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# Vertical price transmission in the Danish food marketing chain

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# Vertical price transmission in the Danish food marketing chain

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***Abstract***

*This purpose of this paper is to investigate price transmission patterns through selected Danish food marketing chains – from primary production to processing, from processing to wholesale and from wholesale to retail prices. Specifically, the study addresses the following research questions:*

- *To what extent are commodity prices transmitted from one stage to another in the food chain?*
- *What is the time horizon in the price transmission?*
- *Is price transmission symmetric – in the short run and in the long run?*
- *Is the degree of price transmission affected by the degree of concentration in the supply and demand stage considered?*

*These questions are analysed theoretically and empirically using econometric analysis. 6 food chains are investigated: pork, chicken, eggs, milk, sugar and apples. Empirical results suggest that for most commodities, price transmission tends to be upward asymmetric, i.e. stronger impact of upward than downward price changes. Most asymmetries in price transmission occur in the retail stage, fewest asymmetries occur in the wholesale stage. At the same time, most asymmetries in price transmission occur in the short run, whereas price transmission is symmetric in the long run in every case except one. Price transmission for commodities subject to price regulation tends to be less asymmetric than for commodities without price regulation. The degree of industry concentration seems to influence both the degree and asymmetry of price transmission, but the influence differs between sectors and stages of the food supply chain. Both transaction costs and imperfect competition seem to contribute to these asymmetries.*

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# Table of contents

# Preface

This research is conducted under the auspices of the project[1] "Perspektiver for og Udvikling over den danske fødevarekæde (phase 2)",[2] commonly known as "The Food Chain Project". This project is funded under the Inovationslov and administered by the Food Economy Directorate of the Danish Ministry of Agriculture (DFFE). The objectives of the project are to:

- measure changes in function, structure and commercial practice in the Danish food industry and compare and contrast these with developments in other countries;
- characterise vertical and horizontal relationships in the Danish food chain and their role in delivering optimal levels of food quality, variety and safety;
- evaluate the efficiency and competitiveness of the Danish food system at each stage of the marketing chain;
- review and evaluate instruments of Danish, EU and foreign public policy in the development of the food marketing chain; and
- communicate research results in a number of media.

This study examines vertical and horizontal price relationships, drawing econometric inference about the efficiency of the Danish food system in transmitting cost and price changes.

The working paper has been prepared by senior research fellow Jørgen Dejgård Jensen and research assistant Anja Skadkær Møller. Senior researchers Derek Baker and Lars Otto participated in the editing of the working paper.

Mogens Lund
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[1] Further information about the project are available from the author at **db@foi.dk**.
[2] "Perspectives and outlook for the Danish food marketing chain".

## Summary and conclusions

Agricultural policy leading to high prices at farm level may be expected to lead to high consumer prices of foods, and similarly lower costs for agriculture may be transmitted into lower food prices for consumers. To the extent that price transmission does not occur, consumers will not benefit from lower production costs in agriculture or food processing – nor will the consumers suffer as a result of higher agricultural costs and prices. The objective of the current study is to investigate short- and long-run vertical price transmission behaviour in the Danish food marketing system. The study focuses on patterns of price variation amongst commodities and stages of the food supply chain, using a set of publicly available data. Furthermore, to the extent that prices are not perfectly transmitted through the food supply chain, the study's objective is to identify the stages where defects in price transmission occur.

From a theoretical viewpoint, a number of arguments concerning the degree of competition as well as transaction costs may provide explanations for asymmetry in price transmission. It may be tempting to consider short-run asymmetries as a result of transaction costs, whereas long-run asymmetries might be the result of imperfections in the market structure.

The point of departure for the analysis is the *food supply chain approach* assuming a down-stream causal structure of price transmission. Data for the analysis has been obtained from Statistics Denmark. Price transmission down the food supply chain (farm-processing-wholesale-retail) has been investigated using econometric methods (cointegration analysis and error-correction models) for 6 food commodities: pork, chicken, eggs, milk, sugar and apples.

**Table 1. Findings concerning symmetries in price transmission in Danish food supply chains**

| | Farmgate -> processing | Processing -> wholesale | Wholesale -> retail |
|---|---|---|---|
| Pork | - ( < ) | - ( - ) | - ( < ) |
| Chicken | | - ( < ) | |
| Eggs | | - ( < ) | |
| Milk | - ( - ) | - ( - ) | - ( < ) |
| Sugar | - ( - ) | - ( - ) | - ( < ) |
| Apples | - ( < ) | - ( - ) | < ( > ) |

Note:

Results outside parenthesis: long run, results inside parenthesis: short run
- symmetric, > downward asymmetric, < upward asymmetric.

The analyses reveal some (almost) general patterns:

1. for most commodities, price transmission tends to be upward asymmetric, i.e. stronger impact of upward than downward price changes;
2. most asymmetries in price transmission occur at the retail stage, and the least asymmetries occur at the wholesale stage;
3. most asymmetries in price transmission occur in the short run, whereas price transmission is symmetric in the long run in every considered case except one;
4. price transmission for commodities subject to price regulation tends to be less asymmetric than for commodities without price regulation; and
5. the degree of industry concentration seems to influence both the extent and asymmetry of price transmission, but the influence differs between sectors and stages of the food marketing chain.

The apparent upward asymmetries in food price transmissions implies a welfare loss for Danish consumers in that they do not benefit from price declines to the same extent as the costs they face in times of price increases in food production. Hence, changes in agricultural policy leading to lower farm prices may not fully benefit the consumers, as some of the price decline is absorbed in the intermediate stages of the food supply chain – either as profits or as deadweight loss in terms of transaction costs.

The current analysis is not sufficiently precise to determine whether market power profits or transaction costs dominate the imperfections in price transmission from

farm to consumer. More research will be needed to improve the precision of the analysis in this respect, for example by means of more detailed empirical models taking into account the impacts of other input prices, cost structures etc. on output prices, possibly by means of firm-level data. Another avenue for further research would be to increase the range of products included in the analysis, as well as attempts to collect more precise data on prices etc. at different stages as a basis for improved estimation of price transmission behaviour in the Danish food supply chain.

# 1. Introduction

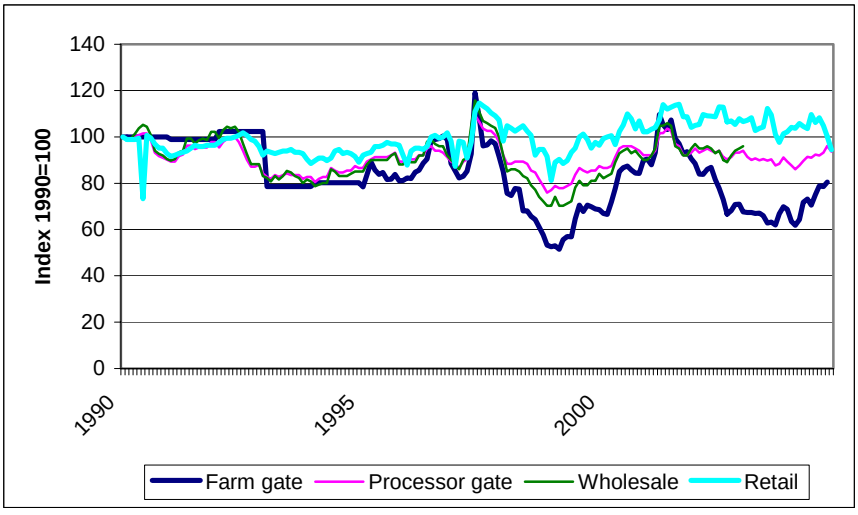
## 1.1. Background

Agricultural policy affects prices and thus the economic welfare of members of the food marketing chain. Agricultural policy leading to high prices at farm level may be expected to lead to high consumer prices of foods, and similarly lower costs for agriculture result in cheaper food for consumers. However, a crucial precondition for this to take place is that price and cost changes at farm level are transmitted through to the prices faced by consumers. To the extent that price transmission does not occur, consumers will not benefit from lower production costs in agriculture or food processing – nor will the consumers suffer as a result of higher agricultural costs and prices. This study investigates price transmission in the Danish food system.

## 1.2. Price patterns

As an example, figure 1 illustrates the development of pig meat prices at different stages of the Danish food supply chain, and the figure confirms that there is some correlation between the pig meat price at the different stages, but also that the wedge between farmers' and retailers' prices has increased during the last 15 years.

**Figure 1. Development in Danish pig meat prices at different stages of the food supply chain, 1990-2004**



### 1.3. Study objectives

The objective of the current study is to investigate price transmission behaviour in the Danish food marketing system. This focuses on patterns of price variation amongst commodities and stages of the food supply chain, using a set of publicly available data. Furthermore, to the extent that prices are not perfectly transmitted through the food supply chain, the study's objective is to identify the stages where defects in price transmission occur. Finally, the price transmission characteristics of the stages will be examined for their short and long term character.

### 1.4. Outline of the report

The paper is organised as follows. This introduction is followed by a brief survey of existing theory of price transmission. Section 3 describes the data and methodology used for the empirical study of the paper, and key results from the analysis are presented in section 4. Finally, section 5 draws some conclusions and perspectives and discusses the potential for improvements of the analysis.

# 2. Price transmission and economic theory

## 2.1. Horizontal and vertical transmission

The issue of price transmission has a long history in the economic literature, surveyed by Meyer and Cramon-Taubadel (2004). A distinction can be drawn between horizontal price transmission – representing the interaction between prices of a given commodity on different markets at the same stage of the supply chain – and vertical price transmission, which represents interactions between prices at different stages. Vertical price interactions can be characterised by degree (of completeness of pass-through of price change), speed, and type of price adjustments through the supply chain. Such changes are usually represented as responses to shocks at some point in the chain.

The degree of price transmission can depend on

- the importance of the delivery from an upstream stage of the chain for the total costs of producing a processed commodity (e.g. live pigs' share of the total costs of producing one kg of pork);
- the competitiveness of the market(s); and
- transaction costs associated with adjusting prices.

## 2.2. Symmetry in transmission

Some recent research effort has targeted asymmetries in price transmission. This encompasses differences in degree or speed of price adjustment, depending on whether the price change is up- or downward. Among factors that can explain such asymmetries, the literature most often finds two major types of explanation: transaction costs and imperfect competition.

### 2.2.1. Transaction costs

Transaction costs have a variety of sources. Menu costs (i.e. costs associated with changing price labels, advertisements etc) may lead to a situation where suppliers are more reluctant to reduce prices than to raise them (Ball and Mankiw, 1994), for example in an inflationary price environment. Uncertainty about whether a price change is temporary or long lasting is also likely to affect decisions on price changes, although whether this leads to upward or downward asymmetry in price transmission is ambiguous.

Time lags in price transmission may be a consequence of firms' holding inventory (Wohlgenant, 1985; Blinder, 1982). Hence, suppliers may be reluctant to lower their prices due to an input price decline, because they fear running down their inventory too quickly – running the risk of disappointing customers (Reagan and Weitzman, 1982). On the other hand, suppliers may be reluctant to increase the prices of products with a short shelf life and thus run the risk of not getting the products sold in time (Ward, 1982).

In addition, some accounting methods (e.g. FIFO) and taxation intricacies may provide incentives for asymmetries in the pricing responses by firms. Suppliers may also fear negative reputation effects, if they raise their prices too often, implying an upward asymmetry in price transmission. It has also been found that policy interventions (or expectations of such interventions) may lead to downward asymmetric price responses by market agents (Gardner, 1975; Kinnucan and Forker, 1987).

Goodwin and Piggott (2001) argue that some threshold price change must be exceeded, if the price change is to be transmitted to other stages of the food supply chain. Hence gains from changing the prices should more than outweigh the transaction costs associated with changing these prices.

### 2.2.2. Imperfect competition

In the presence of imperfect competition (e.g. due to strong concentration) market agents may have incentives – and possibilities – for exhibiting strategic behaviour in terms of pricing their products in ways that prevent raw material price changes from being fully transmitted to the prices of processed commodities. Such strategic explanations of asymmetric price response include:

- market agents' fears of invoking a price war by adjusting their prices downwards (Zachariasse and Bunte, 2003), leading to upward asymmetry in price transmission
- suppliers' possibility of exploiting consumers' geographical constraints and the fact that finding the best offer involves search costs (Benson and Faminow, 1985), also leading to upward asymmetry

Although increased market concentration may lead to a higher degree of strategic behaviour resulting in upward asymmetry in price transmission, the presence of larger firms may also imply presence and/or utilisation of economies of scale, which may

lead to more effective price transmission (McCorriston et al., 2001; Weldegebriel, 2004): the latter depending on the form of cost functions.

### 2.3. Ambiguities in interpretation

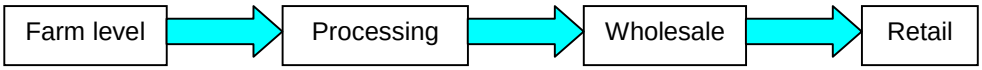
In summary, neither transaction costs nor imperfect competition can lead to unambiguous conclusions about the extent and direction of asymmetries in vertical price transmission. Most of the sources of transaction costs listed here may be expected to lead to upward asymmetry, although exceptions include firm' fear of not selling with short shelf life in time and the fear of interventions from competition authorities. High concentration in an industry may also be expected to lead to upward asymmetry, although economies of scale may in some cases lead to more symmetric price transmission. In specific cases, some of the above arguments may be more relevant than others, when taking specific account of, for example, the nature of the commodities, the structure of the industry, the variability of prices or the legislation surrounding the industry in question.

# 3. Empirical analysis

## 3.1. Conceptual model

The point of departure for the analysis is the *food supply chain approach* as illustrated in figure 2, and the causal structure of price transmission is assumed to follow the arrows in the chain.

**Figure 2. The food supply chain perspective**




Following Kinnucan and Forker (1987) and Bakucs and Fertö (2006), it is assumed that farm prices affect the processor's price, that processor prices affect wholesale price, and that wholesale prices affect retail prices.

## 3.2. Data

Data for the analysis has been obtained from Statistics Denmark. Monthly price data are publicly available at Statistics Denmarks's website (www.statistikbanken.dk), whereas (annual) data concerning market concentration have been provided by Statistics Denmark specially for the purpose. Price data (except farm gate prices) are expressed as price indices, and market concentration is measured in terms of the three largest suppliers' share of the total turnover of the commodity. Tables 2 and 3 provide descriptive statistics on the variables employed

**Table 2. Price data: Descriptive statistics, livestock origin products**

| Commodity | Level | Unit | First obs | Last obs | Mean | Std.dev. | Min | Max |
|---|---|---|---|---|---|---|---|---|
| Pork | Farm gate | DKK/kg | M01-90 | M10-04 | 9,71 | 1,64 | 5,98 | 13,80 |
| | Processor gate | Index(2000=100) | M01-85 | M11-04 | 101 | 8 | 82 | 123 |
| | Wholesale | Index(1990=100) | M01-81 | M12-02 | 96 | 10 | 71 | 121 |
| | Retail | Index(1980=100) | M01-80 | M11-04 | 154 | 20 | 96 | 189 |
| Chicken | Farm gate | DKK/kg | M01-90 | M09-04 | 4,74 | 0,37 | 4,19 | 5,46 |
| | Retail | Index(1980=100) | M01-80 | M09-04 | 133 | 15 | 92 | 163 |
| Eggs | Farm gate | DKK/kg | M01-97 | M09-04 | 1,49 | 0,12 | 1,22 | 1,70 |
| | Retail | Index(1980=100) | M01-80 | M10-04 | 172 | 44 | 92 | 263 |
| Milk | Farm gate | DKK/kg | M01-90 | M09-04 | 2,52 | 0,10 | 2,29 | 2,69 |
| | Processor gate | Index(2000=100) | M01-85 | M10-04 | 94 | 8 | 78 | 108 |
| | Wholesale | Index(1990=100) | M01-81 | M12-02 | 92 | 16 | 50 | 116 |
| | Retail | Index(1980=100) | M01-80 | M10-04 | 179 | 34 | 93 | 230 |
| Sugar | Farm gate | DKK/kg | M01-93 | M12-03 | 0,34 | 0,02 | 0,30 | 0,36 |
| | Processor gate | Index(2000=100) | M01-85 | M10-04 | 98 | 6 | 87 | 109 |
| | Wholesale | Index(1990=100) | M01-81 | M12-02 | 99 | 10 | 68 | 113 |
| | Retail | Index(1980=100) | M01-80 | M10-04 | 122 | 18 | 96 | 157 |
| Apples | Farm gate | kr/kg | M01-97 | M12-03 | 4,34 | 0,41 | 3,74 | 5,02 |
| | Processor gate | Index(2000=100) | M01-85 | M10-04 | 95 | 14 | 66 | 135 |
| | Wholesale | Index(1990=100) | M01-81 | M12-02 | 118 | 20 | 18 | 175 |
| | Retail | Index(1980=100) | M01-80 | M10-04 | 148 | 20 | 93 | 189 |

Source: Statistics Denmark.

**Table 3. Concentration ratios - the 3 largest companies' share of total turnover**

| | 1995-97 | 1998-2000 | 2001-04 |
|---|---|---|---|
| Pig slaughteries | 83% | 91% | 97% |
| Poultry slaughteries etc. | 57% | 59% | 78% |
| Dairies and ice-cream processors | 81% | 87% | 90% |
| Processing and conservation, fruits and vegetables | 63% | 69% | 58% |
| Sugar, sweets, chocolate processing | 77% | 75% | 78% |
| Processing of juice and soft drinks | 82% | 80% | 81% |
| Wholesale meat and meat products | | 30% | 30% |
| Wholesale fruit and vegetables | | 27% | 30% |
| Wholesale, fruit and vegetable juice | | 74% | 78% |
| Butcher shops | 3% | 4% | 5% |
| Fruit and vegetable shops | 7% | 6% | 13% |
| Groceries | 48% | 51% | 52% |
| Supermarkets | 50% | 64% | 57% |
| Warehouses | 95% | 93% | 89% |

Source: Statistics Denmark.

### 3.3. Empirical model and estimation procedure

The following empirical model is estimated employing an error correction specification:

$$\Delta p_t^s = \alpha_s + \beta_s \cdot \Delta p_t^{s-1} - \eta_s \cdot (p_{t-1}^s - \phi_s \cdot p_{t-1}^{s-1}) + \varepsilon_t^s \quad (1)$$

Where $p_t^s$ is the sales price at stage *s* at time *t*, $\Delta$ denotes the first difference between time periods and superscript $s-1$ denotes the stage immediately upstream from stage *s*. $\alpha_s$ is an intercept, interpreted as a linear trend, $\beta_s$ (and to some extend $\phi_s$) represents the price transmission effect and $\eta_s$ is a time-invariant adjustment parameter[3].

In order to investigate possible asymmetries in the food supply chain, we respecify equation (1) as:

$$\Delta p_t^s = \alpha_s + \beta_{s1} \cdot d_t^s \Delta p_t^{s-1} + \beta_{s2} \cdot (1 - d_t^s) \Delta p_t^{s-1} - \eta_s \cdot (p_{t-1}^s - \phi_s \cdot p_{t-1}^{s-1}) + \varepsilon_t^s \quad (2)$$

where $d_t^s$ is a dummy variable equal to one if $\Delta p_t^{s-1} > 0$ and zero otherwise. A significant difference between the two $\beta_s$ coefficients implies asymmetric price transmission in the sense that upward and downward price transmissions differ.

[3] The error-correction approach has been widely used for studying price transmission, e.g. Von Cramon-Taubadel (1998).

As a sensitivity analysis, various specifications of the model have been estimated at each point of interaction in the food supply chain in order to investigate the robustness of the results with respect to the model specification. Furthermore, the model has been estimated on subsets of the data material in order to investigate parameter invariance over time.

### 3.4. Econometric analysis

The error correction model (2) can be estimated, if all included terms are stationary, (i.e. they have time-invariant means, variances and autocovariances). This implies that the series $p^s$, $p^{s-1}$ and $c^s$ should be first order integrated, and that these series should be co-integrated (i.e. CI(1,1)).

Estimation of the model is based on the approach suggested by Engle and Granger (1987) and takes the following steps:

- analysis of univariate processes for each data series to investigate the order of integration and dynamic properties in the individual data series, using augmented Dickey-Fuller tests;
- test for cointegration on the basis of residuals from spurious regressions; and

if data series cointegrate, equation (2) is estimated using linear regression.

# 4. Results

## 4.1. Overview of results

Results from the analyses of univariate processes of the investigated price series are presented in table 4. Dickey-Fuller tests suggest that all the price series are stationary in first differences, and hence are first-order integrated.

**Table 4. Results of univariate ARIMA-analyses**

| Price Variable | Final model | Remarks |
|---|---|---|
| **Pork** | | |
| Farm gate | ARIMA(0,1,1) | |
| Processor gate | ARIMA(9,1,7) | Only few lags significant. |
| Wholesale | ARIMA(0,1,7) | |
| Retail | ARIMA(12,1,12) | |
| Export | ARIMA(12,1,12) | |
| **Chicken** | | |
| Farm gate | ARIMA(3,1,24) | Only few lags significant. |
| Retail | ARIMA(9,1,9) | Only few lags significant. |
| Export | ARIMA(0,1,0) | |
| **Eggs** | | |
| Farm gate | ARIMA(6,1,6) | |
| Retail | ARIMA(0,1,0) | |
| **Milk** | | |
| Farm gate | ARIMA(12,1,7) | Only few lags significant. |
| Processor gate | ARIMA(1,1,10) | |
| Wholesale | ARIMA(22,1,15) | Only few lags significant. |
| Retail | ARIMA(0,1,0) | |
| Export | ARIMA(0,1,1) | |
| **Sugar** | | |
| Farm gate (sugar beet) | ARIMA(0,1,0) | |
| Processor gate | ARIMA(0,1,0) | |
| Wholesale | ARIMA(12,1,12) | |
| Retail | ARIMA(0,1,0) | |
| Export | ARIMA(4,1,15) | |
| **Apples** | | |
| Farm gate | No model estimated | |
| Processor gate | ARIMA(1,1,1) | |
| Wholesale | ARIMA(1,1,1) | |
| Retail | ARIMA(5,1,5) | |
| Export | ARIMA(1,1,2) | |

No common pattern through the respective food chains can be identified from this analysis. For some sectors (e.g. pork, chicken, sugar and apples) price adjustments seem to be most complicated at the retail stage and most rapid at the farm stage, thus supporting this study's assumption of downstream causality from the farm stage to the retail stage. For other sectors (e.g. eggs and milk) the lag structure appears more

complicated at upstream stages, which might suggest a reverse causality structure in price formation.

Co-integration test were conducted for all models using the Engle-Granger procedure. The tests in general support the assumption of co-integration, and thus the validity of the Error Correction specification. In table 5, detailed estimation results from the error correction models are presented.

**Table 5. Estimated price transmission equations**

| | Pork | | | | Chicken | | Eggs | Milk | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Export-farmgate | Farmgate-processing | Processing-wholesale | Wholsale-retail | Export-farmgate | Farmgate-retail | Farmgate retail | Export-farmgate | Farmgate-processing | Proces-sing-wholesae | Wholesa-leretail |
| **Long-run relation** | | | | | | | | | | | |
| Intercept | -39,536 | 70,6183 | -26,863 | 90,8646 | 33,9516 | 196,2966 | 50,3119 | 80,3379 | 154,9552 | -23,6804 | 16,1333 |
| price_u | 1,4048 | 0,2935 | 1,2771 | 0,0623 | 0,5888 | -0,8529 | 0,6869 | 0,2016 | -0,4979 | 1,2207 | 0,9124 |
| price_d | 1,4048 | 0,2935 | 1,2771 | 0,0623 | 0,5888 | -0,8529 | 0,7087 | 0,2016 | -0,52186 | 1,2207 | 0,9124 |
| $R^2$ | 0,8409 | 0,5226 | 0,9571 | 0,0049 | 0,5246 | 0,4419 | 0,3627 | 0,1308 | 0,2187 | 0,9774 | 0,9165 |
| **Error correction relation** | | | | | | | | | | | |
| Dprice_u | 0,7871 | 0,3449 | 1,3313 | 0,3527 | 0 | 0,7011 | 0,2482 | 0 | 0 | 1,4587 | 0,3407 |
| Dprice_d | 0 | 0,2098 | 1,3144 | 0,1482 | 0,0792 | 0 | 0,037 | 0 | 0 | 1,4727 | 0 |
| EC-term | -0,3263 | -0,09108 | -0,1002 | -0,0308 | -0,0887 | -0,0209 | -0,0315 | -0,1069 | -0,0464 | -0,1541 | -0,0512 |
| Lagged price terms | | | | X | X | X | | X | | | |
| Error term process | | | | X | X | | X | X | X | | |
| $R^2$ | 0,2785 | 0,4114 | 0,9214 | 0,2879 | 0,421 | 0,1846 | 0,1396 | 0,6884 | 0,0409 | 0,7516 | 0,0697 |
| White | <.0001 | 0,224 | 0,0615 | <.0001 | 0,001 | 0,2858 | 0,1512 | 0,0002 | 0,1038 | 0,0004 | 0,0099 |
| Breusch-Pagan | 0,0038 | 0,6853 | 0,0015 | 0,021 | 0,443 | 0,4624 | 0,1248 | 0,3609 | 0,1331 | 0,1332 | 0,0022 |
| Breusch-Godfrey | 0,4663 | 0,4065 | 0,0036 | 0,0698 | 0,6433 | 0,0078 | 0,5128 | 0,998 | <.0001 | 0,3257 | 0,0594 |
| Price transmission elasticities | | | | | | | | | | | |
| $E_L^u$ | 1,35 | 0,28 | 1,24 | 0,07 | 0,63 | -0,83 | 0,79 | 0,21 | -0,53 | 1,35 | 0,83 |
| $E_L^d$ | 1,35 | 0,28 | 1,24 | 0,07 | 0,63 | -0,83 | 0,81 | 0,21 | -0,56 | 1,35 | 0,83 |
| $E_S^u$ | 0,76 | 0,33 | 1,29 | 0,38 | 0,00 | 0,69 | 0,28 | 0,00 | 0,00 | 1,62 | 0,31 |
| $E_S^d$ | 0,00 | 0,20 | 1,27 | 0,16 | 0,08 | 0,00 | 0,04 | 0,00 | 0,00 | 1,63 | 0,00 |
| Symmetry | | | | | | | | * | * | | |
| Upward asymmetry | * | * | * | * | | * | * | | | | * |
| Downward asymmetry | | | | | * | | | | | * | |

**Table 5. Estimated price transmission equations (cont.)**

| | Sugar | | | | Apples | | | |
|---|---|---|---|---|---|---|---|---|
| | Export-farmgate | Farmgate-processing | Processing-wholesale | Wholesale-retail | Export-farmgate | Farmgate-processing | Processing-wholesale | Wholesale-retail |
| **Long-run relation** | | | | | | | | |
| Intercept | 95,7828 | 103,2546 | 0,0852 | 158,1437 | 20,5869 | 79,3009 | 0,0239 | 48,4755 |
| price_u | 0,0154 | -0,0438 | 0,9995 | -0,4633 | 0,7315 | 0,4476 | 0,9995 | 0,4587 |
| price_d | 0,0154 | -0,0335 | 0,9995 | -0,4633 | 0,767 | 0,4476 | 0,9995 | 0,4587 |
| $R^2$ | 0,0019 | 0,0101 | 1 | 0,0559 | 0,1559 | 0,0947 | 1 | 0,5822 |
| **Error correction relation** | | | | | | | | |
| Dprice_u | 0 | 0 | 1,0037 | 0,7619 | 0,0148 | 0,056 | 1,0005 | 0,058 |
| Dprice_d | 0 | -0,1087 | 1,0073 | 0 | 0,0143 | -0,0509 | 0,9984 | 0,1017 |
| EC-term | -0,0834 | 0 | -0,3608 | -0,0196 | -0,0444 | -0,1653 | -1,8344 | -0,1635 |
| Lagged price terms | | | | | | | | X |
| Error term process | | | X | | | | X | X |
| $R^2$ | 0,0365 | 0,025 | 0,9988 | 0,0398 | 0,0148 | 0,082 | 1 | 0,135 |
| White | 0,0693 | 0,321 | <.0001 | 0,1569 | 0,8405 | 0,8206 | 0,6208 | 0,9309 |
| Breusch-Pagan | 0,0858 | 0,2461 | 0,2821 | 0,6175 | 0,9621 | 0,314 | 0,0149 | 0,4236 |
| Breusch-Godfrey | 0,6116 | 0,422 | 0,027 | 0,2049 | 0,8337 | 0,8799 | 0,8461 | 0,9039 |
| $E_L^u$ | 0,01 | -0,04 | 1,04 | -0,37 | 0,80 | 0,39 | 1,04 | 0,51 |
| $E_L^d$ | 0,01 | -0,03 | 1,04 | -0,37 | 0,84 | 0,39 | 1,04 | 0,51 |
| $E_S^u$ | 0,00 | 0,00 | 1,05 | 0,61 | 0,02 | 0,05 | 1,04 | 0,06 |
| $E_S^d$ | 0,00 | -0,11 | 1,05 | 0,00 | 0,02 | -0,04 | 1,03 | 0,11 |
| Symmetry | * | | | | | | | |
| Upward asymmetry | | * | | * | * | * | * | |
| Downward asymmetry | | | * | | | | | * |

The estimation of each error correction equation has been conducted in two steps. In the first step, the long run relationship between the price variable at two food chain stages has been estimated using linear regression. The "Long-run relation" (see upper panel of table 5) results show the results of this regression. For example in the pork farmgate-processing relationship, the coefficient 0.2935 represents the impact of a one unit change in the farm gate price on the processor price. Effects of upward price changes (price_u) and downward price changes (price_d) are identical in this example. The goodness-of-fit of this regression is measured by the $R^2$ (0.5226 in the pork farmgate-processor price equation).

In the second stage, the error correction model is estimated, conditional on results of the long-run regression. This conditionality is represented by the EC-term - deviation between observed and predicted values from the long-run regression in the previous period. The estimation coefficients Dprice_u and Dprice_d represent short-run impacts of upstream price changes on the price in the subsequent stage. In the pork farmgate-processing example, the short-run response appears to be stronger in case of upward price changes than of downward changes. The coefficient of the EC-term represents the price adjustments induced by long-run disequilibrium in the previous period. For example, if the observed processor price exceeded the 'predicted' processor price in the previous period, a negative coefficient suggests a downward price adjustment in order to re-approach the long-run equilibrium. As expected, the estimated coefficients for EC-terms are non-positive in all price transmission models.

In the table, indications are given whether the model includes lagged price terms or dynamic error-term processes. Furthermore, the table provides diagnostics for heteroscedasticity (White's and Breusch-Pagan's tests), and for first-order autocorrelation the Breusch-Godfrey test). For White, Breusch-Pagan and Breusch-Godfrey, the table displays the significance of the diagnostic, i.e. the probability of the hypothesis of obtaining the implicit test statistic, if the assumption of no heteroscedasticity (or autocorrelation) were true. The results illustrate some problems with heteroscedasticity in the pork price transmission equations as well as a few others, but overall the model specifications seem not to suffer from problems of autocorrelation.

The bottom part of the table presents the price transmission results in terms of up- (u) and downward (d) price transmission elasticities (E), in the long (L) and short (S) runs.
There are three dimensions to the results presented in table 5: a commodity dimension; a supply chain stage dimension; and a time horizon dimension. Concerning the

commodity dimension, few asymmetries are found for milk and sugar, two commodities that have been governed by guaranteed prices from the EU Common Agricultural Policy (CAP). Some upward asymmetry, i.e. suppliers more likely to transmit increased input prices into their output prices than decreased input prices, has been indicated for pork and poultry commodities, where prices have not been subject to EU intervention. For apple prices, indications are more mixed.

Concerning the supply chain stage dimension, most asymmetries occur in the retail stage, whereas the price transmission in the wholesale stage appears to be fairly symmetric for most commodities (although the sources of asymmetry processing, wholesale or retail for poultry products cannot be identified due to data shortage).

Asymmetries appear to be more prevalent in the short run than in the long run, which was also expected. Indeed, there is only one example of asymmetry in the long run, according to the estimations presented in table 5: apples at the retail stage.

In the following, two cases are discussed and interpreted in greater detail: pork and apples.

### 4.2. Pork

Some 20-30% of a change in the farmgate pork price is transmitted through to the processor's sales price. This figure could be confronted with the fact that pork processors' cost of "raw materials" (of which the main part is pig carcasses) amount to around two thirds of the total costs of slaughteries. Hence, the processing stage seems to absorb part of the price fluctuations on pig carcasses[4]. The transmission of prices from farm to processor level is fairly symmetric, although slight upward asymmetry is indicated in the short run. The speed of adjustment tend s not to be asymmetric.

Sensitivity analyses suggest that the price transmission from farm to processor's price has become more stable over time, whereas there seems to have occurred considerable fluctuations in the price transmission coefficient in the early 1990s. At the same time, there seems to be a correlation between concentration in the slaughtery sector

[4] However, it should be noted that in the Danish cooperative slaughteries, part of the payment to farmers for their deliveries takes place in the form of after-payments - dividends based on delivered amounts - which are presumably not included in the applied price data at the farm level. If these after-payments were included in the farm price data, correspondence between price transmission and pig carcasses' share of total processors' costs might have been higher.

and the stability of the price transmission coefficient. One explanation of this perhaps surprising result might be that processors' fear of triggering a costly price war by reducing sales prices, has declined in association with increasing concentration in the Danish pork processing industry.

The transmission of prices at the wholesale stage appears to be very strong, in that the elasticity of price transmission exceeds one, which is somewhat surprising. However, econometric tests do not reveal a clear causality structure, so one explanation could be that the direction of causality goes from the wholesale to the processor stage, and not as assumed in the estimated model – or that no causality exists, and the pattern is obtained by accident. It should be noted, however, that the estimated coefficient is fairly robust over time. Another explanation for the obtained result might be that firms at the wholesale stage actually increase their margins relatively strongly in times of increasing prices, but (for example due to expectations of further price movements in the same direction) aim to reduce transaction costs related to the number of price adjustments.

In contrast to the price transmission from farm to processing level, the degree of asymmetry and the variation in the degree of asymmetry seems to increase with concentration at the wholesale stage. An explanation for this difference may be that while concentration cf. table 3 is around 97% at the processing stage, it is around 35% at wholesale. It is thus possible that increased concentration at the wholesale stage leads to intensified competition and more strategic behaviour, e.g. fear of price wars etc., whereas the increased concentration in the processor stage represents a movement from intensive competition towards a more monopoly-like situation, where the need for strategic behaviour in the market becomes smaller. Sensitivity analyses also indicate that the speed of adjustment is negatively correlated with the degree of concentration at the wholesale stage.

At the retail stage, the transmission of prices from the wholesale level is relatively weak in the long run, but in the short run, 25-40% of the change in wholesale price is transmitted to retail prices – most significant with upward price changes. One interpretation of this finding is that even though the wholesale price is important, a number of other conditions contribute to determining the retail price, including the form and level of processing at which the meat is sold at retail. The rate of price transmission has been subject to some variation over time, and it appears to be negatively correlated with the degree of concentration at the retail stage (supermarkets etc.). In addition, there has been a weak trend towards narrowing the margin between retail and

wholesale prices for pork (which may also be related to changes in the form of the final product and the extent of in-shop processing of the meat).

### 4.3. Apples/fruits

From the farm-gate to the processing level, apple/fruit prices are symmetrically transmitted by 40% in the long run. In the short run, the price transmission is somewhat weaker and slightly upward asymmetric. The price transmission coefficient appears to be somewhat unstable over time, which may be a result of relatively poor data quality and the fact that a large share of the harvested apples are used for direct consumption, rather than for processing. Hence, the farm-level price data do not precisely reflect the input price of apple processing firms. Still, the overall upward asymmetry in the short run makes sense due to the relatively high degree of concentration in the fruit processing industry.

Changes in wholesale prices of fruits are transmitted to retail prices at a rate of 50%, and fairly stable over time. An interesting feature of this transmission is that the transmission is upward asymmetric in the long run, but downward asymmetric in the short run. One possible explanation for the short-run downward asymmetry could be the relatively short shelf-life of fresh fruits, which may make supermarkets reluctant to increase the prices in the short run and running the risk of not getting their inventory of apples sold. On the other hand, the upward asymmetry in the long run may reflect a retailers' strategy of reducing their market risks in times of high fruit prices, by aiming at a higher retail price while reducing planned sales of fruits with short shelf life. The price transmission tends to be more upward asymmetric, the more concentrated is the retail stage (supermarkets).

### 4.4. Other commodities

For poultry products (chicken and eggs) it was possible to obtain price data for only the farm and retail stages. Hence, it was not possible to analyse price transmission at other stages. The patterns of price transmission from farm to retail are quite similar for the two products, and the underlying market structures are also quite similar – with two dominating processing companies: one cooperative and one privately owned company in each sector, along with a number of fairly small firms. The degree of price transmission from farm to retail is 60-80%, symmetric in the long run but somewhat asymmetric in the short run. There do not seem to be any trends in the price

transmission coefficient, although the transmission coefficient for chicken varies to some extent over time.

For milk and sugar, the price transmission from farm to processor level is rather weak, and in both cases subject to considerable uncertainty, although the price transmission for milk increase over time. As mentioned above, possible reasons for this weak price transmission may be the existing CAP regime providing effectively binding (intervention) prices for dairy products and sugar. Another reason may be that in the case of milk, the processor price is represented by the processor price of fluid milk, whereas a large share of the raw milk is actually processed into other dairy products like butter and cheese. Hence, the processor price may not fully reflect the price development faced by dairy processors. For sugar, the weak price transmission may be explained by the fact that sugar beets constitute only a minor share of total processing costs of sugar. For both commodities, there is a strong (around one-to-one) price transmission through the wholesale stage. In the case of sugar, this rate of transmission is stable over time, whereas for milk it is fairly unstable. From wholesale to retail, the price transmission is strong and symmetric in the long run (80-85%) for milk, whereas the transmission for sugar is weak but symmetric. In the short run, price transmission is asymmetric for both commodities.

# 5. Discussion

In this paper, price transmission down the food marketing chain (farm-processing-wholesale-retail) has been investigated using econometric methods for 6 food commodities: pork, chicken, eggs, milk, sugar and apples. The analyses reveals some (almost) general patterns:

1. for most commodities, price transmission tends to be upward asymmetric, i.e. stronger impact of upward than downward price changes;
2. most asymmetries in price transmission occur at the retail stage, and the fewest asymmetries occur at the wholesale stage;
3. most asymmetries in price transmission occur in the short run, whereas price transmission is symmetric in the long run in every considered case except one;
4. price transmission for commodities subject to price regulation tends to be less asymmetric than for commodities without price regulation; and
5. the degree of industry concentration seems to influence both the extent and asymmetry of price transmission, but the influence differs between sectors and stages of the food chain.

As discussed in section 2, a number of arguments concerning the degree of competition as well as transaction costs, may provide explanations for asymmetry in price transmission. It may be tempting to consider short-run asymmetries to be a result of transaction costs, whereas long-run asymmetries might be the result of imperfections in market structure. If this is the case, most of the asymmetries identified in the empirical analysis may be associated with various types of transaction costs, where menu costs might be one of the most important ones in the retail sector. On the other hand, sensitivity analyses reveal that market concentration seems to influence the price transmission pattern in the long run, suggesting that market structure also has an effect.

The apparent upward asymmetries in food price transmissions implies a welfare loss for Danish consumers in that they do not benefit from price declines to the same extent as they lose from price increases in times of cost increases in food production. Hence, changes in agricultural policy leading to lower farm prices may not fully benefit the consumers, as some of the price decline is absorbed in the intermediate stages of the food marketing chain – either as profits or as deadweight loss in terms of transaction costs.

The results presented in this paper are subject to uncertainty for a number of reasons. The analysis builds on generally available data concerning different stages of the considered food supply chains. As mentioned above, however, changes in the definition or composition of the underlying baskets of commodities may have changed during the data period. Data for some of the price variables were available on a monthly basis, whereas others were available only on a quarterly or annual basis, which of course implies uncertainties in the estimated dynamics of the price transmissions. It should also be mentioned that the specified econometric models are relatively simply, imposing relatively strict assumptions on the transmission of other input prices (e.g. costs of labour or capital) to the output price at a certain stage of the food chain. Concerning rates of concentration, it has been attempted to use rates from the most appropriate industry, but in some cases – especially in the retail stage – both specialised retailers (butchers, green grocers etc.) and broader-focused supermarkets play roles, with supermarkets often dominating market share for most commodities. Supermarkets have been selected as representative for the retail stage for all considered commodities, but this assumption may contribute some uncertainty to the results.

The current analysis is not sufficiently precise to determine whether profits related to market power or transaction costs dominate the imperfections in price transmission from farm to consumer. More research will be needed to improve the precision of the analysis in this respect, for example by means of more detailed empirical models taking into account the impacts of other input prices, cost structures etc. on the output prices, possibly by means of firm-level data. Another avenue for further research would be to increase the range of products included in the analysis, as well as attempts to collect more precise data on prices etc. at different stages as a basis for improved estimation of price transmission behaviour in the Danish food marketing chain.

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