetry if oligopolists are reluctant to risk losing market share by increasing prices. In a similar vein Bailey & Brorsen (1989) consider firms facing a kinked demand curve with the perceived kink either convex or concave to the origin. If a firm believes that no competitor will match a price increase but all will match a price cut, positive asymmetry will result. Otherwise if the firm conjectures that all firms will match an increase but none will match a price cut, negative 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) assume that downward stickyness of retail prices in an oligopolistic environment will lead to positive asymmetry. Similar to a trigger price model they assume that in the presence of imperfect information about the prices charged by other firms, the old output price, after a change in the input price, offers a natural focal point. While cost increases will lead to an immediate increase in output prices, because retail 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) also consider oligopolistic firms that engaged in an unspoken collusion to maintain higher profits. Because of the importance of reputation under such conditions, asymmetric price adjustment 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 signaling an undermining of the unspoken agreement. 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 the 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 in the high demand situation.

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

Kovenock & Widdows (1998) develop a model of duopolistic competition without collusion but with price leadership. Since collusion is assumed impossible, the leader-follower price is lower than the potential collusive price. 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.

Bedrossian & Moschos (1988) stress profitability considerations, suggesting that different levels of profitability among firms within an industry can lead to asymmetry. It is suggested that a relatively profitable firm can more easily take the risk of delaying a price adjustment following a decline in input prices than a firm with lower profitability, because of higher profit margins.

Borenstein et al. (1997) propose that search costs faced by consumers lead to local monopolies that can lead, in turn, to asymmetry. A local monopoly can arise if the costs of searching for a lower price are perceived to be higher than the expected profits from a lower price. Borenstein et al. study the gasoline market, but the mechanism they propose could apply to other markets as well, such as food.

Finally, market power need not only refer to the competitive situation between the firms at a specific level of the marketing chain, it can also result from vertical integration across levels in the chain. To our knowledge, the implications of vertical integration for the symmetry of price transmission have not been examined in the literature.

Compared to the great variety of hypothesised links between market power and asymmetry, there have been only few attempts to test these links empirically. A major problem is that of choosing an appropriate proxy for market power; it is well known that the commonly used concentration measures will be less than perfectly correlated with market power. For the banking sector, Neumark & Sharpe (1992) find evidence for the hypothesis that market concentration leads to asymmetric rigidities. However, Peltzman (2000) finds conflicting results. In his studies fewer number of firms leads to more asymmetry, but more concentration leads to less asymmetry.

3.2 Adjustment and menu costs

Another major explanation for asymmetric price transmission is provided by adjustment costs. Adjustment costs arise if a firm increases or decreases its output or the price of its products. If these costs are asymmetric with respect to an increase or a decrease in output quantities and/or prices the adjustment will be asymmetric. In the case of price changes, adjustment costs are also called menu costs.

For the US beef market, Bailey & Brorsen (1989) show that packers, unlike feedlots, face significant fixed costs. So in the short-run, margins may be reduced to keep the plant operating. Therefore farm prices may rise more quickly and fall more slowly, as a result of competition between different packers (negative asymmetry). In contrast to Bailey & Brorsen, Peltzman (2000) makes a case for positive asymmetry, arguing that it is easier for a firm to disemploy inputs in the case of an output reduction than it is to recruit new input to increase output. This recruitment of inputs will lead to search costs and price premia that skew the adjustment costs to the increasing phase.

Ward (1982) points out that retailers of perishable products might hesitate to raise prices for fear of reduced sales, thus, and spoilage. This would engender negative asymmetry. 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 higher time costs of changing prices and losses of goodwill are expected. Heien's argument leads to the so called menu cost hypothesis originally proposed by Barro (1972). Here a change in the nominal price 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 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[4]. 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 asymmetric price transmission, but he does report evidence of greater asymmetries in more fragmented supply chains where one might expect menu costs to be higher.

In summary, as was the case for the explanations of asymmetry in which market power is involved, attempts to explain asymmetric price transmission using adjustments costs can lead to contradictory and ambiguous results. A difference between market power and adjustment costs could be that while both could produce asymmetries in the speed of price transmission, only market power is capable of leading to long lasting asymmetries in the magnitude of adjustment to positive and negative input price shocks. Furthermore, as argued by Bailey & Brorsen (1989), adjustment costs probably do not vary by location, so spatial asymmetric price transmission is unlikely to be caused by adjustment costs.

3.3 Miscellaneous

A number of additional explanations for asymmetric price transmission has been proposed. 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 asymmetric price adjustment if it leads wholesalers or retailers to believe that a reduction in farm prices will only be temporary because it will trigger government intervention, while an increase in farm prices is more likely to be permanent.

Kinnucan & Forker and v. Cramon-Taubadel (1998) mention the potential of asymmetric price transmission in the marketing margin model developed by Gardner (1975). In this model, the farm-retail price spread depends on shifts in retail-level demand and shifts in farm-level supply. Gardner deduces a stronger impact of retail-level demand shifts than of farm-level supply shifts. Hence, an asymmetric distribution of either demand or supply shifts would also lead to observable asymmetric price transmission.

Bailey & Brorsen (1989) show that asymmetric price adjustment can arise due to asymmetric information. If larger firms benefit from economies of size in information gathering, asymmetric information between competing firms is the result. Same authors 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 while citing a spokesman for a large buyer of broilers who claims that price decreases are not reported as quickly as price increases.

Inventory management is sometimes proposed as a possible cause of asymmetric price transmission. Balke et al. (1998), for example, show that accounting methods such as FIFO (first in first out) can lead to asymmetric price transmission. Blinder (1982) develops a model in which the non-negative inventory restriction generates positive asymmetry. And Reagan & Weitzman (1982) argue that in periods of low demand firms will adjust the produced quantity and increase inventory rather than decrease output prices. In periods of high demand, on the other hand, firms will increase prices. In combination with asymmetric perceived costs of low

[4] Kuran (1983) shows how asymmetry arises if a monopolistic firm expects inflation.

and high inventory stocks, because of the fear of a stockout, this could lead to positive asymmetry.

While this list of potential explanations for asymmetry is probably not exhaustive, the general impression is of a bouquet of often casual explanations, with each being able to produce a wide range of asymmetric price transmission. Many explanations have been proposed that produce asymmetry in the 'generic' sense, but there is very little in the literature that can serve as a basis for empirical tests that could distinguish between different causes. Granted, a firm with market power, for example, might be able to behave in a way that would produce asymmetry, but what exact quantitative expression of asymmetry (positive, negative, of magnitude or of speed), if any, would represent the optimal use of this firm's power? Few answers to this sort of question have been suggested to date.

4. Identifying asymmetric price transmission

Unfortunately, the explanation of asymmetric price transmission is not the only problem researchers face. Another problem is that of testing for the presence and measuring the extent of asymmetry. In the following we briefly review the methods that have been developed to date.

One characteristic of the literature on asymmetric price transmission and especially estimation techniques is the strong focus on agricultural markets. Unlike other fields of economics, agricultural economics is characterised by a long running interest in testing for asymmetry. Oddly enough, however, this extensive literature appears to have had little impact on research in other areas of economics. In his otherwise comprehensive empirical analysis of asymmetry, for example, Peltzman (2000) does not cite any part of the agricultural literature.

4.1 The evolution of different test specifications

Different authors use different notations when presenting their results, often making it difficult to compare the different approaches. In the following we denote a firm's output price in period t as p_t^{out}. Furthermore, we assume that p_t^{out} is caused by the input price in t, denoted

p_t^{in}. Assuming symmetric and linear price adjustment, the following equation can be used to study price transmission:[5]

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

There is a long history of estimating asymmetric adjustment in the broader sense of irreversibility. Farrell (1952) was the first to investigate irreversibility empirically, focusing on the estimation of irreversible demand functions.[6] In agriculture, Tweeten & Quance (1969) used 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 price transmission using our notation:

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

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 include only increasing input prices and another variable 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. Asymmetric adjustment obtains if β_1^+ and β_1^- are significantly different, which can be evaluated using a standard F-test.

In the ensuing years Tweeten & Quance's technique was adopted and adapted to the study of price transmission processes. As a reaction to Tweeten & Quance, Wolffram (1971) proposed another variable splitting technique which explicitly includes first differences in the equation to be estimated:[7]

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

In equation (3), $\Delta p_t^{in} = p_t^{in} - p_{t-1}^{in}$. The recursive sums of all positive and all negative changes in the input price are as explanatory variables in the regression. Wolffram (1971) claims that this test is superior to that proposed by Tweeten & Quance, because their method yields an incorrect estimate of the parameters β_1^+ and β_1^- in equation (2). If equation (2) does represent

[5] If logarithms of prices are used (e.g. Peltzman, 2000; Goodwin & Piggott, 2001), a constant relative rather than a constant absolute margin is assumed.
[6] Marshall (1936) mentions the possibility of irreversible demand response.
[7] Wolffram (1971) mentions that irreversibility is not limited to price-supply relations. Trail et al. (1978) and Young (1980) propose a modified test specification for supply irreversibilities that accounts for so-called ratchet effects. This is not pursued here because it offers no germane methodological insights.

the actual data generating process, and if asymmetry is the case ($\beta_1^+ \neq \beta_1^-$), then p_t^{out} and p_t^{in} must drift apart. With increasing sample length this drift will become increasingly pronounced, leading to increasing estimates of α rises and biased estimates of β_1^+ and β_1^-.

Gollnick (1972) improved Wolffram's approach in a way that makes the test for asymmetry easier to calculate. By reparametrising equation (3) Gollnick produced:

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

which has the advantage that the t-value of the parameter β_1^- can be used to test directly for asymmetry, eliminating the need to estimate the restricted equation corresponding to (3) to calculate an F-statistic. Gollnick also introduced a reparametrisation of equation (4) that containing only first differences and not the sums of these differences as explanatory variables:

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

Gollnick pointed out that the assumption of a non-zero α in (5) implies the presence of a trend in (4).[8] Furthermore, ε_t in (4) and γ_t in (5) must be related by $\gamma_t = \varepsilon_t - \varepsilon_{t-1}$. Therefore, only one of these residual terms can be normally and independent distributed, implying that either (4) or (5) is misspecified. As an indication of this, autocorrelation is often found in test approaches that make use of parametrisations in levels (i.e. equations (3) and (4)).[9]

Houck (1977) presented a specification (6) that is similar to the Wolffram approach, but operationally clearer. Unlike Wolffram he didn't take the first observation 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 $p_t^{out} - p_0^{out}$:

$$p_t^{out*} = \alpha t + \beta_1^+ \sum_{t=1}^{T} D^+ \Delta p_t^{in} + \beta_1^- \sum_{t=1}^{T} D^- \Delta p_t^{in} + \varepsilon_t \quad (6)$$

Like Gollnick, Houck also proposed a specification that includes only first differences of the increasing and decreasing phases of the explanatory variables without summing these as in equation (3). The result is a straightforward reparametrisation of (5):

$$\Delta p_t^{out} = \alpha + \beta_1^+ D^+ \Delta p_t^{in} + \beta_1^- D^- \Delta p_t^{in} + \gamma_t \quad (7)$$

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[8] 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).

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

$$p_t^{out*} = \alpha t + \sum_{j=1}^{K} (\beta_j^+ \sum_{t=1}^{T} D^+ \Delta p_{t-j+1}^{in}) + \sum_{j=1}^{L} (\beta_j^- \sum_{t=1}^{T} D^- \Delta p_{t-j+1}^{in}) + \varepsilon_t \quad (8)$$

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

The number of lags K and L in equations (8) and (9) can differ, because there is no *a priori* reason to expect equal lag-lengths for the increasing and decreasing phases of the explanatory variables. Boyd and Brorsen (1988) were the first to use the inclusion of lags to differentiate between the magnitude and the speed of an asymmetry based on various comparisons between individual β–coefficients and sums of these coefficients. Hahn (1990) attempted to generalise all of the approaches discussed so far (for reasons which will become clear immediately, these can be refered to as the 'pre-cointegration' approaches). He proposes a Generalised Switching Model which, however, had little impact on the following literature.

The first attempt to draw on cointegration techniques in testing for asymmetric price transmission is v. Cramon-Taubadel & Fahlbusch (1996). This was later elaborated by v. Cramon-Taubadel & Loy (1996) and v. Cramon-Taubadel (1998), who demonstrate that tests based on equations such as (3), (5) and (7) are inconsistent with cointegration between p_t^{in} and p_t^{out}. They, therefore, suggest that an error correction model (ECM), extended by the incorporation of asymmetric adjustment terms,[10] may be used to test for asymmetric price transmission between cointegrated prices. According to this approach, first the cointegration relationship is estimated according to equation (1). In the event of cointegration, the lagged cointegrating residuals μ_{t-1} are split into positive and negative phases as outlined above and used in the estimation of an error correction equation. In this equation, lagged price differences on the right hand side can also be split, leading to the following specification:

$$\Delta p_t^{out} = \alpha + \sum_{j=1}^{K} (\beta_j^+ D^+ \Delta p_{t-j+1}^{in}) + \sum_{j=1}^{L} (\beta_j^- D^- \Delta p_{t-j+1}^{in}) + \phi^+ ECT_{t-1}^+ + \phi^- ECT_{t-1}^- + \gamma_t \quad (10)$$

As above, F-tests can be used to test for asymmetry.

Scholnick (1996) also uses an error correction model to test for asymmetric adjustment of interest rates, while Borenstein et al. (1997) uses a specification similar to (10) in which the

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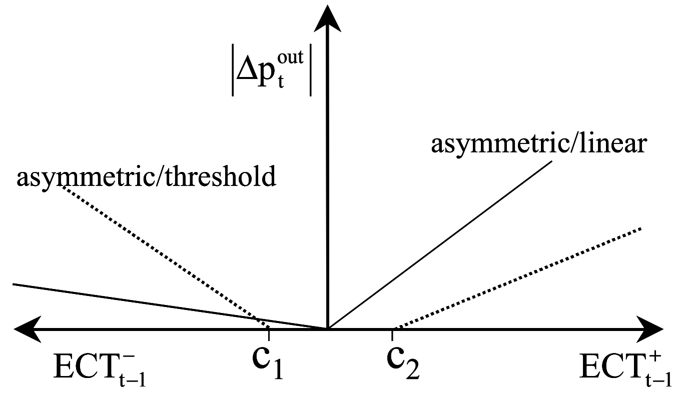
[9] see Appendix I

[10] This had first been proposed by Granger and Lee (1989).

Dia. 4: types of error correction



error correction term is not segmented. Balke et al. (1998) and Frost & Bowden (1999) also employ variants of the asymmetric error correction model.

All of these applications are based on linear error correction. Following the threshold approach introduced by Tong (1983), it is conceivable that deviations from the long-run equilibrium price relationship (1) will only lead to price responses if these deviations exceed a specific threshold level. In diagram 4 a threshold error correction scheme is compared with asymmetric but linear error correction. Note that in diagram 4, c_1 need not equal c_2, and that the threshold scheme nests standard linear error correction (symmetric or not) when $c_1 = c_2 = 0$. Azzam (1999) suggests that threshold error correction is plausible in the presence of adjustment costs.

Two different applications of the threshold error correction approach are documented in the literature. 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 any long run equilibrium.[11] Based on Balke & Fomby (1997) and Tsay (1989), Goodwin & Holt (1999), Goodwin & Harper (2000) and Goodwin & Piggott (2001) test for non-linearity in the form of thresholds in the error correction term. If linearity is rejected, a multiple threshold error correction model is estimated. Equation (11) shows one specification including two thresholds c_1 and c_2:[12]

$$\Delta p_t^{out} = \begin{cases} \alpha^1 + \sum_{j=1}^{K} (\beta_j^1 \Delta p_{t-j+1}^{in}) + \phi^1 ECT_{t-1} + \gamma_t & \text{if } ECT_{t-1} < c_1 \\ \alpha^2 + \sum_{j=1}^{K} (\beta_j^2 \Delta p_{t-j+1}^{in}) + \phi^2 ECT_{t-1} + \gamma_t & \text{if } c_1 \le ECT_{t-1} \le c_2 \\ \alpha^3 + \sum_{j=1}^{K} (\beta_j^3 \Delta p_{t-j+1}^{in}) + \phi^3 ECT_{t-1} + \gamma_t & \text{if } ECT_{t-1} > c_2 \end{cases} \quad (11)$$

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[11] The result is improved inference regarding the presence of cointegration. Abdulai (2000, 2002) uses the Enders and Granger framework in an application to Swiss pork markets.

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

Besides agricultural markets, especially those for gasoline and financial products (interest rates) are also commonly tested for asymmetric price transmission. Outside of agricultural economics, however, a number of more eclectic approaches to testing for asymmetry can be found. Carlton (1986), for example, bases his test of asymmetric price adjustment on an purely descriptive analysis. He claims that in the case of negative asymmetric transmission, the smallest positive price change should be smaller than the smallest negative price change. Finally, recent studies of asymmetric adjustment within the banking sector include more sophisticated but often inconsistent tests. 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 asymmetric price transmission; there is little sense of methodological progress based on a broad consensus among practitioners. Some recent publications have made use of 'pre-cointegration' test methods (e.g. Schertz et al., 1997; Peltzman, 2000) without refering to these.[13] 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 asymmetric price transmission in the gasoline market. In this study, no mention is made of the extensive agricultural economic literature. While the incorporation of time series concepts such as cointegration and threshold effects certainly represents refinement, as new methods have been added to the toolbox, there appears to be no broad agreement that others have become obsolete and should be removed.

4.2 A summary of applications of different test methods

In the following we briefly review the empirical applications of the methods outlined above. To date there have been 38 publications in major journals on the estimation of asymmetric price transmission, 25 of which have appeared in the last decade. An overview of these publications can be found in appendix 1. 25 of 38 are concerned with agricultural products, 12 of these with meat markets. 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 U.S. markets; 7 deal with

[13] Peltzman (2000) essentially makes use of a test that is identical to one proposed by Gollnick in 1971. To be fair, he also makes use of a test which includes an error correction term. However, this term is not based on estimated deviations from a long run equilibrium but, rather, is calculated as the simple unweighted difference between output and input price indices.

spatial and the rest with vertical price transmission. Most applications are based on monthly and weekly price data (22 and 11 studies, respectively), while daily, fortnightly and quarterly data are each used once.

Nearly half of the tests for asymmetric price transmission make use of some variant of the 'pre-cointegration' approaches (17 of 38). ECM and threshold approaches which take the time-series characteristics of the data into consideration are employed in 11 papers (4 ECM / 7 threshold). 7 studies, primarily based on non-agricutural markets, apply a variety of other approaches.

It would be interesting to find out if there is a link between the estimation method and the results obtained. However, only 3 studies apply different tests to the same data (see below). Table 1 presents the 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 38 publications yield 197 individual tests of asymmetric price transmission. Of these, 93 apply a pre-cointegration test based on first differences (equations (7) and (9)), 47 apply a pre-cointegration approach based on recursive sums of first differences (equations (3), (6) and (8)), 31 apply an asymmetric error correction model (equation (10)) and 28 apply either threshold or other techniques.

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	197	93	47	31	10	18
Symmetry maintained	102	30	36	17	2	17
Symmetry rejected	95	63	11	14	8	1
Symmetry rejected (%)	48	68	23	45	80	6

Note that Peltzman's (2000) tests are not included in table 1, because his 282 individual tests would 'swamp' our analysis. However, Peltzman's results can be compared with those that are based on pre-cointegration methods using first differences (second row in table 1). 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 asymmetric price transmission in 68% of their tests. Over all applications in the literature, 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 (23 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.

4.3 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. V. Cramon-Taubadel & Loy (1999) take a first stab at proposing a comprehensive testing procedure based on diagnostic 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 is especially true when the recursive sums of positive and negative price changes are included on the right hand side of a test regression (see equation 3, 6 and 8). Gauthier & Zapata 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, behaviour of the different asymmetry tests in the presence of data anomalies is another important issue. V. Cramon-Taubadel & Meyer (2000) study the behaviours of the available tests in the presence of structural break in the underlying price series using Monte Carlo simulations. They find that all methods lead to a significant over-rejection 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, they recommend that tests for structural breaks be employed prior to tests for asymmetry to improve the reliability of inference regarding the symmetry of price transmission.

A third important issue is that of data frequency. It was mentioned above that most tests for asymmetry in the literature are based on monthly data (22 of 38 publications). Only two papers specifically address the issue of data frequency; v. Cramon-Taubadel & Loy (1996) contrast the results of using weekly and monthly data, while Borenstein et al. (1997) work with weekly and fortnightly data. V. Cramon-Taubadel & Loy (1996) point out that any empirical attempt to quantify dynamic relationships such as price transmission require data with a frequency exceeding the actual 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 of weeks, monthly and even lower frequency price data will be inappropriate (v. Cramon-Taubadel, Loy & Musfeldt 1995; Boyd & Brorsen 1988). In view of the fact that data frequency plays a crucial role in attempts to identify and quantify price transmission, the lack of attention to this issue in the literature on asymmetry to date is notable.

Fourth, only few studies explicitly attempt to link empirical confirmation of asymmetric price transmission to the factors that have been proposed as possible causes of asymmetry in the theoretical literature. 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). Miller & Hayenga (2001) propose a frequency-based approach to testing for asymmetry. They argue that standard time domain methods can mask “…asymmetries that occur in subsets of the frequency domain…” (p. 561), and that different causes will tend to generate asymmetries in different subsets of this domain. They, therefore, propose a band spectrum regression to estimate asymmetric adjustment in low- and high-frequent price changes. These studies suggest interesting avenues for future research that would address the problem that, as Azzam (1999) formulates, so far asymmetry test are more useful in describing how markets look than how they work.

Finally, only few authors distinguish between asymmetry that is statistically significant and asymmetry that is economically meaningful (see, for example, v. Cramon-Taubadel, 1998). 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 asymmetry. Certainly, while adjustment costs might lead to artefactual asymmetry that is statistically significant but economically negligible, it would be reasonable to expect any asymmetry that is caused by the conscious use of market power to be economically meaningful, i.e. to produce a significant increase in eonomic profits.

5. Conclusion

The main results of this survey of the literature on asymmetric price transmission are sobering. The two main strands of this literature – the theoretical strand that discusses possible causes for asymmetry and the methodological strand that discusses empirical tests – both present a very broad range of results – theories and methods, respectively – but 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 asymmetry. An additional fault line in the literature that cuts across both the theoretical and methodological strands separates agricultural economics from the rest of the discipline. Agricultural economics has been responsible for the majority of publications on the topic of asymmetric price transmission 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.

The good news, of course, is that a great deal of interesting research beckons. Given the potential implications of asymmetric price transmission 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

no	author	year	Journal	method test	causality	time series	data product	ver./spat.	region	frequency	period	results asym./sym.	problems
1	Heinen	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.	-	x	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	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	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	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	Willet, Hansmire & Bernand	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 (f)	threshold	-	x	pork	vertical	switzerland	monthly	1988:1-1997:9	asymmetry	

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 E
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