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**Theoretical analysis of price transmission:
A case of joint production**

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Zusammenfassung

Um die Preisbeziehungen entlang der Wertschöpfungskette bei Lebensmitteln zu bewerten, ist es notwendig, die Prozesse der Preisbildung theoretisch zu erklären. Es gibt einige theoretische Modelle, die aber allesamt Monoproduktansätze sind, eine Modellierung der Preiszusammenhänge für den Multiproduktfall fehlt bislang. Die vorliegende Dissertation möchte hierzu einen Beitrag leisten.

Ein erstes Modell in diesem Bereich stammt von Gardner (1975), der die Methode der Gleichgewichtsverschiebung verwendet. Die Methode der Gleichgewichtsverschiebung wurde Mitte des letzten Jahrhunderts entwickelt und findet noch heute im Bereich der theoretischen Marktmodellierung Anwendung. McCorrison et. al. (2001) verwenden diesen Ansatz, um den Einfluss von Marktmacht und Skalenerträgen auf die Höhe der Preistransmissionselastizität zu bestimmen. Sie können zeigen, dass die Preistransmission bei vollkommenem Wettbewerb stärker ist als bei nicht vollkommenem Wettbewerb. Die Preistransmission ist zudem bei Industrien mit steigenden Skalenerträgen höher als bei Industrien mit konstanten Skalenerträgen. Die Sensibilitätsanalyse im Rahmen verschiedener Szenarien zeigt, dass die Wirkungen der Skalenerträge die der Marktmacht verstärken oder reduzieren können. Sowohl Gardner als auch McCorrison et. al. (2001) haben sich bei ihren Untersuchungen auf einen einzelnen Output beschränkt. Im landwirtschaftlichen Bereich gibt es viele Beispiele für Multiinputs und Multioutputs bei der Verarbeitung, z.B. die Verarbeitung von Milch zu Butter und Magermilchpulver.

In der vorliegenden Arbeit wird deshalb die Preistransmission aufbauend auf dem Modell von McCorrison et. al. (2001) für einen Multioutput und Multiinputfall modelliert. Als Beispiel dient die Milchverarbeitung, die einerseits Koppelprodukte wie Butter und Milchpulver oder Käse und Molke produziert, wobei beide Gruppen selbst also Käse und Butter Substitute darstellen. Die Ergebnisse verdeutlichen die Rolle der Verbundproduktion für die Preistransmission. So ist die Preistransmission bei vollkommenem Wettbewerb nicht mehr gleich dem Anteil des landwirtschaftlichen Inputs wie im Modell von McCorrison et. al. (1989). Bei perfektem Wettbewerb sowie konstanten Skalenerträgen hängt die Transmission des Preises verbundener Endprodukte von dem Anteil des landwirtschaftlichen Inputs und von der Elastizität der Nachfrage der gemeinsam produzierten Güter sowie von dem Anteil der verbunden produzierten Produkte am Brutto-Endprodukt ab. Die Preisänderung eines Inputs wird in Abhängigkeit von den Preiselastizitäten der Nachfrage unterschiedlich auf die Preise der im Verbund produzierten Endprodukte übertragen.

Summary

In order to improve the market-based relationships between the stakeholders of the food chain and to increase transparency along the chain it is necessary not only to detect the incomplete price relationship, but also to identify the causes of its malfunctioning. A number of studies investigate the mechanism of price transmission in order to theoretically identify the causes of incomplete price transmission. This dissertation intends to enlarge the theory on this issue. Following Gardner (1975), such studies traditionally use the equilibrium displacement methodology for this purpose. Since the middle of the last century, the equilibrium displacement methodology has been developed to incorporate new features, thus, contributing to the new results and discoveries in price transmission theory. For example, McCorrison et al. (2001) study the impact of market power and returns to scale on price transmission elasticity. By assigning certain values to the model parameters they prove that price transmission under perfect competition is higher than under imperfect competition, and that price transmission in the industry with increasing returns to scale, is higher than in the industry, with constant returns to scale. The sensitivity analysis within different scenarios shows that the role of returns to scale may either reinforce or offset the impact of market power. Gardner and McCorrison et al., however, focus on a single output product, whereas agricultural inputs often serve as ingredients for multiple outputs. Multiple outputs are generated spontaneously from a single production process so that the increase in production of one good cannot take place without a simultaneous increase in production of the other good. Therefore this work extends the model of McCorrison et al. (2001) for price transmission in the case of multi-inputs-multi-outputs. Dairy industry is chosen as an example for this model, which produces goods-complements in production such as butter and skim milk powder or cheese and whey, however, both groups present the example of goods-substitutes in production, such as cheese and butter. Model results show that it is necessary to consider the properties of joint production when estimating the price transmission of jointly-produced goods because the price transmission of a jointly-produced output is different from that of a single output. The price transmission of a joint output is not equal to the share of agricultural input, as it is in the case of a single output (McCorrison et al., 1989). In the case of perfect competition and constant returns to scale, the price transmission of a joint output depends not only on the share of the agricultural input, as in the case of a single output, but additionally on the elasticities of demand of the jointly-produced goods and on the share of the joint output in a gross output. The price of an input is differently transmitted to two jointly-produced goods depending on two independent retail demand elasticities of those goods.

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CHAPTER 1

Introduction

Background of the topic

Agricultural prices have displayed extreme fluctuations over the last two years, reaching exceptional levels in the second half of 2007 and the first months of 2008 before falling sharply in the wake of the economic crisis (European Commission, 2009a). Since then, the prices of many commodities have come down to levels comparable to or even lower than those reached before the start of the price surge. However, consumer food prices continued to increase, and only started declining in May 2009, raising concerns about the functioning of the food supply chain. These changes have caused considerable hardship for agricultural producers while currently implying that consumers are not getting a fair deal (European Commission, 2009b). The magnitude, delay and asymmetry in the adjustment of food prices have raised serious concerns about the functioning of the EU food supply chain and the distribution of value-added between primary producers, processors, wholesalers and retailers. The effective distribution of benefits among the food supply chain is crucial to remain competitive (regarding consumers wanting lower prices and agricultural producers higher prices). This is important, first, for the efficient welfare distribution in the society, and second, to ensure that various economic actors fully benefit from agricultural policy reforms toward greater market orientation.

There are a number of studies estimating incomplete price transmission on various agricultural markets (e.g. Houck, 1977; Kinnukan & Forker, 1987; Griffith & Piggott, 1994; Zhang et al., 1995; Punyawadee et al., 1991; Traill & Henson, 1994; Worth, 2000; Parrot et al., 2001; Sanjuan & Gil, 2001; Ben-Kaabia & Gil, 2007; etc.). However, in order to improve the market-based relationships between the stakeholders of the food chain and to increase transparency along the chain it is necessary not only to detect the incomplete price relationship, but also to identify the causes of its malfunctioning. There are a number of studies investigating the mechanism of price transmission in order to theoretically identify the causes of incomplete price transmission.

Theory and methodology

Studies investigating the theoretical underpinnings of price transmission tend to describe the adoption process of a price variable in response to deviations from a given target level.

Following Gardner (1975) such studies traditionally use the equilibrium displacement methodology for this purpose. Since the middle of the last century the equilibrium displacement methodology has been developed to incorporate new features, thus, contributing to the new results and discoveries in price transmission theory (e.g., Gardner, 1975; Heien, 1980; Wohlgenant, 1989; Schroeter & Azzam, 1990; Holloway, 1991, McCorrison et al., 1985, etc.). McCorrison et al. (2001) study the impact of market power and returns to scale on price transmission elasticity. By assigning certain values to the model parameters they prove that price transmission under perfect competition is higher than under imperfect competition, and that price transmission in the industry with increasing returns to scale, is higher than in the industry, with constant returns to scale. The sensitivity analysis within different scenarios shows that the role of returns to scale may either reinforce or offset the impact of market power.

Development of the theory and methodology

Major studies on the theoretical aspects of price transmission typically focus on a single output product. For instance, Gardner (1975), Heien (1980), Wohlgenant (1989), Holloway (1991) and McCorrison et al. (1998; 2001) use two inputs and one output framework, and only Schroeter and Azzam (1990) note that a “single” output could potentially represent a set of multiple outputs produced in fixed proportions. Agricultural inputs often serve as ingredients for multiple outputs. In dairy industry multiple outputs include goods-complements in production (butter and skim milk powder or cheese and whey) and substitutes in production (butter and cheese). In order to detect the impact of price transmission on production decisions of dairy processors price transmission of multiple outputs should be estimated. In order to estimate price transmission for multiple outputs we first have to incorporate the impact of goods-complements in production into the system. Our results show that the aggregated price transmission of goods-complements in production is not equal to price transmission of a single output, which means that the effect of goods-complements in production must be considered when estimating price transmission for goods-substitutes in production. This study thoroughly investigates the impact of goods-complements in production, which are also called jointly-produced goods.

Jointly-produced goods are generated spontaneously from a single production process so that the increase in production of one good cannot take place without a simultaneous increase in production of the other good (Fanno, 1974). Price of one jointly-produced good is only one part of the global cost, being directly dependent on the price of another joint good. Hence, one risks

losing information when estimating the price transmission elasticity for a jointly-produced good if the impact of another jointly-produced good is ignored.

Empirical studies on the dairy market (Kinnukan & Forker, 1987; Serra & Goodwin, 2003; Chavas & Kim, 2005) lack the theoretical background on price transmission for jointly-produced products. Mostly, they use Gardner's framework as the one relevant to their study and assume unique retail demand elasticity while estimating the price transmissions for various dairy products, despite the fact that there is no prove that the price transmission elasticity of a single product is identical to that of a jointly-produced product.

To fill the gap in the theory of price transmission, we extend the study of McCorrison et al. (2001) to the case of two jointly-produced goods by constructing a cohesive conceptual framework to investigate the theoretical properties of the price transmission from input to two jointly-produced outputs. We are primarily interested in whether the price transmission elasticity of a single output is the same as or different from that of a jointly-produced output. Second, we compare the price transmission elasticities of jointly-produced goods. We verify whether they are identical or different, and determine the cases when they are identical or different. Third, we identify whether the market power and returns to scale parameters equally affect the transmission elasticities of jointly-produced goods. Fourth, we determine whether the impact of other parameters on the price transmission elasticities of jointly-produced goods is different from the impact on the price transmission of a single good. Finally, we verify whether markets have a cross-impact on the price transmission elasticities of jointly-produced goods.

Research aims

The study attempts to address the following two questions:

- (1) *Theory and methodology*: What is price transmission and what type of methodology might be used to investigate theoretical properties of price transmission?
- (2) *Development of the theory and methodology*: Is the price transmission of a jointly-produced good, or an aggregated price transmission of a set of jointly-produced goods identical to that of a single output? Specifically, the question identifies whether the results by McCorrison et al. (2001) are valid for the case of jointly-produced good.

These questions contribute to the description of the base knowledge of the theory on price transmission.

Value of this research

This is one of the first studies that attempts to review research on theoretical aspects of price transmission and investigates the theoretical aspects of price transmission for jointly-produced outputs.

Frames of the research

Market structure constraints

A number of research studies have extended Gardner's (1975) equilibrium displacement model - to include various assumptions of market structure. Holloway (1991) extends Gardner's framework of perfect competition in the marketing sector to a conjectural-variations oligopoly model. Schroeter and Azzam (1990) decompose a marketing margin into components reflecting the marginal cost of processing industry, oligopoly and oligopsony price distortions and an output price risk component. McCorrison et al. (2001) assume production, processing and retailing levels with processor, applying oligopoly power against retailers. In the model "Price transmission in joint production" we do not extend market structure for the oligopsony case: instead, we leave the market structure as in McCorrison et al. (2001) for the sake of comparison between the price transmissions of single vs. jointly-produced goods.

The nature of production

McCorrison et al. (2001) study the impact of processing the agricultural input on the transmission of prices for a single output. Agricultural inputs often serve as ingredients for multiple outputs. Multiple outputs can be either substitutes, such as butter and cheese, or complements, such as butter and skim milk powder. For the latter case of joint products we extend the model by McCorrison et al. (2001). Further research would be to extend the model of goods-complements in production to the case of goods-substitutes in production.

Outline

The research questions indicated above reflect the outline of the study. In the second chapter “Literature review” the definition of price transmission is composed and the major studies, investigating theoretical aspects of price transmissions, are reviewed and structured. In the third chapter we give a detailed overview of an equilibrium displacement model by McCorrison et al. (2001). The overview contains description of the market structure, input factors and an output commodity, specification of the processing technology, market forms and firm’s behaviour, solution techniques, resulting equation of price transmission elasticity, numerical application of model results and a sensitivity analysis. This chapter also provides additional explanations for McCorrison et al. (2001) results.

The fourth chapter first presents the theoretical framework of the model “Price transmission for joint products”. Second, it discusses the price transmission elasticity of a joint product and its main determinants. Third, it provides a sensitivity analysis and key results that are achieved in the model “Price transmission for joint products”. The subsection price transmission for a single vs. jointly-produced output discusses whether it is plausible to apply the results achieved for the price transmission of a single output to a case of a joint output. The subsection price transmission for a single vs. aggregated joint outputs clarifies whether it is essential to detect the impact of goods-complements in production when estimating price transmission for goods-substitutes in production. Then the determinants of the price transmission elasticity of a jointly-produced good are discussed in great detail through the case studies. The chapter ends with a sensitivity analysis with respect to the market power parameter, elasticity of supply of materials input, elasticities of demand of joint products, parameters describing inputs combination, parameters describing throughput separation and returns to scale parameter.

CHAPTER 2

Literature review

This chapter draws attention to the problem of incomplete price transmission, defines it and discusses the reasons for estimating price transmission. Reviewing the literature sources we focus on the factors impacting price transmission and discuss research methodology which allows investigating theoretical aspects of price transmission.

2.1. Definition of price transmission

An efficient marketing system is essential to keep the pace of economic growth. In an efficient marketing system, producers are able to get remunerative prices to their products and consumers to get the product at affordable prices (Kanakaraj, 2010). An efficient marketing system in agriculture is the pre-condition to achieve food security. An uninterrupted, qualitative food supply ensures healthy people and hence, a healthy society.

The extent of marketing efficiency depends on the nature of market structure, market conduct and market performance. Seller and buyer concentration, the firms size and entry conditions are the main elements of market structure, impacting the nature of competition and pricing within the market. Market conduct indicates the behavior of market agents with regard to price determination, sales promotion tactics and the regulatory activities of government. Price formation has a direct link with these actions. If market agents determine prices on the basis of some collusive tactics, it will lead to an imperfect price transmission within the given market or in-between the markets, and therefore to the inefficient marketing system as a whole. On the other hand, if price is determined in the way of a perfectly competitive market, it resembles an effective marketing system.

The economic result of market structure and of market conduct represents market performance (Kanakaraj, 2010 p. 53). Market performance resembles price level, profit margin, level of investment, reinvestment of profit etc. In an economy, if the price fixed by the firm is just equal to average cost (the condition in perfect competition), the market is said to be performing well or efficient. In other words, through the level of prices and the level of profit margin, one can determine the degree of market efficiency.

There are two criteria to measure marketing efficiency. One is market integration and the other is price spread. For examining the efficiency of a marketing system, one must inevitably look at the degree to which village primary, secondary and terminal markets are related to each other (Lele, 1971), which requires to address the concept of integrated markets. Whenever the actions of agents of one market affect the actions of agents of other markets, it is said to be a situation of integrated market (Kanakaraj, 2010, p. 3). Markets are known to be interlinked when transaction in one influences the terms of exchange in other markets. Petzel and Monke (1979-80) defined integrated markets as markets in which prices of differentiated products do not behave independently. Ravallion (1986) observes that equilibrium will have the property that, if trade takes place at all between any two regions, then price in the importing region equals price in the exporting region plus the unit transport cost incurred by moving between the two. Goodwin and Schroeder (1991) caution that markets that are not integrated may convey inaccurate price information that might distort producer's marketing decision and contribute to inefficient product movements. Thus, the degree of market integration determines the efficiency of a certain market.

Another criteria to measure market efficiency is considered to be a price spread. Price spread is denoted as the difference between the price received by the producer and the price paid by the consumers for a commodity at a point of time (Kanakaraj, 2010, p. 59). Price spread might be similarly defined as the difference between the retail price of product and its value in production. This difference includes charges for assembling, processing, storing, transporting, wholesaling and retailing. Lesser the difference more efficient is the market system. Lower price spread allows producers and consumers to gain from affordable price and reasonable profit, thus contributing to higher market efficiency. Economic literature (Gardner, 1975; Schroeter and Azzam, 1991; etc.) sometimes operate with the term marketing margin, which in principal reflects the similar subject as the price spread. The "marketing margin" as computed by USDA is equal to the difference between the average price paid by consumers for a finished product with an agricultural raw material base and payment received by farmers for equivalent quantities of the raw material product (Beckman and Buzzell, 1995).

Farm-retail price spread and marketing margin are static measures of relationship between prices, while price transmission concept offers to measure comparative static or dynamic price relationships. Price transmission is a statistical relationship between prices, which might be either horizontal (special) between certain markets or regions, or vertical, such as from farm to

retail level. Literature analyzing horizontal price linkages, however, precedes the literature analyzing vertical price linkages. The first dates back more than one-hundred years and was typically concerned with spatial price relationships, *i.e.*, links between prices at different locations (Vavra and Goodwin, 2005). Concepts pertaining to the spatial transmission of price shocks play, for example, a very important role in theories associated with market integration (Ardeni, 1989; Baffes, 1991; Gardner and Brooks, 1994; Blauch, 1997; Baffes and Ajwad, 2001; Petzel and Monke, 1980; etc.). Petzel and Monke (1980), for example, investigate price linkages among the countries and examine the structure of price interactions. They state that prices for different locations cannot move independently in an integrated market system, *i.e.*, in an integrated market system price in the country-buyer should be equal to the price in the country-seller plus transportation and transaction costs (the law of one price). In markets which are not integrated by the price mechanism, price movements across countries and qualities would be essentially independent.

In agricultural economics literature the vertical price transmission is defined as a statistical relationship between farm and retail prices. Caps and Sharewell (2005) estimate vertical price transmission as the percentage change in retail price of a product due to a one percent change in the corresponding farm price. McCorrison et al. (2001) achieves vertical price transmission as the ratio between price change occurring at the farm gate and the commensurate change in price at the retail level. The price change at the farm-gate occurs due to the exogenous shift factor, which represents the source of the supply shock affecting agricultural sector. Such changes in prices might be transmitted along the marketing chain both downstream from farm to retail and upstream from retail to farm (Schnepf, 2009).

Vavra and Goodwin (2005) divide the vertical price transmission into the magnitude, speed and direction of change that are generated at different levels of the marketing process. For example, if a shock in the primary commodity market at the farm level induces an upward shock to the retail price, then what is the size and timing of any impacts on retail prices? Alternatively, one can evaluate the impacts on farm level prices following a shock whose first incidence is on retail prices. Schnepf (2009) characterizes vertical price transmission by magnitude, speed of adjustment and asymmetry. His reason for estimating the magnitude of price transmission is to answer the question: how big is the response at each level to a shock of a given size at another level? As already mentioned, this process is known as the degree (magnitude) of vertical price transmission.

Farm-retail price spread and price transmission concepts are traditionally used in literature on agricultural economics whereas conventional economics literature speaks about the cost pass-through (Ravn et al., 2007; Nakamura, 2006; Goldberg, 1995; etc.). The cost pass-through represents the similar conception to the price transmission, however, from the point of view of a single firm, when transmission of firm costs to the firm prices is examined. While price transmission represents relationship between consumer and producer prices, the cost pass-through represents relationship between product's costs and its output price. Ravn et. al (2007) defines the cost pass-through as the pass-through of changes in marginal costs to retail and wholesale levels, and considers it to be incomplete if a 1 percent increase in marginal cost leads to a less than 1 percent increase in prices. Following the number of empirical studies, which document that marginal cost shocks are not fully passed through to prices at the firm level and that prices are substantially less volatile than costs, Ravn et al. (2007) developed a model, which shows that firm-specific marginal cost shocks are not fully passed through to product prices. That is, in response to a firm-specific increase in marginal costs, prices rise, but by less than marginal costs, leading to a decline in the firm-specific mark-up of prices over marginal costs. This is strategic behavior of the firms willing to keep their customers by reducing the fluctuations of prices for their products. Firms find it optimal to narrow profit margins in the current period to limit the decline in future habitual demand triggered by the price increase.

The interest to price transmission has gained remarkable attention in the current political and scientific society. There are plenty of questions about this issue raised by the policy circles and business societies, which scientific studies attempt to answer. Do price shocks completely transmit from production to the retail level? What is the incidence of marketing costs on retail prices and farm prices? Does market power affect the transmission of price shocks from farm to retail levels? Who benefits under the condition of incomplete transmission of prices? Trade liberalisation likely over-estimates the benefits to consumers in countries that have gone through policy reform, because the reduction in farm prices might not be immediately or fully transmitted to final consumers (Vavra and Goodwin, 2005). As a result, there would be smaller positive effects on consumer welfare and a possible increase in rents for the firms in the downstream sector. Thus, it is important to understand the processes related to transmission of price changes as price transmission assumptions along the supply chain play an important role in determining the size and distribution of welfare effects of trade policy reform (Vavra and Goodwin, 2005).

2.2. Theoretical research on price transmission

Although the methods of testing for empirical evidence may have indirect relevance to the objectives of the present study, this body of research is not directly applicable. The degree (magnitude) of vertical price transmission is the focus of this study, and the literature review below summarizes briefly work in this field.

A huge bank of research exists on the topic of price transmission, which includes outstanding empirical and theoretical papers. However, the existing literature is far from being unified or conclusive, with little focus on the theoretical underpinnings (Meyer and von Cramon-Taubadel, 2004). In this section we highlight the theoretical research on price transmission investigation and deeply explore the causes of vertical price transmission. A number of studies have estimated the degree of price transmission between price changes occurring at the farm gate and the appropriate change in price at the retail level, searching for the theoretical determinants of price transmission. Studies discussed in this chapter estimate the impact of different kinds of elasticities impacting price transmission.

2.2.1. Factors determining farm-retail price transmission

The focus on measuring the degree of price transmission is based on the concern that there are some characteristics of the food market, which lead to the less-than-full pass-through of prices. For example, McCorrison et al. (1989; 2001) estimate the impact of different types of the elasticities on the relationship between farm and retail prices. These investigations report that if the share of an agricultural input increases, price transmission increases; if the elasticity of demand for an output increases, price transmission decreases (in a case of perfect competition); if the elasticity of substitution between inputs increases, price transmission increases; the impact of the elasticity of supply for marketing inputs on price transmission is ambiguous depending on the degree of market power (McCorrison et al., 1989). In McCorrison et al. (2001) such parameters as the share of agriculture, the elasticity of output demand, the elasticity of substitution between inputs and input supply elasticity were investigated for their impact on price transmission elasticity. According to the study results, if the share of agricultural input increases, price transmission increases; if the elasticity of demand for output increases, price transmission decreases (in a case of perfect competition); if the elasticity of substitution between inputs increases, price transmission increases; the impact of the elasticity of supply for marketing inputs on price transmission is ambiguous.

Research about the impact of different elasticities on price transmission is initially developed by Gardner (1975). With the help of the equilibrium displacement approach (EDM), Gardner investigates the relationship between farm and retail prices. The partial equilibrium framework of the EDM involves a linear approximation of changes in prices and quantities of inputs and outputs arising from new technology or weather conditions. The assumed industries represent a system of demand-and-supply relationships with base prices and quantities used to define an initial equilibrium. The impact of any exogenous change in the system, such as a new technology or a climate shock, is modeled as a shift in demand or supply from that initial equilibrium.

The EDM in agricultural economics traditionally represents one output market for a food product and two input markets, one of which is directly affected by the external shock. A common way to describe these three markets in the tradition of Brandow (1962), Gardner (1975), Heien (1980), Wohlgenant (1989), Schroeter and Azzam (1991), Holloway (1991) and McCorriston et al. (1989; 2001) is by the following system of six conditions :

1. Supply of an output,
2. Demand for an output,
3. Supply of a first input,
4. Demand for a first input,
5. Supply of a second input,
6. Demand for a second input.

However, the way of writing these conditions in mathematic form varies from study to study. It depends directly on the tasks and goals the authors pursue in their works. Although the main elements of this approach had already been used by Brandow (1962), Gardner (1975) is the first who generalized the system and gave an exhaustive analysis of all possible findings and effects of the EDM. Brandow's (1962) study is an early example of equilibrium models used in agricultural economics, which was no doubt a notable example for Gardner's (1975) investigation. In Gardner's (1975) study, a static equilibrium is "displaced", being affected by a certain economic shock. Thus, the term Equilibrium "Displacement" Model (EDM) has been attached to a system of six equations. In this system Gardner (1975) offers a general functional form, which is not restricted to a particular case as it was in Brandow's (1962) study. Brandow's (1962) equilibrium model in its task has to determine the interrelation of the elasticities of demand for inputs and one output, and the interrelation of the elasticities of supply for inputs and

one output. Brandow (1962) proved that demand for one input, quantities of other inputs held constant, is elastic, unit elastic or inelastic accordingly, as a demand for output is elastic, unit elastic or inelastic. If both inputs have the same supply elasticity, e.g., k , then the supply elasticity of output is also k . If supplies of inputs are perfectly elastic, so is the supply of an output. If the quantities of inputs are fixed, so is the quantity of an output.

Gardner (1975) approaches EDM differently, than Brandow (1962) does. His main interest is the farm-retail price spread. According to Gardner (p. 400) price spread might be measured by the difference between the retail and farm price, by the ratio of the prices, by the farmer's share of the food dollar, or by the percentage marketing margin. Gardner (1975) thoroughly investigates the change in the farm-retail price ratio due to the shocks displacing the equilibrium situation. For that he introduces the food demand shift, farm product supply shift and marketing input supply shift in the six-condition system. Gardner (1975) not only finds the impact of these shifters on the retail-farm price ratio, but also examines this impact in different economic scenarios. For example, the impact of the food demand shift on the retail-farm price ratio is found under the different supply elasticities of agricultural and material inputs and different elasticities of substitution between inputs. The impact of a farm supply shift on the retail-farm price ratio is found under the different elasticities of substitution between inputs and different supply elasticities of marketing input. The impact of a marketing input supply shift on the retail-farm price ratio is estimated under the marketing input price change, different elasticities of substitution between inputs and different supply elasticities of agricultural input.

As a result, Gardner concludes (1975, p. 406) that no simple mark-up pricing rule - a fixed percentage margin, a fixed absolute margin or a combination of the two - can in general accurately depict the relationship between the farm and retail price. This is so because these prices move together in different ways depending on whether the shock occurs from a shift in retail demand, farm supply or marketing inputs. Events that increase (decrease) the demand for food will reduce the retail-farm price ratio, and percentage marketing margin, if marketing inputs are more (less) elastic in supply than farm products. Events that increase (decrease) the supply of farm products will increase (decrease) the retail-farm price ratio. Events that increase (decrease) the supply of marketing inputs will decrease (increase) the retail-farm price ratio. Specific results concern the retail-farm price ratio under the impact of price control for an output good and price control for an agricultural input. According to these results, an effective price ceiling on retail food will reduce the price of farm products (unless the supply of farm products is perfectly elastic). Retail-farm price ratio will increase (decrease) if the elasticity of supply of farm products is less (greater) than that of marketing inputs. Supporting the price of farm products

above the unrestricted market equilibrium level will reduce the retail-farm price ratio. Some additional results report that the farm-level demand for agricultural products will be more or less elastic than the retail demand for food as elasticity of substitution is correspondingly greater or less than retail demand elasticity. The last investigations of Gardner's (1975) study concern the farmer's share of the food dollar. The percentage price spread is analytically distinct from the farmer's share of the food dollar, and the two will behave differently under changing market conditions unless the elasticity of substitution between inputs equals zero. If this elasticity equals one, the farmer's share is constant. If it is greater than one, an increase in the marketing margin will be accompanied by an increase in the farmer's share of the food dollar. Otherwise, lower margins go together with an increased farmer's share. The elasticity of substitution between farm products and marketing inputs in producing retail food can be estimated by dividing observed changes in the farmer's share of the food dollar by observed changes in the ratio of farm to retail food prices.

In this study Gardner (1975) developed a system of equations which formally allow to explain what happen to the farm-retail price ratio in each circumstance, namely under the conditions of food demand shift, farm supply shift, marketing input supply shift. Such analysis is important for trade policy to understand the size and welfare effects of the price changes occurring on different levels of the food chain. Gardner (1975) also pointed out that, apart from other causes, incomplete farm-to-retail price ratio might be the result of government intervention to support producer prices.

Studies working with the EDM approach traditionally refer to Gardner (1975) and often extend his model for new assumptions. For example, the study of Heien (1980) assumes that the supply and demand are not in balance and that this imbalance is the determining factor causing price changes in auction-type markets. Heien (1980) makes this because he attempts to put forth a theory of food price determination which is consistent with Gardner's (1975) model, but which goes beyond it and describes the dynamics of the sector. The dynamics is described by a simple inequality of supply and demand, indicating that they are not continuously in balance. The whole marketing chain price system is moved by the cycle of different time periods. Thus, the solution properties of the model allow for convergent growth and damped and explosives cycles. Another novelty of Heien's (1980) study is that the change in retail food price is modeled to be caused by changes in prices at lower levels in the marketing chain. Heien (1980) extends Gardner's (1975) framework by adding up a wholesale level in addition to the retail and farm ones. This aspect is shown in the theoretical model and examined in the empirical part. Heien (1980) concludes that the cost change is transmitted via mark-up type pricing rules which he allows to be consistent

with the firm's optimization behavior. The mark-up type pricing rule is given by the condition of marginal costs equal to price, where price in its turn is equal to the sum of input prices each multiplied by the exogenous coefficient in a static case and endogenous coefficient in a dynamic case. Exogenous coefficients represent the physical units of input products needed to produce one output unit (Heien, p. 12). Endogenous coefficients represent values endogenous to the Gardner model which will change differentially depending on how farm and other inputs prices change as a result of various shifts in their basic determinants (Heien, pp. 13-14).

A paper by Michael Wohlgenant (1989) contributes to the theory of derived demand and enriches the findings achieved before by Brandow (1962) and Gardner (1975). Brandow (1962) worked on derived demand elasticities, Gardner (1975) investigated the absolute amount of retail and farm elasticities in accordance with the elasticity of substitution between inputs. Wohlgenant (1989) discussed the absolute amount of farm demand elasticities in accordance with the elasticity of substitution between farm and marketing inputs. Wohlgenant (1989) proved that derived demand elasticities for farm outputs are considerably larger (in absolute value) than in a case when the assumption of fixed input proportions is imposed.

2.2.2 Imperfect market structure as a determinant of price transmission

Much research has been done investigating factors impacting the farm-retail price ratio; however, McCorrison et al. (1989) is one of the first, who started to model the market structure having an impact on price transmission. In the study (1989), they show that market power will reduce the degree of price transmission between the farm and retail stages. Thus, if downstream markets are imperfectly competitive price transmission is less than complete. This result was long expected in agricultural economics literature, as all previous investigations were done under the assumption of perfect competition. Thus, McCorrison et al. (1989) drew particular attention to the market structure as one of the determinants of price transmission, and boosted the number of studies modeling imperfect competition scenarios in food markets. McCorrison's (1989) proxy variable for imperfect competition arises from the profit maximization condition and implies a ratio of marginal increase in the industry-produced quantity and a marginal increase in the quantity produced by a single firm. This ratio includes the reaction of the rivals to the marginal increase in the output of a single firm.¹ In this model (1989) McCorrison et al. assume different scenarios for this ratio and set up its values exogenously. Holloway (1991), however,

¹ $\theta = \frac{\partial Q}{\partial Q_i} = 1 + \frac{\partial \sum_{j=1}^n Q_j}{\partial Q_i} = 1 + \theta^*$, $j \neq i$, where θ is the proxy variable for imperfect competition and θ^* measures the output reaction of its rivals to a change in its own output. Q is the industry produced quantity and Q_i is the quantity produced by a single firm.

offers to model it endogenously. The main goal of the Holloway's study is to find out how Gardner's model (1975) may be extended to allow for non-competitive behavior in food marketing. The objectives of Holloway's (1991) study are to provide a conceptual framework for the analysis of imperfect competition and to assess the analytical consequences of non-competitive behavior. The theoretical development focuses on the determinants of conduct using the term of conjectural elasticities. The magnitudes of these elasticities are determined by the two values of two market structure variables such as the responsiveness of demand for firms' products and the size of the fixed costs they incur upon entering the market. These two variables may generate perfectly competitive equilibrium, or equilibrium which may diverge from the one obtained from the perfect competition. Holloway (1991) concludes that the dynamics of conduct in the food industries may be extremely important in explaining price movements at both the farm and retail levels. Schroeter and Azzam (1990) paper provides a conceptual and empirical framework for analyzing marketing margins in a noncompetitive food-processing industry facing output price uncertainty. One of the major results of their model is that one must consider the possibility of non-competitive conduct in the industry when estimating marketing margins, and that the output price uncertainty is a significant factor in determination the marketing margins.

The recent study of McCorrison et al. (2001) pushed forward the assumption of the market structure impact on price transmission. It shows that price transmission may be greater in industries with increasing returns to scale than in markets characterised by constant returns to scale (both compared whether under perfect or imperfect competition circumstances, respectively). They proved that the industry returns to scale may either reinforce or offset the impact of market power in this industry. Therefore, the major contribution of McCorrison et al. (1989; 2001) is the theoretically proven definition of market power and returns to scale as the factors impacting the degree of price transmission.

2.2.3. Price transmission in different production conditions

Studies investigating the farm-retail price relationship usually assume a single output. Salhofer and Sinnabell (1999) note that the assumption of a single output is very simple and it can be extended in all directions. The assumption of a single output restricts findings to a particular case of a single output, while multiple outputs are a common case in empirical situations. An example of multiple outputs is a dairy industry, which produces goods-complements in production such as butter and skim milk powder or cheese and whey, however, both groups present the example of goods-substitutes in production, such as cheese and butter. Dairy processors have constantly to make a choice which goods to produce, butter and skim milk powder or cheese and whey. This

decision depends as well on the values of price transmissions of these goods, which in their turn depend, first, on the impact of different parameters (such as for example market power) on price transmission and, second, on the impact of other multiple outputs, such as goods-substitutes and goods-complements in production. If a dairy processor is able to apply market power he or she would certainly choose to produce such goods among the goods-substitutes, i. e. butter and cheese, which price transmission is lower in order to achieve the highest profit.

However, there are no studies to our knowledge which model and estimate price transmission incorporating characteristics of multiple outputs as the principal determinants of the degree of price transmission likely to arise. Schroeter and Azzam (1991) note that a “single” output could potentially represent a set of multiple outputs produced in fixed proportions. In dairy industry multiple outputs include goods-complements in production (butter and skim milk powder or cheese and whey) and substitutes in production (butter and cheese). In order to estimate price transmission for goods-substitutes in production we first have to incorporate the impact of goods-complements in production into the system. Our results show that the aggregated price transmission of goods-complements in production is not equal to price transmission of a single output, which means that the effect of goods-complements in production should be considered when estimating price transmission for goods-substitutes in production. This study thoroughly investigates the impact of goods-complements in production, which are also called jointly-produced goods.

Economic literature defines the conception of jointly-produced goods and describes possible ways of economically modeling such production conditions (Fanno, 1974; Sraffa, 1960; Salvatory and Steedman, 1988; Schefold, 2005; etc.). Fanno (1974) defines joint outputs as generated spontaneously from a single production process so that the increase in production of one good cannot take place without a simultaneous increase in production of the other good. Prices of such goods are based on the unit of measure of these products, while the global cost is based on the unit of global production. Global cost may be of the same kind as the unit of measure of finished products, but may also be different and therefore cannot be separated and distributed among the finished goods, so that the price of one jointly-produced good is only a part of the global cost, being directly dependent on the price of another joint good. In this study we show formally that the assumption of jointly-produced goods will affect the degree of price transmission.

Some studies (Kinnukan and Forker, 1987; Serra and Goodwin, 2002; Aguiar and Santana, 2002) estimate price transmission of dairy products by regressing farm-gate milk price on a

single dairy product, without considering the impact of its joint outputs. However, our study results show that under the same market conditions a different price transmission for jointly-produced goods, than for a single output, is expected. In other words the value of price transmission of a dairy product should include the impact of goods produced in fixed proportions with this dairy product. For example, the estimated value of price transmission of butter should contain the impact of skim milk powder price, or the estimated value of price transmission of cheese should contain the impact of whey price, etc.

This study does not only extend production conditions commonly used in previous studies on price transmissions, it also incorporates investigations on market structure and different kinds of elasticities impacting joint products' price transmission. Incorporating the assumption of jointly-produced outputs into the theoretical framework of the model by McCorrison et al. (2001) we receive results for the same tasks as in McCorrison et al. (2001), however, for the jointly-produced goods. Therefore to implicitly understand the conception, the tasks, and the methodology used in the study, we first delve into the discussion of the equilibrium displacement model (EDM) of McCorrison et al. (2001) in the coming chapter.

CHAPTER 3

General structure of the equilibrium displacement model (EDM) by the example of the McCorriston et al. (2001) study

The McCorriston et al. (2001) model presents the latest generation of the EDM, incorporating hypotheses about the factors impacting price transmission such as market power and non-constant returns to scale. In this chapter we thoroughly discuss all steps of the modelling framework of this study and give a detailed description of the mathematical method.

3.1. Market structure, input factors and an output commodity

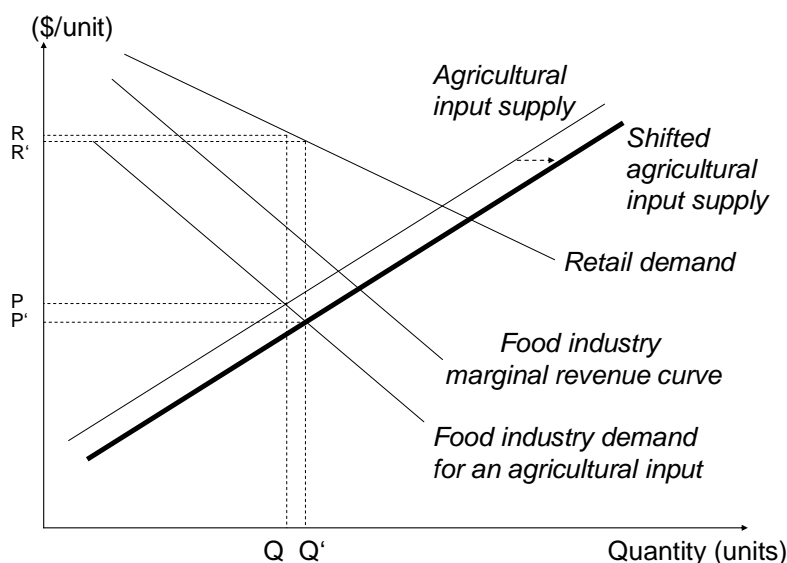
We describe here an equilibrium model where main agents of a vertical market chain interact for production and distribution of a certain product. It is assumed that among the three market agents, i.e. retailers, processors and producers, market power is applied only by processors (food industry). The food industry is assumed to be oligopolistic; however, for reasons of simplicity we assume that it does not exert the oligopsony power against the suppliers of inputs (producers). We assume a high number of retailers as well as agricultural producers, operating in the market.

Figure 1 indicates the oligopolistic food industry (a cartel case), which does not exert oligopsony power against the supply of inputs. Food industry marginal revenue curve is a curve marginal to the retail demand. From the food industry marginal revenue curve, subtract marginal costs to get perceived marginal revenue net of marginal costs, which in the bilateral price-taking case is the food industry-derived demand curve for an agricultural input. Agricultural input quantity and price are determined as the coordinates of the point on the intersection of agricultural input supply and food industry demand for an agricultural input.

Retail price is the final demand price R at quantity $Q \equiv A$, where Q is the output quantity, and A is the agricultural input quantity². The task of the model is to find the price transmission under the given market structure when agricultural input supply shifts. Thus, the value of price

² For graphical simplicity we assume that $Q \equiv A$, which means that agricultural input quantity is transformed into the output quantity. However, in the model assumptions Q is not \equiv to A because output is assumed to be produced by two inputs, i.e. agricultural and material inputs.

transmission is calculated as a percentage change in the output price divided by the percentage change in the input price.



P (P') – agricultural input price before a shift (after a shift)

R (R') – output product price before a shift (after a shift)

Q (Q') – output quantity before a shift (after a shift)

Figure 1 Vertical price transmission in a non-competitive downstream market affected by shifted input supply

Source: adapted from Schroeter, Azzam and Zhang (2000)

Demand for inputs

This food industry uses agricultural inputs in combination with other variable inputs, e.g., material inputs. In case of butter production, milk may serve an example of agricultural input, and separating equipment is an example of material input. Demands for agricultural and material inputs are derived by the cost minimisation procedure. This is because firms seek to produce the required amount of an output using minimum amounts of inputs. The cost minimisation procedure is achieved by the Lagrange-multiplier method. Minimise total input costs: $\min(PA+WM)$ subject to the following constraints: $f(A,M) = Q$, where P is the price of the agricultural product, A is the quantity of agricultural product, W is the price of material input, and M is the quantity of material input.

$$L = PA+WM + C(Q - f(A,M)) \tag{1}$$

Differentiating by A will give the optimal amount of agricultural input, or the agricultural input demanded:

$$\begin{aligned}\frac{\partial L}{\partial A} &= P - Cf_A = 0 \\ P &= Cf_A,\end{aligned}\tag{2}$$

where f_A defines the output product increase caused by the increase of an agricultural input for a unit, and C is marginal costs (for this see the proof in Chiang, 1967a).

Differentiating by M will give the optimal amount of material input, or the material input demanded:

$$\begin{aligned}\frac{\partial L}{\partial M} &= W - Cf_M = 0 \\ W &= Cf_M,\end{aligned}\tag{3}$$

where f_M defines the output product increase caused by the increase of the material input for a unit.

Thus, we received the agricultural input demand function: $P = C \cdot f_A$, and the material input demand function: $W = C \cdot f_M$, where C is marginal costs. Converting these demand functions into a logarithmic form (percentage changes) will give correspondingly:

$$d \ln P = d \ln C + d \ln f_A\tag{4}$$

$$d \ln W = d \ln C + d \ln f_M.\tag{5}$$

Empirical studies concerning imperfect competition traditionally assume constant marginal costs of a firm; however, ignoring the fact that the firm's degree of market power depends on the nature of the firm's costs. Morrison Paul (1999) notes that mark-up models are often based on constructing products' demand functions without detailed consideration of the underlying cost structure. In fact, constant returns to scale are often assumed, thus, ignoring the potential linkage between scale economies and mark-up behaviour. However, there are some empirical studies (Strak and Morgan, 1995; Millan, 1999; Allen et al., 1998) highlighting the importance of economies of scale in considered food industries. Therefore to check for the principal impact of the economies of scale on price transmission elasticity, we incorporate returns to scale parameter ρ into the firm's demand function (equations 6 and 7).

Wohlgenant (1999) shows that a positive relationship between the aggregate price spread and the agricultural raw material price could result from input substitution between the agricultural input and other inputs in response to changes in the agricultural input price. As some empirical studies have proved that input substitution is significant for food industries (Wohlgenant, 1989; Goodwin and Brester, 1995), we incorporate the parameter of input substitution into the modelling framework (equations 6 and 7).

Thus, the final demand functions for agricultural and material inputs, respectively, are:

$$d \ln P = d \ln C - \frac{\beta}{\sigma\rho} (d \ln A - d \ln M) + \frac{\sigma(\rho-1)}{\sigma\rho} d \ln Q \quad (6)$$

$$d \ln W = d \ln C + \frac{\alpha}{\sigma\rho} (d \ln A - d \ln M) + \frac{\sigma(\rho-1)}{\sigma\rho} d \ln Q \quad (7)$$

where $(-\frac{\beta}{\sigma\rho} (d \ln A - d \ln M) + \frac{\sigma(\rho-1)}{\sigma\rho} d \ln Q)$ is achieved from $(d \ln f_A)$,

and $(\frac{\alpha}{\sigma\rho} (d \ln A - d \ln M) + \frac{\sigma(\rho-1)}{\sigma\rho} d \ln Q)$ is achieved from $(d \ln f_M)$.

P and W are prices for agricultural and material inputs, respectively; A and M are quantities of agricultural and material inputs, respectively; α and β are output elasticities with $\alpha + \beta = \rho$; ρ is the (short-run) returns to scale measure with ρ greater than (equal to, less than) unity representing increasing (constant, decreasing) returns to scale and σ is the elasticity of substitution between agricultural and material inputs. For the details of these transformations, see Appendix 1.

Supply of inputs

In perfect competition, single producers have no effect on equilibrium prices; however, aggregated supply needs not to be perfectly elastic. For the inverse aggregated supply for agricultural (A) and material (M) inputs, the following functions are assumed:

$$P = k(A, Z) \quad (8)$$

$$W = g(M), \quad (9)$$

where P and W are prices of A and M respectively. The variable Z is the exogenous shift factor. We assume that the shock (Z) representing the impact such as bad weather or a tax on agricultural input occurs in the agricultural sector, thus, displacing the market to a new equilibrium.

Equations (8) and (9) are converted into the logarithmic form (Appendix 2). Inverse input supply functions in the logarithmic form are:

$$d \ln P = \varepsilon d \ln A + \varphi d \ln Z \quad (10)$$

$$d \ln W = \gamma d \ln M, \quad (11)$$

where $d \ln P$ and $d \ln W$ are percentage changes in prices for agricultural and material inputs, respectively and $d \ln A$ and $d \ln M$ are percentage changes in quantities of agricultural and material inputs, respectively. $d \ln Z$ is a percentage change in the shock affecting agricultural production. ε , φ and γ are input supply elasticities.

Output demand

Agricultural and material inputs generate a single homogenous output commodity. A large number of consumers buy this output commodity from the oligopolistic food industry. The inverse demand function of the output commodity is given by:

$$R = h(Q), \quad (12)$$

where R is the price of the output commodity and Q is the output quantity.

Totally differentiating the given demand function and converting it to a logarithmic form yields:

$$d \ln Q = -\eta \cdot d \ln R, \quad (13)$$

where $d \ln Q$ is the percentage change in the output product, $d \ln R$ is the percentage change in price for the output product and η is the industry elasticity of demand, given with the absolute value. A detailed conversion of (12) to (13) is given in Appendix 3.

3.2. Specification of the processing technology and the output supply function

Two inputs (agricultural and material) are transformed into the output product by the processing industry's production technology. Following the common tool of the EDM framework, we give here a general form of production function, which does not represent any specific form of production function, but just indicates the fact of the existence of this production function. We assume that this industry is represented by n number of firms, which all have identical production functions. The common production function of this output is homogenous of degree ρ , i.e., doubling the amounts of inputs will increase the output quantity by 2^ρ .

Capital can also be potentially considered in the production function. However, as we assume the capital to be fixed in the short run, and this specification is consistent with the short run equilibrium, capital is not included in the modelling framework. Production function is assumed to allow for inputs substitutability. Let us then write the production function as follows:

$$Q = f(A, M), \quad (14)$$

where A stands for an agricultural input, M stands for material input. Totally differentiating this production function and converting it to the logarithmic form yields:

$$d \ln Q = \alpha d \ln A + \beta d \ln M, \quad (15)$$

where $d \ln Q$ is the percentage change in the output product; $d \ln A$ and $d \ln M$ are the percentage changes in the agricultural and material inputs, respectively and α and β are the output elasticities. The conversion procedure of the production function into the logarithmic form is shown in Appendix 4.

3.3. Market forms and firms behaviour

According to the model assumptions, market power should have an impact on price transmission. To implement this assumption into the model, we assume the oligopolistic food industry. Oligopolies tend to maximize their profits. Thus, we obtain the first-order condition for profit maximisation to find the retail price on the downstream market.

$$\Pi_i = R(Q) \cdot Q_i - C_i(P, W, Q_i), \quad (16)$$

where

Π_i - profit function of the i 'th firm

$R(Q)$ - output product price

Q_i - quantity of output product, produced by the i 'th firm

C_i - costs of the i 'th firm

P - price of agricultural input

W - price of material input

Knowing that the output price R is a market price depending on the whole industry's output Q , and this total output in its turn depends on each firm's output Q_i ($Q = \sum_{i=1}^n Q_i$), we will hold the first-order condition for one firm's profit maximisation:

$$\frac{\partial \Pi_i}{\partial Q_i} = \frac{\partial Q_i}{\partial Q_i} R(Q) + \frac{\partial R(Q)}{\partial Q} \cdot \theta_i \cdot Q_i - \frac{\partial C_i(P, W, Q_i)}{\partial Q_i} = 0, \quad (17)$$

where $\theta_i = \frac{\partial Q}{\partial Q_i}$, and is called *conjectural variation parameter* for firm i . With the conjectural

variation parameter, we check for the relationship of the whole industry output to the output of one particular firm i . $\theta = \frac{\partial Q}{\partial Q_i} = 1 + \frac{\partial \sum_{j=1}^n Q_j}{\partial Q_i} = 1 + \theta^*, j \neq i$, where θ is the proxy variable for imperfect competition and θ^* measures the output reaction of its rivals to a change in its own output. Q is the industry produced quantity and Q_i is the quantity produced by a single firm. If reaction of the rivals is zero, the ratio is equal to one and implies a cournot oligopoly.³ If reaction of the rivals is bigger than zero, the ratio is bigger than one and implies a collusive outcome. If reaction of the rivals is minus one, the ratio is equal to zero and implies a perfect competition.

³ McCorriston et al. (2001) name the case, when conjectural variations equal to one, a monopoly or collusive outcome.

Assume n firms of the same size and identical cost structure, and sum the profit maximisation function over all of them (noting that $Q = \sum_{i=1}^n Q_i$), will give:

$$R = \lambda \cdot C, \quad (18)$$

where $\lambda = \frac{n\eta}{n\eta - \theta}$, and C is marginal costs. For the detailed derivation of this outcome see Appendix 5.

Thus, oligopoly condition here is the price R equal to marginal costs C multiplied by the industry mark-up coefficient λ . λ is the mark-up of price over costs, n is the number of firms in the food industry, η is the absolute value of the retail food price elasticity ($\eta = \left| \frac{\partial Q}{\partial R} \cdot \frac{R}{Q} \right|$) and θ is the aggregate conjectural variation or a market power parameter. Thus, the higher the conjectural variation or market power parameter θ , the higher the mark-up of price over costs parameter λ , and the higher the oligopoly price on the market R . We also assume that conjectural variation parameters are identical across all firms in the food industry.

Condition $R = \lambda \cdot C$ is an equilibrium condition for a non-competitive (oligopoly) outcome. As the food industry is oligopolistic, the price the consumer pays is higher than the marginal costs of the processor and is equal to $R = \lambda \cdot C$, where λ is a mark-up charged by the oligopolist and C implicates marginal costs.

3.4. Solution techniques

The EDM approach uses a standard set of partial equilibrium solution techniques such as equilibrating supply and demand on production and distribution levels and then solving the system of equilibrium equations.

Modelling the input market equilibrium, we equate input demand functions (6) and (7) with input supply functions (10) and (11). The input markets clearing conditions converted into a logarithmic form then yield the following for agricultural and material inputs, respectively:

$$\varepsilon d \ln A + \varphi d \ln Z = d \ln C - \frac{\beta}{\sigma\rho} (d \ln A - d \ln M) + \frac{\sigma(\rho-1)}{\sigma\rho} d \ln Q \quad (19)$$

$$\gamma d \ln M = d \ln C + \frac{\alpha}{\sigma\rho} (d \ln A - d \ln M) + \frac{\sigma(\rho-1)}{\sigma\rho} d \ln Q. \quad (20)$$

If we replace $d \ln C$ (indicated in equations (19) and (20)) with the fraction $(1+\mu)d \ln R$, we will confirm that the marginal costs for each of the industry's inputs are derived from the industry output price R (derivation of $d \ln C = (1+\mu)d \ln R$ is given in Appendix 6). Thus, we receive (21) and (22):

$$\varphi d \ln Z = - \left[\frac{\beta + \varepsilon\sigma\rho - \alpha\sigma(\rho-1)}{\sigma\rho} \right] d \ln A + \left[\frac{\beta + \beta\sigma(\rho-1)}{\sigma\rho} \right] d \ln M + \left[\frac{(1+\mu)\sigma\rho}{\sigma\rho} \right] d \ln R \quad (21)$$

$$0 = \left[\frac{(1+\mu)\sigma\rho}{\sigma\rho} \right] d \ln R + \left[\frac{\alpha + \alpha\sigma(\rho-1)}{\sigma\rho} \right] d \ln A - \left[\frac{\alpha + \gamma\sigma\rho - \beta\sigma(\rho-1)}{\sigma\rho} \right] d \ln M. \quad (22)$$

Detailed transformation procedures for the above equations are shown in Appendixes 7 and 8.

Modelling the output market equilibrium we equate the quantity of output supplied to the downstream market $Q = f(A, M)$ with the inverse output demand function $R = h(Q)$. The output market clearing condition, converted into a logarithmic form, then yields:

$$0 = \alpha d \ln A + \beta d \ln M + \eta d \ln R. \quad (23)$$

As a result, we conclude with the system of equilibrium conditions:

(a) Agricultural input clearing condition

$$\varphi d \ln Z = - \left[\frac{\beta + \varepsilon\sigma\rho - \alpha\sigma(\rho-1)}{\sigma\rho} \right] d \ln A + \left[\frac{\beta + \beta\sigma(\rho-1)}{\sigma\rho} \right] d \ln M + \left[\frac{(1+\mu)\sigma\rho}{\sigma\rho} \right] d \ln R \quad (24)$$

(for derivation see Appendix 7).

(b) Material input clearing condition

$$0 = \left[\frac{(1+\mu)\sigma\rho}{\sigma\rho} \right] d \ln R + \left[\frac{\alpha + \alpha\sigma(\rho-1)}{\sigma\rho} \right] d \ln A - \left[\frac{\alpha + \gamma\sigma\rho - \beta\sigma(\rho-1)}{\sigma\rho} \right] d \ln M \quad (25)$$

(for derivation see Appendix 8).

(c) Output clearing condition

$$0 = \alpha d \ln A + \beta d \ln M + \eta d \ln R. \quad (26)$$

Focusing on the measure of price transmission from the farm-gate to the retail level, we derive solutions for two endogenous variables: farm gate price for the agricultural input and the output product price. We assume that the exogenous shock Z arises in the agricultural sector and, thus, influences the price transmission elasticity from the side of the agricultural supply. The procedure for deriving the price transmission elasticity is then to solve the system of equilibrium equations (a), (b) and (c) following the shock Z , which occurred in the agricultural sector.

3.5. Price transmission elasticity

Solving the system of equilibrium equations yields solutions for the output commodity price R , and the agricultural input price P , respectively:

$$d \ln R = \frac{[\alpha\rho(1+\gamma\sigma)] \varphi d \ln Z}{(\mu+1)\rho(\rho+\alpha\gamma\sigma+\beta\varepsilon\sigma) - \eta(\beta\gamma+\varepsilon\alpha+\varepsilon\sigma\gamma - \varepsilon\sigma\beta(\rho-1) - \alpha\sigma\gamma(\rho-1) - \rho(\rho-1))} \quad (27)$$

$$d \ln P = \frac{(1+\mu)\rho(\rho+\alpha\sigma\gamma) - \alpha\sigma\eta\gamma(\rho-1) - \rho\eta(\rho-1) + \beta\eta\gamma}{(\mu+1)\rho(\rho+\alpha\gamma\sigma+\beta\varepsilon\sigma) - \eta(\beta\gamma+\varepsilon\alpha+\varepsilon\sigma\gamma - \varepsilon\sigma\beta(\rho-1) - \alpha\sigma\gamma(\rho-1) - \rho(\rho-1))} \quad (28)$$

The expression for the farm to retail price transmission affected by the exogenous shock in the agricultural sector is given by the following ratio: $\frac{d \ln R}{d \ln Z} / \frac{d \ln P}{d \ln Z}$. After certain simplifications (shown in Appendix 9), price transmission elasticity between agricultural input and output product prices is described as follows:

$$\frac{d \ln R / d \ln Z}{d \ln P / d \ln Z} = \tau = \frac{\alpha\rho(1+\gamma\sigma)}{(\rho+\alpha\gamma\sigma)[(1+\mu)\rho - \eta(\rho-1)] + \beta\eta\gamma}, \quad (29)$$

where $d \ln P$ is the percentage change in the agricultural price, $d \ln R$ is the percentage change in the output commodity price, α and β are output elasticities with $\alpha + \beta = \rho$, ρ is the returns to

scale measure, σ is the elasticity of substitution between agricultural and material inputs, γ is the inverse elasticity of supply of material inputs, η is the absolute value of the retail elasticity of demand and μ is the elasticity of the industry mark-up.

Following the assumption that the food industry is characterized by the non-constant returns to scale, we define the output elasticities α and β as the shares of inputs in the industry cost function S_A and S_M , taken according to the cost structure ρ of the given industry:

$$\alpha = S_A \rho \quad (30)$$

$$\beta = S_M \rho, \quad (31)$$

where S_A (S_M) is the share of agricultural (material) inputs in the industry cost function.

Then, the price transmission equation can be rewritten as:

$$\tau = \frac{S_A \rho (1 + \gamma \sigma)}{(1 + S_A \gamma \sigma) [(1 + \mu) \rho - \eta (\rho - 1)] + (1 - S_A) \gamma \eta}. \quad (32)$$

Let us analyse the received equation according to the study task. The first task tends to examine the impact the market power parameter has on the price transmission elasticity. Looking for this impact, we compare two cases: price transmission in the competitive benchmark (where $\mu = 0$), and in the non-competitive benchmark (where $\mu \neq 0$). Set up market power parameter equal to zero and the returns to scale parameter equal to one to receive the competitive benchmark for price transmission elasticity:

$$\tau_c = \frac{S_A (1 + \gamma \sigma)}{(1 + S_A \gamma \sigma) + (1 - S_A) \gamma \eta}. \quad (33)$$

Now find the ratio of τ_c / τ to check for the market power impact:

$$\frac{\tau_c}{\tau} = 1 + \frac{\mu (1 + S_A \gamma \sigma) - \eta [(\rho - 1) / \rho] [(1 + S_A \gamma \sigma) + (1 - S_A) \gamma]}{(1 + S_A \gamma \sigma) + (1 - S_A) \gamma \eta}. \quad (34)$$

To see the impact of the market power parameter more clearly, we set $\gamma = 0$:

$$\frac{\tau_c}{\tau} = 1 + \mu - \eta(\rho - 1) / \rho. \quad (35)$$

If the industry is characterised by the constant returns to scale ($\rho = 1$), μ determines the extent of the price transmission elasticity's deviation from the competitive benchmark: $\tau_c / \tau = 1 + \mu$. With $\theta > 0$ and n relatively small, τ_c will exceed τ ⁴.

McCorriston et al. (2001) confirm that the impact of market power on price transmission is unambiguous, thus the increase in market power leads to the decrease of price transmission. However, they do not show it technically, for example, differentiating the price transmission equation by the proxy of market power. We offer to use J as a proxy, representing the degree of market power, where $J = \theta/n$ is an adjusted Lerner index⁵. Partially differentiating the equation (32) by J gives the equation (36), which is less than zero. This proves that the increase in market power leads to the decrease in price transmission elasticity:

$$\frac{d\tau}{dJ} = -\frac{S_A \rho^2 (1 + \gamma\sigma) (1 + S_A \gamma\sigma) (1 + \eta)\eta}{(\eta - J)^2 \psi}, \quad (36)$$

where $\psi = \left[(1 + S_A \gamma\sigma) \left(\left(1 + (1 + \eta)J / (\eta - J) \right) \rho - \eta(\rho - 1) \right) + (1 - S_A) \gamma\eta \right]^2$. Thus, with a higher number of firms in the industry, the degree of price transmission will increase.

Let us now check which impact has a cost structure of the industry on price transmission. We assume a perfectly competitive case to eliminate the impact of market structure and to examine the impact of cost structure alone. When $\mu = 0$, the ratio of $\tau_c / \tau = 1 - \eta(\rho - 1) / \rho$ (achieved

⁴ Noting that $\mu = \omega\theta / (n\eta - \theta)$.

⁵ Rewrite equation (17) to receive $[\frac{Q_i}{Q_i} R(Q) - C_i'(Q_i)] / R = [-\frac{\partial R(Q)}{\partial Q} \cdot \theta_i \cdot \frac{Q_i}{Q}] / R$, and then to receive

$$L = -\frac{\partial R(Q)}{R} \cdot \theta_i \cdot \frac{Q_i}{Q}. \text{ Since } \frac{Q_i}{Q} = \frac{1}{n} \text{ and } \frac{\partial R(Q)}{\partial R} = \frac{\partial Q}{\partial R}, \quad L = \frac{1}{n} \cdot \frac{1}{\eta} \cdot \theta. \text{ Lerner index, adjusted by the}$$

corresponding demand elasticity, is equal to $L\eta = -\theta/n$. Both $J = \theta/n$ and the elasticity of demand η in (36) represent the absolute value.

from equation 35). Now, if $\rho > 1$ (the food industry is characterised by increasing returns to scale), then $\tau_c / \tau < 1$. In other words, the price transmission elasticity in the industry, characterised by increasing returns to scale, is higher than in the industry, characterised by constant returns to scale. The same is true for the opposite case: if $\rho < 1$, then $\tau_c / \tau > 1$, and the price transmission under decreasing returns to scale is lower than under the constant returns to scale.

The impact of short-run returns to scale on the elasticity of price transmission can be readily confirmed by differentiating (32) with respect to ρ :

$$\frac{d\tau}{d\rho} = \left[S_A (1 + \gamma\sigma)\eta \left(1 + \gamma \left(1 - S_A [1 + \sigma(\rho - 1)] \right) \right) \right] / \varphi^2, \quad (37)$$

$$\text{where } \varphi = (1 + S_A \gamma\sigma) [(1 + \mu)\rho - \eta(\rho - 1)] + (1 - S_A) \gamma\eta,$$

assuming $\gamma - \eta = 0$

$$\frac{d\tau}{d\rho} = \frac{S_A \eta}{[\rho - \eta(\rho - 1)]^2}. \quad (38)$$

Apart from these findings, one more effect is detected, i.e. price transmission in an imperfectly competitive industry operating in the increasing returns to scale environment could be higher than in a perfectly competitive industry with constant returns to scale. Thus, the role of ρ may either reinforce or offset the impact of market power.

Elasticity of substitution between agricultural and material inputs

McCorrison et al. (2001) study the impact of the elasticity of substitution on price transmission by changing this parameter's value from 0.5 to 0.25. This leads them to the conclusion that the decrease in its value causes a decline in price transmission elasticity. The technical analysis below proves this result for the rest of the possible parameter values.

The impact of the elasticity of substitution between agricultural and material inputs on price transmission is given as follows:

$$\frac{d\tau}{d\sigma} = S_A \rho \gamma (1 - S_A) (\rho + \rho\mu - \eta\rho + \eta + \gamma\eta) / \varphi^2, \quad (39)$$

$$\text{where } \varphi = (\rho + \rho\mu - \eta\rho + \eta + S_A \gamma\sigma\rho + S_A \gamma\sigma\rho\mu - S_A \gamma\sigma\eta\rho + S_A \gamma\sigma\eta + \gamma\eta - S_A \gamma\eta).$$

Knowing that $S_A < 1$, when the expression in the brackets (40)

$$(\rho + \rho\mu - \eta\rho + \eta + \gamma\eta) \quad (40)$$

is greater than zero, then $\frac{d\tau}{d\sigma} > 0$. This means that the increase in the elasticity of substitution between agricultural and material inputs will lead to the increase in price transmission. Expression (40) cannot be lower than zero, because in this case the whole equation (32) becomes negative. This, however, is not allowed, as price transmission elasticity can be interpreted only in positive signs. Expression (40) can also not be equal to zero, because in this case price transmission will be zero. Therefore parameter σ will contribute only to the increase in price transmission.

In a special case of constant returns to scale ($\rho=1$), the increase in the elasticity of substitution of agricultural and material inputs will lead to the increase in price transmission:

$$\frac{d\tau}{d\sigma} = S_A \rho \gamma (1 - S_A) (1 + \mu + \gamma\eta) / \varphi^2, \quad (41)$$

Elasticity of supply of material input

The description of the impact of the supply of material input on price transmission in McCorriston et al. (2001) is limited by changing this parameter's value from 0.5 to 1, which shows that increase in the elasticity of substitution of material input leads to the increase in price transmission. Our analysis shows that there are some additional results which show that the impact of the elasticity of supply of material input on price transmission is ambiguous. Equation (42) implicates that the increase in the elasticity of supply of material input will lead to the increase in price transmission with smaller values for ρ and η .

$$\frac{d\tau}{d\gamma} = S_A \rho (1 - S_A) \left[\sigma \rho (1 + \mu) + \sigma \eta (1 - \rho) - \eta \right] / \varphi^2, \quad (42)$$

$$\text{where } \varphi = \left(\rho + \rho\mu - \eta\rho + \eta + S_A \gamma \sigma \rho + S_A \gamma \sigma \rho \mu - S_A \gamma \sigma \eta \rho + S_A \gamma \sigma \eta + \gamma\eta - S_A \gamma \eta \right).$$

Knowing that $S_A < 1$, when the expression in the brackets $\left[\sigma \rho (1 + \mu) + \sigma \eta (1 - \rho) - \eta \right]$ from equation (42) is greater than zero, then $\frac{d\tau}{d\gamma} > 0$. With lower values for η and with all values for

η lower than

$$\eta = \sigma \rho (1 + \mu) / \left[\sigma (\rho - 1) + 1 \right], \quad (43)$$

equation (42) will be greater than zero. Thus, we conclude that when retail demand is inelastic, the increase in the elasticity of supply of material's input will raise price transmission. However, when retail demand is more elastic, namely, its value is higher than equation (43), the increase in the elasticity of supply of material's input will reduce price transmission.

In a special case of constant returns to scale ($\rho=1$) and industry, characterised by perfect competition ($\mu=0$), increase in the elasticity of supply of material input will lead to the increase in price transmission elasticity only if elasticity of substitution between inputs is greater than price elasticity of demand ($\sigma>\eta$). This is because (42) will be reduced to (44):

$$\frac{d\tau}{d\gamma} = S_A \rho (1 - S_A) (\sigma - \eta) / \phi^2 \quad (44)$$

Price elasticity of demand

McCorriston et al. (2001) demonstrate the impact of the price elasticity of demand on price transmission only by reducing the value of this parameter from 0.4 to 0.2. We prolong this analysis in a technical variant by differentiating equation (32) with respect to η . This gives an ambiguous result:

$$\frac{d\tau}{d\eta} = -S_A (1 + \gamma \sigma) \left\{ (1 + S_A \gamma \sigma) \left[1 - \rho - \rho \theta (\theta + n) / (n\eta - \theta)^2 \right] + (1 - S_A) \gamma \right\} / \phi^2, \quad (45)$$

where $\phi = (1 + S_A \gamma \sigma) \left\{ [1 + (1 + \eta) \theta / (n\eta - \theta)] \rho - \eta (\rho - 1) \right\} + (1 - S_A) \gamma \eta$. Knowing that $S_A < 1$, when the

expression in the brackets $\left[1 - \rho - \rho \theta (\theta + n) / (n\eta - \theta)^2 \right]$ from the equation (45) is greater than zero,

then $\frac{d\tau}{d\eta} < 0$. It is obvious that with the smaller values for ρ , and with all values for ρ lower

than

$$\rho = 1 / \left[1 + \theta (\theta + n) / (n\eta - \theta)^2 \right], \quad (46)$$

this expression will be greater than zero and equation (45) will be lower than zero. This means that with degrees of returns to scale lower than (46), an increase in the elasticity of demand will

lead to a decrease in price transmission. On the other hand, when returns to scale are higher than (46), an increase in the elasticity of demand will lead to an increase in price transmission.

In a special case of constant returns to scale ($\rho=1$), an increase in the elasticity of demand will lead to a decrease in price transmission:

$$\frac{d\tau}{d\eta} = -\frac{S_A(1+\gamma\sigma)\eta(1+S_A\gamma\sigma+\gamma-\gamma S_A)}{(1+\mu+S_A\gamma\sigma+S_A\gamma\sigma\mu+\gamma\eta-\gamma\eta S_A)}. \quad (47)$$

Eventually, increasing returns to scale contributes to the increase in price transmission elasticity when elasticity of retail demand increases. The increase in the elasticity of demand reduces the impact of the monopoly power, and therefore certainly leads to the increase in price transmission. On the other hand, an industry under constant and decreasing returns to scale contributes to the decrease in price transmission elasticity when elasticity of retail demand increases.

3.6. Numerical application of model results and a sensitivity analysis

In the previous section we received the resulting equation for price transmission elasticity, and discussed the main tendencies of its changes. According to it, monopoly mark-up tends to reduce price transmission, while increasing returns to scale increase the transmission of prices, thus offsetting even the effect of imperfect competition. McCorrison et al. (2001) illustrate numerically the magnitudes of these effects. We repeat this procedure, first, with parameter values given in McCorrison et al., and, second, with different parameter values for some more investigations.

Table 1 below highlights the comparison of resulting transmission elasticities given in McCorrison et al. (2001) and recalculated in the current study. Impacts of market structure and functional forms of the demand curve are also presented in Table 1. The adjustment on the demand side depends on the functional form of the demand curve. To catch up the effect of the functional forms two types of demand curves are considered: linear and log-linear forms. The log-linear form implies that the demand function has a constant elasticity, the derivative of which is equal to zero, i.e. $\omega=d\ln\eta/d\ln R=0$, thus, $\mu=\omega\theta/(n\eta-\theta)=0$. In other words, the impact of market power in a case of constant elasticity of demand is eliminated.

With the linear demand function, perfect competition, constant returns to scale, and an agricultural input share equal to 0.5, price transmission elasticity for agricultural input is equal to 0.51. This implies that in a perfect competition and constant returns to scale case the price transmission of each input is equal to its share in the industry costs function.

Table 1 Comparison of price transmission elasticities under different parameter values assumed by McCorrison et al. and in the current study

	McCorrison et al. (2001)	Present study	
	Price transmission (linear demand)		
	(1)	(3)	(4)
Perfect competition and constant returns to scale	0.510	0.522	0.524
Imperfect competition and constant returns to scale	0.322	0.347	0.347
Imperfect competition and increasing returns to scale	0.341	0.520	0.529
Parameter values			
Elasticity of the industry mark-up (μ)	0.636	0.636	0.636
Elasticity of supply of material input (γ)	0.5	1.5	1.8
Increasing returns to scale (ρ)	1.25	∞	∞

where $S_A(S_M)=0.5$, $\rho = 1$ for constant returns to scale, $\rho = 1.25$ and $\rho = \infty$ for increasing returns to scale; $\sigma = 0.5$; $\eta = 0.4$.

Due to imperfect competition, price transmission elasticity is reduced from 0.510 to 0.322. This result leads to a conclusion that with a lower degree of monopoly mark-up in the industry, price transmission will show higher values.

Increasing returns to scale contribute to the increase in price transmission elasticity from 0.322 to 0.341. In the log-linear demand case, the effect of increasing returns to scale is more dramatic: it lets the price transmission in imperfect competition and increasing returns to scale (0.560) overshift the price transmission in a perfect competition case (0.510). This shows that price transmission in a constant elasticity of demand case is higher under increasing returns to scale

than under constant returns to scale. Increasing returns to scale increase price transmission elasticity. Over-shifting implies that the output price decreased more than the input price did. Thus, with the log-linear demand in the industry, characterised by increasing returns to scale, output price decreased more than input price.

The McCorriston et al. study shows the over-shifting only for the log-linear demand case. We attempt to simulate a linear demand case for the over-shifting. Simulation results in Table 1 show that the over-shifting in a linear demand case is possible only if increasing returns to scale acquire a very big - and at the same time not realistic - value. Thus, if returns to scale equal to eternity and elasticity of supply of material input equals to 1.8, price transmission elasticity in imperfect competition and increasing returns to scale (0.529) is higher than price transmission elasticity in perfect competition and constant returns to scale (0.524). In case the elasticity of supply of material input is equal to 1.5, price transmission in imperfect competition and increasing returns to scale (0.520) is almost complete with the case of perfect competition (0.522).

Next, we simulate to check the effects of the rest of the parameters on price transmission elasticity. Results are presented in Table 2 and indicate the difference between the competitive case⁶ and the imperfect competition with increasing returns to scale case, taken in percentage.

⁶ The competitive case stands for the price transmission elasticity under perfect competition and constant returns to scale (equation 33), estimated with a linear demand function.

Table 2 Results of the sensitivity analysis for major determinant parameters of the price transmission elasticity

	Number of firms		
	n=3	n=6	n=12
	(1)	(2)	(3)
Deviation of imperfect competition with increasing returns to scale from perfect competition and constant returns to scale related to the number of firms ($n=3, n=6, n=12$), taken in percentage ^a	-3.16	11.75	20.39
$\eta=0.2$ ($\eta \neq 0.4$)	-32.88	-9.43	3.75
$\sigma=0.001$ ($\sigma \neq 0.5$)	-13.25	0.03	7.72
$\gamma=1$ ($\gamma \neq 0.5$)	1.38	16.44	25.11
$\rho=1.5$ ($\rho \neq 2$)	-9.71	3.12	10.44

^a Price transmission elasticity for perfect competition and constant returns to scale are calculated using equation 33 with the following parameter values: $S_A(S_M)=0.5$, $\sigma =0.5$, $\gamma =0.5$, $\eta =0.4$. The same parameters are used in deriving the imperfect competition transmission elasticity under increasing returns to scale with, in addition $\theta =0.2$ and $\rho = 2$. The number of firms $n=3, n=6, n=12$ refer to the case of imperfect competition. The other entries in this table refer to the sensitivity to the extent of the deviation from the competitive transmission elasticity with constant returns to scale, when the parameters change.

The first figure in Table 2 (top left) indicates that price transmission elasticity in the case of imperfect competition and increasing returns to scale is 3.16 per cent lower than the price transmission elasticity in the case of perfect competition and constant returns to scale. The second, third, fourth and the fifth lines of Table 2 indicate the difference between transmission elasticity under perfect competition with constant returns to scale, and under imperfect competition with increasing returns to scale, the last taken with the changed parameters.

The retail elasticity of demand, η , plays a significant role for the transmission elasticity from the farm to retail level. We change this elasticity only for the case of imperfect competition. The lower elasticity of retail demand (0.2 instead of 0.4) leads to the decline in price transmission elasticity; on the other hand, the increase in the retail demand elasticity leads to the increase in price transmission. The increase in the elasticity of demand reduces the impact of the monopoly power, and therefore certainly leads to the increase in price transmission, which is good for farmers and consumers. However, technical analysis in the section 3.5 of this chapter shows that

η will not always lead to the increase in price transmission. Thus, under certain conditions it may also lead to the decline in price transmission; as it is for example indicated in Table 3. The first figure in Table 3 (top left) indicates that price transmission elasticity in the case of imperfect competition and increasing returns to scale is 9 per cent lower than the price transmission elasticity in the case of perfect competition and constant returns to scale. The second line in Table 3 indicates the difference between transmission elasticity under perfect competition with constant returns to scale, and under imperfect competition with increasing returns to scale, the last taken with the changed price elasticity of retail demand. Thus, we conclude that when returns to scale are higher (1.25), the decrease in the price elasticity of demand will decrease price transmission (the difference between the base case and considered case increases from 9 to 22). However, when returns to scale are lower (0.4), the decrease in the price elasticity of demand will increase price transmission (the difference between the base case and considered case decreases from 46 to 40).

Table 3 Impact of the elasticity of retail demand on price transmission

	<i>n</i> = 5	
	$\rho=1.25$	$\rho=0.4$
	(1)	(2)
Base case ^a	-9	-46
$\eta=0.2$ (not $\eta=0.4$)	-22	-40

^a For a detailed description of calculating the values implicated in this table see footnotes of Table 2.

Simulations for collusive or monopoly outcome with demand elasticity greater than one, shown below in Table 4, confirm some of the results received with the demand elasticity equal to 0.4. Such results indicate that price transmission in imperfect competition and constant returns to scale is lower than under perfect competition and constant returns to scale. However, price transmission elasticity in imperfect competition and increasing returns to scale may be equal to perfect competition case (if $\rho=1.25$), or may even over-shift (if $\rho=1.5$) the perfect competition case not only in the log-linear demand case, as McCorrison et al. (2001) show, but also in the case of a linear demand function (see Table 4).

Table 4 Comparison of price transmission elasticities when price elasticity of retail demand is lower and higher than one

	McCorriston et al. (2001)		Present study	
	Price transmission (linear demand)			
	(1)	(2)	(3)	(4)
Perfect competition and constant returns to scale	0.510	0.510	0.446	0.446
Imperfect competition and constant returns to scale	0.322	0.322	0.367	0.367
Imperfect competition and increasing returns to scale	0.341	0.356	0.446	0.521
	Parameter values			
Price elasticity of demand (η)	0.5	0.5	1.1	1.1
Increasing returns to scale (ρ)	1.25	1.5	1.25	1.5

where $S_A(S_M)=0.5$, $\sigma =0.5$, $\gamma =0.5$.

A very small value of the elasticity of substitution between agricultural and material inputs is offered as a proxy for a situation in which the agricultural input may hardly be substituted with material input, e.g. milk and machinery in butter production. Therefore, in the analysis shown in Table 2, we set σ to be very low ($\sigma=0.001$) to look for consequences of such low substitutability for price transmission elasticity. According to the results, higher substitutability of inputs leads to an increase in price transmission. This implies that a farm's share in an output price is larger when the agricultural input is easily substituted with machinery, and lower when inputs are hardly substitutable. Technically the elasticity of substitution has a direct impact on the changes in price of agricultural input, and therefore has an impact on price transmission elasticity. Intuitively, the higher the substitutability between inputs, the higher the change in input price, the easier the changes in the input price occur, the higher the price transmission elasticity.

Table 2 (column 1) shows that the over-shifting may occur not only because of the increasing returns to scale, but also due to other parameters changes such as, for example, the elasticity of supply of material input.

According to the sensitivity results indicated in Table 2, the inverse elasticity of supply of material input, γ , increases price transmission elasticity. This is good for farmers, because their

share of a retail good's price in this case increases. However, this result is not exhaustive. In section 3.5 of this chapter by technical analysis we show that the impact of elasticity of supply of material input on the price transmission elasticity depends on the interdependencies of the other parameters. The numerical example is illustrated in Table 5, below. The first figure in Table 5 (top left) indicates that price transmission elasticity in the case of imperfect competition and increasing returns to scale is 9 percent lower than price transmission elasticity in the case of perfect competition and constant returns to scale. The second line of Table 5 indicates the difference between transmission elasticity under perfect competition with constant returns to scale, and under imperfect competition with increasing returns to scale, the last taken with the changed elasticity of supply of material input. Thus, we conclude that when retail demand is inelastic (0.4), the increase in the elasticity of supply of material's input will raise price transmission (the difference between the base case and considered case decreases from 9 to 6). However, when retail demand is more elastic (0.8), the increase in the elasticity of supply of material's input will reduce price transmission (the difference between the base case and considered case increases from 1 to 3). This confirms the ambiguous impact of the elasticity of material input on price transmission.

Table 5 Impact of the elasticity of supply of material inputs on price transmission

	<i>n</i> = 5	
	$\eta=0.4$	$\eta=0.8$
	(1)	(2)
Base case ^a	-9	-1
$\gamma=1 (\gamma \neq 0.5)$	-6	-3

^a For a detailed description of calculating the values implicated in this table see footnotes of Table 2.

The impact of returns to scale parameter is indicated in Table 2. The value of returns to scale parameter decreases in the sensitivity analysis from 2 to 1.5 (Table 2), which leads to the decline of price transmission elasticity. These implications prove that the industry structure, namely, increasing, constant or decreasing returns to scale, have a direct impact on price transmission elasticity. Increasing returns to scale increase price transmission. Decreasing returns to scale decrease price transmission (Table 2). This, in its turn, has an impact on farmers' and consumers' welfare. Thus, the industry, characterised by increasing returns to scale, contributes to farmers' and/or to consumer's income.

Results of the sensitivity analysis suggest that transmission elasticity is especially sensitive to the parameters that determine the mark-up elasticity μ (especially to the number of industry firms n). Thus, varying the number of firms in the industry changes the transmission elasticity significantly (Table 2). Already with $n = 6$ the price transmission elasticity with increasing returns to scale over-shifts the one of the competitive case and constant returns to scale by 11.75 per cent. Over-shifting occurs due to increasing returns to scale. Within 12 industry firms and increasing returns to scale, the price transmission over-shifts the perfectly competitive case by 20.39 per cent (Table 2).

Table 6, below, referring to Table 2 in McCorrison et al. (2001), indicates recalculated values without parentheses, and figures, given in McCorrison's Table 2, in parentheses.

Table 6 Comparison of recalculated results of sensitivity analysis and results displayed in McCorrison et al. (2001)

	Number of firms		
	n=2	n=5	n=10
	(1)	(2)	(3)
Deviation of imperfect competition with increasing returns to scale from the competitive benchmark case	-33	-9	0.3 (0.4)
$\eta=0.2$ ($\eta \neq 0.4$)	-64	-22	-7
$\sigma=0.25$ ($\sigma \neq 0.5$)	-36 (-26)	-13	-5
$\gamma=1$ ($\gamma \neq 0.5$)	-30 (-15)	-1 (-6)	9 (3)
$\rho=1.125$ ($\rho \neq 1.25$)	-34 (-24)	-12	-4

Note: Figures, given in parentheses are indicated in Table 2 in McCorrison et al., (2001).

McCorrison (2001) state that decreasing returns to scale reduce price transmission elasticity, or in other words the smaller returns to scale, the lower price transmission elasticity. However, the figure given McCorrison's (2001) paper - in parentheses in the last line of the first column in Table 6 above (-24) - does not support this hypothesis, as it is higher than the elasticity of a perfect competition (a benchmark) case (-33). Our calculation shows that here the figure -34 should present to indicate that lower returns to scale decrease price transmission elasticity. Our recalculation offer figure -30 instead of (-15) for the inverse elasticity of supply of material input γ in the first column, -1 instead of (-6) in the second column, 9 instead of (3) in the third

column; -36 instead of (-26) for the elasticity of substitution of agricultural and material inputs σ (column 1); and 0.3 instead of 0.4 for the deviation of imperfect competition with increasing returns to scale from the competitive benchmark case when $n=10$.

In the footnotes to tables 1 and 2 in McCorrison et al. (2001), monopoly mark-up coefficient, μ , has a value of 0.636 instead of 1.4.

Summarising, the numerical sensitivity analysis proves two main hypotheses offered in the study. First, imperfect competition decreases price transmission elasticity. And second, the cost structure of the industry determines price transmission elasticity.

Results, achieved by the discussed model, are extraordinary and in some sense unexpected, i.e. it proves that price transmission might be incomplete even under perfect competition. Thus, empirical findings (such as in Griffith and Piggott (1994); Peltzman (2000); etc.), showing that imperfect competition (market power) does not necessarily mean imperfect price transmission, or perfect competition in the industry does not necessarily lead to a complete price transmission, now have a theoretical background.

Results achieved in this study might be successfully used for economic predictions, e.g., a farmer has to know that the lower the elasticity of substitution between agricultural and material inputs, the lower the price transmission elasticity for his agricultural output. A farmer, interested in economic predictions, should be aware of the nature of the industry he is dealing with. Thus, if he is dealing with an industry, characterised by increasing returns to scale, then an increase in the demand elasticity for the retail product will lead to an increase in price transmission of the agricultural output. On the other hand, if he is dealing with an industry, characterised by constant or decreasing returns to scale, then an increase in the demand elasticity for the retail product will lead to a decrease in price transmission of the agricultural output. Results of the model show that the impact of the elasticity of demand of material input on price transmission elasticity is difficult to predict, as it depends on the interaction of several parameters simultaneously.

The McCorrison's et al. (2001) study did not achieve the boundaries of the EDM approach, however. This model might be a good starting point to research the new assumptions. We chose this model to investigate the issue of price transmission elasticity in joint production. In the next chapter we extend McCorrison's (2001) model for the case of two jointly-produced goods and discuss achieved results.

CHAPTER 4

Price transmission for joint products

4.1. Theoretical framework of the model “Price Transmission for Joint Products”

We concentrate on the example of dairy products to check for the price transmission elasticity in the case of joint production. For that, we assume a number of milk processing firms producing two homogenous products, goods-complements in production such as butter and skim milk powder. These firms together form a dairy industry. The industry produces two joint products using two independent inputs, such as milk and all kinds of other material inputs (creamers equipment, labour, etc.). To keep the algebra manageable, all other inputs apart from milk are subsumed into a single “material” input. The assumption of a Leontief production technology for the milk-processing sector appears acceptable because the possibilities for substituting material inputs for milk in response to changing factor prices are limited, especially in the short-run situation considered here. We assume capital inputs to be fixed due to the considered short-run term frame. Among the three agents existing in the market (e.g. producers, processors and retailers), market power is applied only by processors (dairy industry). The dairy industry is assumed to be oligopolistic, while not exerting the oligopsony power against the suppliers of inputs (producers). The interactions between firms are modelled through the use of conjectural variations. In deriving the price transmission elasticity, we assume that the agricultural input exogenously shifts. This is, however, not restrictive; the model could be extended for a shift in material input as well. The model flow is displayed in the Figure 2, below.

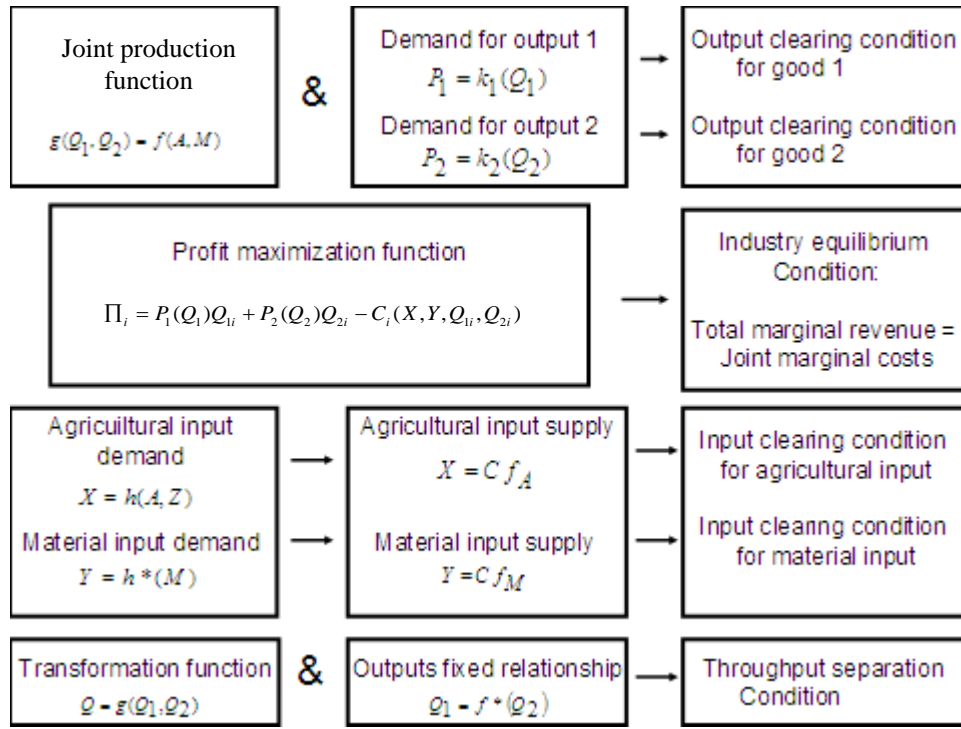


Figure 2 Set-up of the model⁷

Note: The system of equations (A.8b), (A.18)-(A.22) in Appendix 10 forms the clearing conditions presented on the right side of this figure.

This study extends the model of McCorrison *et al.* (2001) for the case of two jointly-produced outputs. To economise on the algebraic implications, a parsimonious description of the model is used. The inverse demand functions for the two jointly-produced outputs are respectively given by

$$P_1 = k_1(Q_1) \quad (48)$$

$$P_2 = k_2(Q_2), \quad (49)$$

where P_1 is the price of the first output and P_2 is the price of the second output. Q_1 and Q_2 are the quantities of the corresponding goods. As these two outputs are produced in fixed proportions, one output is the function of the other: $Q_1 = f^*(Q_2)$.

⁷ Where Q_1, Q_2 are the quantities of the output goods and Q is the quantity of the throughput. P_1, P_2 are prices of the output goods, C is the marginal joint costs variable. A and M are quantities of agricultural and material inputs, X and Y are prices of agricultural and material inputs, respectively. f_A and f_M are marginal products of agricultural and material inputs, respectively.

The dairy industry joint production function is a combination of the production function $Q = f(A, M)$ and the transformation function $Q = g(Q_1, Q_2)$, and is given by

$$g(Q_1, Q_2) = f(A, M), \quad (50)$$

where A stands for an agricultural input, M stands for material input and Q is a throughput between the inputs and the final outputs. The joint production function is assumed to be homogenous of degree ρ .

The input supply functions in the inverse form for the agricultural (A) and material (M) inputs are given by the following equations

$$X = h(A, Z) \quad (51)$$

$$Y = h^*(M) \quad (52)$$

where X and Y are the prices of A and M , and Z represents the exogenous shock in the agricultural sector (e.g. the drought or foot-mouth disease).

The dairy industry has oligopolistic structure. Processing firms maximize profits. In the joint production case the oligopolies' profit equals to the difference between the total gross return and the total cost. The total gross return in the case of two goods produced jointly comes from the sum of partial returns on Q_1 and Q_2 (Fanno, 1974). We also assume that all n firms in the industry have identical profit maximization functions given by

$$\Pi_i = P_1(Q_1)Q_{1i} + P_2(Q_2)Q_{2i} - C_i(X, Y, Q_{1i}, Q_{2i}), \quad (53)$$

The first-order condition with respect to the throughput is

$$\frac{\partial \Pi_{1i}}{\partial Q_i} = P_1 \cdot \frac{\partial Q_{1i}}{\partial Q_i} + \frac{\partial P_1}{\partial Q_1} \cdot \frac{\partial Q_1}{\partial Q} \cdot \theta \cdot Q_{1i} + P_2 \cdot \frac{\partial Q_{2i}}{\partial Q_i} + \frac{\partial P_2}{\partial Q_2} \cdot \frac{\partial Q_2}{\partial Q} \cdot \theta \cdot Q_{2i} - \frac{\partial C_i(X, Y, Q_i)}{\partial Q_i} \quad (54)$$

where Q_i is a throughput, which is a function of inputs, represented by milk and material inputs, which is modelled as a transformation function of two jointly-produced goods. Parameters

$\frac{\partial Q_1}{\partial Q} = \frac{\partial Q_{1i}}{\partial Q_i} = k_1$ and $\frac{\partial Q_2}{\partial Q} = \frac{\partial Q_{2i}}{\partial Q_i} = k_2$ are the technical coefficients representing the share of the

first and the second jointly-produced outputs in the throughput, respectively.⁸ Parameter

$\theta = \frac{\partial Q}{\partial Q_i} = 1 + \frac{\partial \sum_{j \neq i} Q_j}{\partial Q_i}$ is the conjectural variation parameter for the processing firm i . For $\theta=0$

the markets for jointly-produced goods are perfectly competitive, while $\theta=1$ implies a cournot oligopoly and $\theta > 1$ implies monopoly or collusive outcome. Given that the parameter of conjectural variation is a proxy for the behavioural aspect of oligopoly, it might stay constant, even when the number of firms in the industry changes. The same applies for the second market.

If n firms in the industry are of an equal-size with identical cost structures, then $\frac{Q_{1i}}{Q_1} = \frac{Q_{2i}}{Q_2} = \frac{1}{n}$.

Thus, we receive the n -firms oligopolistic industry profit maximization condition given by

$$P_1 = \lambda C - \lambda \varphi P_2, \quad (55)$$

where $\lambda = n\eta_1 / (nk_1\eta_1 - k_1\theta)$ is a market power mark-up, that reflects the industry mark-up of price over costs, $\varphi = (nk_2\eta_2 - k_2\theta) / n\eta_2$ is a pass-through coefficient from the second product's price to the first product's price. We assume that θ is the aggregate conjectural variation parameter of the dairy industry, which is identical across all firms in this industry. n is the number of firms in the industry, η_1 and η_2 are demand elasticities for the two jointly-produced outputs, and k_1 is a fixed ratio between a throughput and a first output, representing the share of one firm's first output in the throughput of this firm. The same is true for k_2 , respectively.

4.2. Price transmission elasticity of a joint product and its main determinants

We derive the price transmission elasticity for the first jointly-produced output (E_1) by solving the equations (48) to (55) following the exogenously occurring shock Z in the agricultural sector.

⁸ Because the relationship between Q_i and Q_{1i} is fixed, they will change in constant proportion to each other. Thus, we say that the ratio $\partial Q_{1i} / \partial Q_i$ represents the share of Q_{1i} in Q_i . The throughput Q_i is not only a function of agricultural and material inputs, it is also an aggregate product of two jointly-produced outputs.

Appendix 10 describes the derivation procedure of the price transmission elasticity for the first jointly-produced output, which is given by

$$\frac{d \ln P_1}{d \ln X} = E_1 = \frac{\delta \eta_2 Sa \rho a (\gamma \sigma + 1)}{D}, \quad (56)$$

Note: D is the denominator, given in Appendix 10 in equation A.10.25

where Sa is the share of agricultural input in the industry cost function, defined as $Sa = \alpha / \rho$. α is the output elasticity for agricultural input and is equal to $\alpha = \rho - \beta$, β is the output elasticity for the material input, and ρ is the (short-run) returns to scale parameter which is greater than (equal to, less than) unity representing increasing (constant, decreasing) returns to scale. μ is the elasticity of the industry mark-up and is equal to $\mu = \omega_1 \theta / (n \eta_1 - \theta)$ with ω_1 representing the change in the elasticity of demand of the first product for a given change in the retail price of this product. ν is the pass-through elasticity from the second product's price to the first product's price, and is equal to $\nu = \omega_2 \theta / (n \eta_2 - \theta)$ with ω_2 representing the change in the elasticity of demand of the second product for a given change in the retail price of this product. σ is the elasticity of substitution between agricultural and materials inputs, which is equal to zero because we assume that milk and materials inputs cannot be substituted in butter production. δ is the ratio of the percentage change in the quantity of the first good to the percentage change in the quantity of the second good, which in the case of goods-complements, produced in fixed proportions, equals unity. $a = \lambda C / P_1$, $b = \lambda \varphi ((C \lambda - P_1) / \varphi \lambda) / P_1$, and their difference is equal unity⁹.

The price transmission elasticity for the second jointly-produced product (E_2) is derived by the analogy with the price transmission elasticity for the first product (E_1). It appears that price transmission from agricultural input to the first output is not same as that to the second output: $E_1 - E_2 \neq 0$ (see equation A.10.25 in Appendix 10). Thus, $\frac{E_1}{E_2} = \frac{\delta \eta_2}{\eta_1}$. As the fixed coefficient

⁹ This is because $P_1 = \lambda C - \lambda \varphi P_2$ and b is equal to $b = \frac{\lambda \varphi P_2}{P_1}$.

δ ¹⁰ in our case, and in all other cases, when goods are produced in fixed proportions, equals one, the ratio of price transmission elasticities of the first and the second jointly-produced goods is determined by the reversed ratio of demands for those goods. Only in the case when demands for both jointly-produced goods are identical, i.e., $\eta_1 = \eta_2$, their price transmission elasticities are the same.

Let us now investigate the main determinants of price transmission for jointly-produced goods using the equation of E_1 (56). The effects of market power and returns to scale lead to significant changes in price transmission. Thus, to receive the price transmission for the industry characterised by constant returns to scale, operating in the competitive market, we set $\mu = 0$, $\nu = 0$, $\rho = 1$ and $\sigma = 0$ ¹¹. Knowing that $\delta = 1$ and $a - b = 1$, price transmission elasticity for the first output under perfect competition and constant returns to scale (E_{1c}) reduces to

$$E_{1c} = \frac{2\eta_2 Sa}{\eta_1 \eta_2 (2 + 4\gamma(1 - Sa)) + \eta_1 + \eta_2}. \quad (57)$$

With the elasticity of supply of material input (γ) equal to zero, price transmission elasticity will be $E_{1c} = 2\eta_2 Sa / (2\eta_1 \eta_2 + \eta_1 + \eta_2)$. If in perfect competition and constant returns to scale $\eta_1 = \eta_2 = 1$, price transmission elasticity is 1/2 of the share of the agricultural input in the industry's cost function ($E_{1c} = \frac{Sa}{2}$). In the case of $\eta_1 = \eta_2 = 2$, price transmission elasticity in perfect competition and constant returns to scale is 1/3 of the share of the agricultural input in the industry's cost function (Sa). This means that even in perfect competition the value of price transmission elasticity is not fixed; it depends on parameter values such as returns to scale, elasticity of substitution between inputs, elasticity of supply of material input and retail elasticities of demand. The higher the elasticities of demand, the lower the price transmission elasticity. Price transmission elasticity equals the share of agricultural input if elasticities of demand are highly inelastic ($\eta_1 = \eta_2 = 0.01$).

¹⁰ δ is the ratio of percentage change in the output of one good over the percentage change in the output of the other good.

¹¹ σ is the elasticity of substitution between agricultural and material inputs, which equals to zero because we assume that milk and material inputs cannot be substituted in the butter production.

Under the same conditions but with market power, pass-through coefficient and returns to scale effects price transmission elasticity for the first output (E_1) equals

$$E_1 = \frac{2\eta_2 Sa \rho}{2\eta_1 \eta_2 (\rho + 2\gamma(1 - Sa)) + \rho(\eta_2(1 + \mu) + \eta_1(1 + \nu))} \quad (58)$$

Comparing the price transmission elasticity in perfect competition and constant returns to scale (E_{1c}) with the price transmission elasticity in imperfect competition and non-constant returns to scale (E_1) we highlight the impacts of market power, pass-through coefficient and returns to scale. Thus, dividing E_{1c} over E_1 , we have

$$\frac{E_{1c}}{E_1} = \frac{2\eta_1 \eta_2 (2 - \rho + 2\gamma(1 - Sa)) + \rho \eta_1 (1 + \nu) + \rho \eta_2 (1 + \mu)}{2\eta_1 \eta_2 (1 - 2\gamma Sa + 2\gamma) + \eta_1 + \eta_2} \quad (59)$$

To see the role of market structure more transparently, we assume $\gamma = 0$. Then, equation (59) reduces to

$$\frac{E_{1c}}{E_1} = \frac{2\eta_1 \eta_2 (2 - \rho) + \rho \eta_2 (1 + \mu) + \rho \eta_1 (1 + \nu)}{\rho (2\eta_1 \eta_2 + \eta_1 + \eta_2)} \quad (60)$$

If the industry is characterised by the constant returns to scale, $\rho = 1$, then equation (60) reduces to

$$\frac{E_{1c}}{E_1} = \frac{2\eta_1 \eta_2 + \eta_2 (1 + \mu) + \eta_1 (1 + \nu)}{2\eta_1 \eta_2 + \eta_1 + \eta_2} \quad (61)$$

To see the pure impact of market structure, we set the elasticities of retail demands equal to two ($\eta_1 = \eta_2 = 2$) to receive

$$\frac{E_{1c}}{E_1} = 1 + \mu + \nu \quad (62)$$

Equation (62) implies that with the monopoly power indicator (μ) greater than zero and/or the pass-through coefficient (ν) greater than zero, the ratio of price transmissions in competitive and uncompetitive environments is higher than unity ($E_{1c}/E_1 > 1$). In other words, price

transmission in a competitive environment (E_{1c}) will be higher than in an uncompetitive environment (E_1), and the over-shift will be equal to $(\mu+\nu)$. Thus, μ and ν determine the extent of the deviation of price transmission elasticity from the competitive benchmark. The higher the elasticity of monopoly mark-up μ , as well as the pass-through coefficient ν , the lower the transmission indicator in imperfect competition and the bigger the difference between the price transmission elasticities in perfect and imperfect competition. Assuming the perfectly competitive industry, we are able to emphasise the impact of returns to scale on price transmission elasticity. With $\mu = 0$ and $\nu=0$ equation (60) will be reduced to

$$\frac{E_{1c}}{E_1} = \frac{4\eta_1\eta_2 - 2\eta_1\eta_2\rho + \rho\eta_1 + \rho\eta_2}{\rho(2\eta_1\eta_2 + \eta_1 + \eta_2)}, \quad (63)$$

which implies that if $\rho=1$, then $E_{1c}/E_1=1$; however if $\rho > 1$, then $E_{1c}/E_1 < 1$. This means that price transmission with increasing returns to scale is higher than that with constant returns to scale (if both conditionally are estimated under perfect competition). With $\rho < 1$, price transmission with constant returns to scale will over-shift that with decreasing returns to scale ($E_{1c}/E_1 > 1$). This makes it obvious that the returns to scale parameter might change the incidence of transmission elasticity. The role of returns to scale can either impede or reinforce the role of the market power in the industry.

The impact of returns to scale on price transmission elasticity can be confirmed by partially differentiating equation (58) by ρ :

$$\frac{\partial E_1}{\partial \rho} = \frac{8Sa\eta_1\eta_2(1+\gamma(1-Sa))}{(2\eta_1\eta_2\rho - 4\eta_1\eta_2 - \rho\eta_2\mu + 4\eta_1\eta_2\gamma Sa - \rho\eta_1 - \rho\eta_2 - 4\eta_1\eta_2\gamma - \rho\nu\eta_1)^2} > 0. \quad (64)$$

Equation (64) is greater than zero, as Sa can not be bigger than one. Therefore we conclude that the increase in the returns to scale parameter ρ leads to the increase in the price transmission elasticity.

The impact of oligopoly power on price transmission can be detected by partially differentiating the equation (58) by J , where $J = \theta/n$ is an adjusted Lerner index¹² which is responsible for the degree of market power in the industry. As the partial derivative is less than zero, the increase in the degree of market power leads to the decrease in price transmission elasticity:

$$\frac{\partial E_1}{\partial J} = -8Sa\rho \left[k_1\eta_1(1+\eta_1)(k_2\eta_2 - \tau)^2 + k_2\eta_2(1+\eta_2)(k_1\eta_1 - \tau)^2 \right] < 0. \quad (65)$$

4.3. Interpretation of results and sensitivity analysis

One of the main results achieved in this study is that price transmission for a jointly-produced output is different from that for a single output. This result is thoroughly discussed in the next section, “Price transmission for a single vs. jointly-produced output”. Then, we fulfil a sensitivity analysis for determinants of price transmission elasticity of a jointly-produced good. Problems are addressed more precisely in the case studies in the last part of this chapter.

4.3.1. Price transmission for a single vs. jointly-produced output

When estimating price transmission elasticity for a joint output good, using the conception of a single output (τ), we must confirm whether we estimate E_1 or E_2 , or we estimate both in the case of $\eta_1 = \eta_2$ ¹³. Thus, four possible cases may occur:

1. $\tau = E_1 = E_2$,
2. $\tau = E_1$ but $\tau \neq E_2$,
3. $\tau = E_2$ but $\tau \neq E_1$,
4. $\tau \neq E_1 \neq E_2$.

To check this numerically, - we attach the same values to the parameters for τ , E_1 and E_2 estimation. We set the number of firms for τ , E_1 and E_2 estimation $n=100$, elasticity of substitution between agricultural and material inputs $\sigma=0.5$, returns to scale elasticity of supply $\rho=1$, of material inputs $\gamma=0.5$, agricultural share in total inputs used

¹² The Lerner index for the first product, adjusted by the corresponding demand elasticity, is equal to $L_1\eta_1 = -\theta/n$, and for the second product is equal to $L_2\eta_2 = -\theta/n$. We take $J = \theta/n$ because η_1 and η_2 are negative.

¹³ If $\eta_1 = \eta_2$, then $E_1 = E_2$. If $\eta_1 \neq \eta_2$, then $E_1 \neq E_2$. This is because $E_1 = \delta\eta_2 E_2 / \eta_1$ and $\delta=1$. For details see equation A.10.26 in Appendix A.10.

$S_A = 0.5$, conjectural variations parameter $\theta = 0.05$, elasticity of demand for an output $\eta = 0.4$ ¹⁴. Additional parameters for E_1 and E_2 estimation are the coefficient indicating fixed production proportions $\delta = 1$, the share of one firm's first output in the throughput of this firm $k_1 = 0.3$, and the share of one firm's second output in the throughput of this firm $k_2 = 0.7$. Elasticity of demand of the second joint product η_2 is calibrated until we reach the conditions $\tau = E_1$ or $\tau = E_2$ (Table 7).

Table 7 Calibration of η_2 to reach the conditions $\tau = E_1$ or $\tau = E_2$

Varied parameter	τ	E_1	E_2
	(1)	(2)	(3)
$\eta_2 = 0.4$	0.510	0.352	0.352
$\eta_2 = 0.36$	0.510	0.371	0.413
$\eta_2 = 0.315$	0.510	0.405	0.514
$\eta_2 = 0.245$	0.510	0.509	0.832
$\eta_2 = 0.23$	0.510	0.551	0.959

Note: $n=100$, $\sigma=0.5$, $\rho=1$, $\gamma=0.5$, $S_A=0.5$, $\theta=0.05$, $\eta=0.4$, $\eta_1=0.4$, $\delta=1$, $k_1=0.3$, $k_2=0.7$

First line of Table 7 indicates that $\tau \neq E_1 = E_2$, which means that price transmission of a single output is different from price transmission elasticities of jointly-produced goods. Thus, the first condition above, $\tau = E_1 = E_2$, is not valid. Instead of that, the fourth condition, $\tau \neq E_1 \neq E_2$, takes place in major cases of this table. The second condition, $\tau = E_1$ but $\tau \neq E_2$, is fulfilled when $\eta_2 = 0.245$, and the third condition, $\tau = E_2$ but $\tau \neq E_1$, is fulfilled when $\eta_2 = 0.315$.

From this analysis, becomes clear that τ never equals to $E_1 = E_2$, and it equals to E_1 or to E_2 only in some special cases. Therefore it is correct to consider the properties of joint production when estimating price transmission.

According to McCorrison et al. (1989: 191), the “perfect” price transmission occurs when the price transmission elasticity equals to the share of the agricultural product, used in the food industry’s cost function. In other words, the “perfect” price transmission is defined as the *perfect price transmission* = Sa , where $0 > Sa \geq 1$. For this condition to occur, the elasticity of supply of material input should be equal to zero, and the condition of perfect competition must

¹⁴ Demand elasticities for joint production are assumed to be equal to 0.4 in order to be compared to the results of the study by McCorrison et al. (2001). However, we admit that elasticity of demand may be only greater than one in the monopoly outcome.

be fulfilled. McCorrison et al. (2001) shows that if perfect competition and the elasticity of supply of material input equals to zero, price transmission depends on the share of agriculture, returns to scale and the elasticity of demand of an output (equation 66):

$$\tau_c = \frac{Sa\rho}{\rho - \eta(\rho - 1)}. \quad (66)$$

In this case, if constant returns to scale occur, we have:

$$\tau_c = Sa. \quad (67)$$

If we set the same parameter values for the key determinants such as $\mu=0, \gamma=0, \rho=1$ to estimate the price transmission elasticity of a joint output, - we will receive the following equation (68):

$$E_{1c} = \frac{a\delta\eta_2 Sa}{\delta\eta_2 - a\delta\eta_1\eta_2 + b\eta_2}, \quad (68)$$

$$\text{where } a = \frac{0.3(nk_1\eta_1 - k_1KV)}{1.9\eta_1 n} \text{ and } b = \frac{\left(\frac{0.3\eta_1 n}{nk_1\eta_1 - k_1KV} \right) - 1.9}{1.9}.$$

Thus, we may say that price transmission elasticity of a joint product in a case of perfect competition, constant returns to scale and elasticity of supply of material input equal to zero depends on Sa, η_1, η_2, k_1 . Number of firms n tends to eternity in perfect competition, conjunctural variations parameter KV and a coefficient $-\delta$, determining that the outputs relationship are externally given and fixed.

In other words, price transmission of a jointly-produced good in a case of perfect competition, constant returns to scale and elasticity of supply of material input equal to zero depends not only on the share of agriculture, as in the case of a single output, but also on the elasticities of demand of both jointly-produced goods and a coefficient determining the share of the first joint output in a gross output.

The calibration of the values of η_1, η_2, k_1 may give us a condition when $E_1 = Sa$. Thus, giving the values to the variables $\eta_1 = 0.83, \eta_2 = 0.4$, and a parameter $k_1 = 0.3$, we receive $E_1 = Sa$.

These results lead us to the conclusion that the conception of price transmission for a single output, developed by the whole range of studies working with the EDM approach, is not valid for the case of joint outputs.

4.3.2. Price transmission for a single vs. aggregated joint outputs

According to Schroeter and Azzam (1991) the "single" output could represent a set of multiple outputs produced in fixed proportions. However, our study results show that price transmission for a "single" output can not represent the aggregated price transmission of a set of multiple outputs produced in fixed proportions. Thus, price transmission of a "single" output is equal to 0.5, whereas the aggregated price transmission of a set of joint outputs in a ceteris paribus case is equal to 0.3. If price transmission of a first output good is 0.3, and of a second jointly-produced output is 0.3, then the price transmission of a joint good is also 0.3.¹⁵

It might be checked by introducing the prices for the outputs, such as e.g. 2\$ and 5\$ for both jointly-produced goods respectively. 30% out of price 2\$ gives the value of 0.6\$, and out of price 5\$ gives the value of 1.5\$. Aggregating these values gives 2,1\$ (0.6\$+1.5\$). The aggregated transmitted value 2.1\$ is 30% of the aggregated price 7\$ (2\$+5\$). Thus, in a case when joint products price transmissions are equal each to 0.3, the aggregated price transmission for multiple outputs produced in fixed proportions is equal to 0.3. Price transmission of a single output under the same possible conditions is equal to 0.5.

This leads us to a conclusion, that price transmission of a "single" good can not represent aggregated price transmission of multiple outputs produced in fixed proportions.

4.3.3. Determinants of price transmission elasticity of a jointly-produced good

In this section we conduct the sensitivity analysis for the case of price transmission in joint production with respect to two groups of model parameters: external parameters that describe the underlying market organisation, and internal parameters that describe the underlying production technology.

In these two groups of parameters, the two elements that are of particular interest namely are the type of market structure and returns to scale. In this section we discuss how different market

¹⁵ See table 7, first line.

structures and returns to scale affect price transmissions of jointly-produced goods. We will test whether these parameters have an identical or different impact on both joint goods. We will discuss the sensitivity of the direction of price transmission change with respect to all parameters. The magnitude of change will be examined with regard to some parameters only.

In particular, we will discuss three scenarios: change in the market structure alone, change in returns to scale alone and a combination of these two scenarios.

a. Sensitivity with respect to the market organisation parameters

Market organization forms the way, in which exchange in a market takes place. It is determined by a combination of factors, including:

- 1.a. market power parameter (μ), which determines the ability of a producer to set the price, and conjectural variation (θ), which has an impact on market power parameter;
- 2.a. elasticity of supply of materials input;
- 3.a. and elasticities of demand of jointly-produced goods.

1.a. Market power

We start by testing several market structure scenarios by considering different degrees of market power in the industry with alternative returns to scale. We seek to determine how the variation in market power affects price transmission for two jointly-produced goods under different returns to scale. We also aim to check whether this impact is identical for two price transmission elasticities.

We consider several scenarios for the market power parameter (μ) under constant returns to scale (Table 8) and under increasing returns to scale (Table 9). $\mu=0$ corresponds to the perfect competition in the industry and $\mu=0.145$ to the monopoly, with values ranging between these values, such as $\mu=0.006$ to $\mu=0.033$ corresponding to different degrees of imperfect competition, with higher values corresponding to higher degrees of imperfect competition.

Table 8 Sensitivity of price transmission for two jointly-produced goods with respect to market power under constant returns to scale

Scenarios for market power	First jointly-produced good		Second jointly-produced good	
	Price transmission (E1)	Deviation from the previous scenario (%)	Price transmission (E2)	Deviation from the previous scenario (%)
	(1)	(2)	(3)	(4)
1. $\mu=0$	0.3304	-	0.4956	-
2. $\mu=0.006$	0.3292	0.3631	0.4938	0.3631
3. $\mu=0.012$	0.3282	0.3037	0.4923	0.3037
4. $\mu=0.019$	0.3270	0.3656	0.4905	0.3656
5. $\mu=0.027$	0.3256	0.4281	0.4884	0.4281
6. $\mu=0.033$	0.3244	0.3685	0.4866	0.3685
7. $\mu=0.1454$	0.3056	-	0.4584	-

Note: $\mu=0$ corresponds to the case of perfect competition (number of firms tend to infinity), $\mu=0.006$ corresponds to the case of 20 firms in the industry, $\mu=0.012$ corresponds to the case of 11 firms in the industry, $\mu=0.019$ corresponds to the case of 7 firms in the industry, $\mu=0.027$ corresponds to the case of 5 firms in the industry, $\mu=0.033$ corresponds to the case of 4 firms in the industry, and $\mu=0.1454$ corresponds to the case of monopoly. $\rho=1$, $Sa = 0.5$, $\eta_1=0.6$, $\eta_2=0.4$, $\theta=0.05$, $k_{1i} = 0.3$, $k_{2i} = 0.7$, $\delta = 1$, $\gamma=0.5$ and $\sigma=0$.

Table 8 and Figure 3 below present results of the sensitivity analysis for the key price transmission determinant of the model: market power indicator. We find that under different degrees of market power, price transmissions for two jointly-produced goods are different in absolute terms, whereas their changes in relative terms are identical (compare columns 2 and 4 of Table 8).

The economic interpretation is the following: oligopolistic processor takes two jointly-produced goods as a single global output. The total gross return the oligopolist receives is made by the sum of the partial returns from the two jointly-produced goods. It is naturally in the interest of the oligopolist that the total gross return is as high as possible. However, for this total gross return to be the highest possible, it is necessary for the individual partial returns that make it up also to be as high as possible. Thus, the increased degree of market power is transferred to both jointly-produced goods at a maximum. If market demands differ in the two markets, price transmission absolute values are different. However, relative changes in price transmissions are identical, being a maximum transfer of the increased degree of market power of an oligopolistic processor.

Table 9 and Figure 4 show the sensitivity of price transmission with respect to the market power indicator under increasing returns to scale. It appears that under increasing returns to scale, price transmissions of two jointly-produced goods are higher than those under constant returns to scale (compare Tables 8 and 9). Moreover, the same changes in the market power under the increasing returns to scale lead to the greater changes in the price transmission estimates. For example, the change in the *E1* from the first to the second scenario under the constant returns to scale is 0.36 per cent (Table 8, column 2), but under the increasing returns to scale it is 0.52 per cent (Table 9, column 2). Thus, the more effective industry functioning reduces the impact of market power, but increases the changes in this impact.

The sensitivity of price transmission according to the pure returns to scale scenario is considered in Section 3.4.2 in the context of production technology.

Table 9 Sensitivity of price transmission for two jointly-produced goods with respect to market power under increasing returns to scale

Scenarios for market power	First jointly-produced good		Second jointly-produced good	
	Price transmission (E1)	Deviation from the previous scenario (%)	Price transmission (E2)	Deviation from the previous scenario (%)
	(1)	(2)	(3)	(4)
1. $\mu=0$	0.4934	-	0.7401	-
2. $\mu=0.006$	0.4908	0.5269	0.7362	0.5269
3. $\mu=0.012$	0.4886	0.4482	0.7330	0.4346
4. $\mu=0.019$	0.4859	0.5525	0.7289	0.5593
5. $\mu=0.027$	0.4829	0.6174	0.7244	0.6173
6. $\mu=0.033$	0.4803	0.5384	0.7204	0.5521
7. $\mu=0.1454$	0.4401	-	0.6602	-

Note: $\rho=0.5$. See in the notes for Table 9 the values of other parameters for price transmission estimations.

Under decreasing returns to scale (Table 10 and Figure 3 below) the effect of market power is damped but less pronounced (volatile) than this effect in the cases of constant (Table 8) and increasing (Table 9) returns to scale.

Table 10 Sensitivity of price transmission for two jointly-produced goods with respect to market power under decreasing returns to scale

Scenarios for market power	First jointly-produced good		Second jointly-produced good	
	Price transmission (E1)	Deviation from the previous scenario (%)	Price transmission (E2)	Deviation from the previous scenario (%)
	(1)	(2)	(3)	(4)
1. $\mu=0$	0.1659	-	0.2488	-
2. $\mu=0.006$	0.1656	0.1808	0.2484	0.1607
3. $\mu=0.012$	0.1653	0.1811	0.2480	0.1610
4. $\mu=0.019$	0.1650	0.1814	0.2476	0.1612
5. $\mu=0.027$	0.1647	0.1818	0.2470	0.2019
6. $\mu=0.033$	0.1644	0.1821	0.2466	0.2023
7. $\mu=0.1454$	0.1594	-	0.2391	-

Note: $\rho=1.5$. See in the notes for Table 9 the values of other parameters for price transmission estimations.

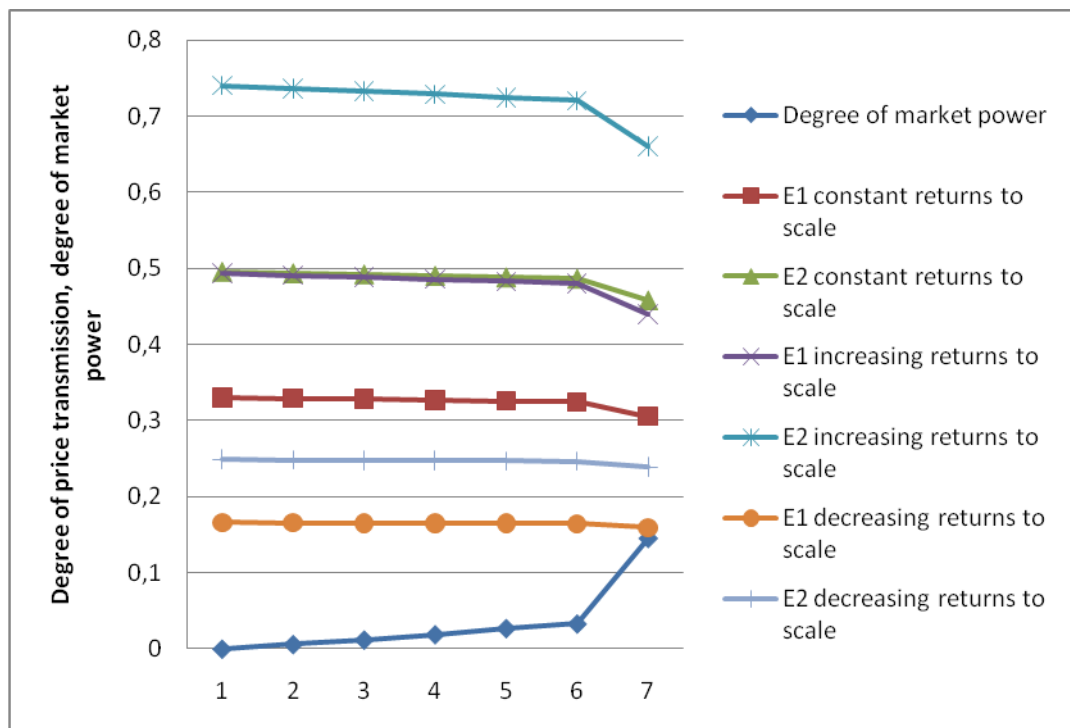


Figure 3. The impact of market power on the dynamics of price transmission in different types of economies of scale

2.a. Elasticity of supply of material input

Price elasticity of supply measures the sensitivity of the quantity of a good supplied to the changes in the market price for that good. Thus, the price elasticity of input supply affects the quantity of input used in production and hence the quantity of output produced, which in turn has a direct impact on price transmission elasticity.

In our model, we have two price elasticities of factor supply: price elasticity of agricultural input supply and price elasticity of material input supply.¹⁶

Following, we discuss the impact of the elasticity of material input supply on price transmission. We discuss it, first, for the case when inputs are pure complements¹⁷ ($\sigma=0$) and, second, for the case when they are not complements ($\sigma\neq 0$). The first case corresponds perfectly to our reference example of butter production when milk cannot be substituted with dairy separator equipment. The impact of the elasticity of supply of material input on price transmission ($E1$ and $E2$) when agricultural and material inputs are perfect complements ($\sigma=0$) appears to be unambiguous (equation 69). We find that an increase in the elasticity of supply of materials input leads to the decline in price transmission elasticities for both jointly-produced goods.¹⁸

$$\frac{dE1}{d\gamma} = -\frac{\delta\eta_2 Sa\rho a(2\delta\eta_2 a\eta_1(1-Sa))}{\varphi^2} < 0, \quad (69)$$

where

$$\varphi = -\rho\delta\eta_2\mu b - \delta\eta_2 a\rho\eta_1 + 2\delta\eta_2 a\gamma\eta_1 + \rho b v\eta_1 + \rho\delta\eta_2 - 2\delta\eta_2 a\gamma\eta_1 Sa + \rho\delta\eta_2\mu a + 2\delta\eta_2 a\eta_1 + \rho b\eta_1.$$

The economic reason for this result can be illustrated with a reference to a certain shock from the agricultural supply side, e.g. the decrease in the supply of agricultural inputs (Figure 4a). The agricultural input supply shift decreases the derived supply for the retail product such that the price for the retail product increases (Figure 4c). So long as the agricultural and material inputs are complements, the decrease in the agricultural input will lead to the corresponding decrease in material input usage (Figure 4b). Thus, the demand function for material input in this case is fixed and therefore absolutely inelastic. Figure 4c shows the corresponding changes on the retail

¹⁶ Since we estimate price transmission elasticity from agricultural input to output, price elasticity of agricultural input supply has no impact on price transmission elasticity

¹⁷ This is measured by the elasticity of substitution between factor inputs (σ).

¹⁸ Note that $Sa < 1$

market. Retail supply shifts to the left as a result of the change in the agricultural and material inputs. However, the slope of the retail supply depends on the slope of the supply of material input. The higher the elasticity of material input supply, the higher the elasticity of the retail supply. As shown in Figure 4c, the market power mark-up is higher under the more elastic supply of the retail product, thus the price transmission elasticity in this case is lower, which is also indicated in equation (69).

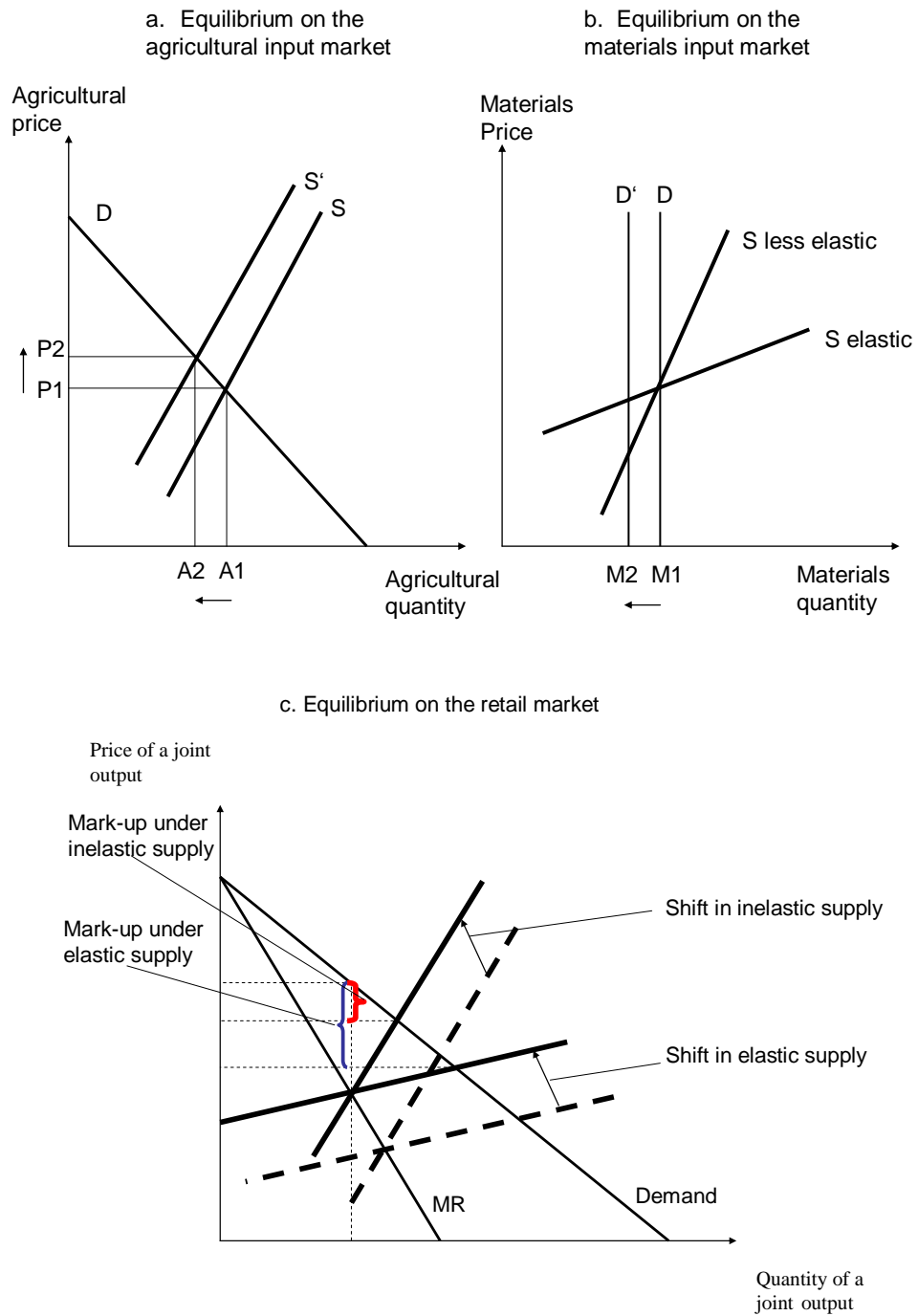


Figure 4 Price movements for inputs-complements (case of $\sigma=0$)

The case of butter production normally shows no substitutability between agricultural and material inputs. Thus, a certain amount of milk might be used with a combination of a certain number of pieces of creaming equipment for a production of a certain amount of butter and skim milk powder. However, in this example, a negligible degree of substitutability might occur if we were to assume a special type of separation equipment able to absorb more fat from the same amount of milk. In this case, elasticity of substitution between inputs will be very small, but different from zero ($\sigma \neq 0$). To check for this case, we again fulfil the differentiation of EI by γ while holding $\sigma \neq 0$ (equation 70).

$$\frac{dEI}{d\gamma} = Sa\rho\delta\eta_2a \frac{\left[\sigma\rho b\eta_1(1+\nu)(1-Sa) \right] - \left[\eta_1\eta_2\delta a(1-Sa)(\rho\sigma+2)(1-\sigma) \right] + \left[\delta\rho\sigma(\mu\eta_2(1-Sa)+\eta_2) \right]}{\psi^2},$$

where ψ stays for a fraction¹⁹. (70)

Equation (70) acquires a negative sign only in the case when the second component enclosed in the squared brackets in the numerator is negative and gives an absolute value bigger than the sum of the first and the third squared brackets in the numerator. This component will be negative only in the case when $\sigma < 1$. Thus, when the elasticity of substitution is less than unity, increase in the elasticity of supply of material input will lead to the decrease in price transmission. However, when the elasticity of substitution is equal or bigger than unity, the increase in the elasticity of supply of material input will lead to the increase in price transmission. We implicated these results in the numerical sensitivity analysis in Table 11.

¹⁹

$$\psi = \rho\delta\eta_2\mu b + \delta\eta_2a\rho\eta_1 - 2\delta\eta_2a\gamma\eta_1 - \rho b\nu\eta_1 - \rho\delta\eta_2 + Sa\rho\gamma\sigma\delta\eta_2a\eta_1 + 2\delta\eta_2a\gamma\eta_1Sa - 2\delta\eta_2a\gamma\sigma\eta_1Sa - \rho\delta\eta_2\mu a - 2\delta\eta_2a\eta_1 + Sa\rho\gamma\sigma\delta\eta_2\mu b - Sa\rho\gamma\sigma\delta\eta_2 - Sa\rho\gamma\sigma\delta\eta_2\mu a - Sa\rho\gamma\sigma b\nu\eta_1 - Sa\rho\gamma\sigma b\eta_1 - \rho b\eta_1$$

Table 11 Changes in price transmission elasticity for the first good under different elasticities of supply of material input (γ) and elasticities of substitution between inputs (σ)

	$\sigma=0$		$\sigma=0.1$		$\sigma=1$		$\sigma=2$	
	$\gamma=0.2$	$\gamma=1.2$	$\gamma=0.2$	$\gamma=1.2$	$\gamma=0.2$	$\gamma=1.2$	$\gamma=0.2$	$\gamma=1.2$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Change in E1	0.3595	0.2511	0.3634	0.2709	0.3953	0.3995	0.4256	0.4836

Note: The results are derived under $\mu=0.069$ which corresponds to 2 firms in the industry, $\rho=1$, $Sa=0.5$, $\eta_1=0.6$, $\eta_2=0.4$, $\theta=0.05$, $k_{1i}=0.3$, $k_{2i}=0.7$, and $\delta=1$.

Whenever $\sigma \rightarrow \infty$, the price transmission elasticity does not react to any changes in the elasticity of supply of material input. Such a high degree of elasticity of substitution implies that one input can be perfectly substituted by another input. Thus, when agricultural input is perfectly substitutable with material input, the changes in the elasticity of supply of material input have no impact on the price transmission elasticity.

We did not present results from the sensitivity analysis for the second price transmission elasticity $E2$ because $E1$ is a linear homogenous function of $E2$. Therefore the overall impact of parameters on $E1$ is identical to that on $E2$. Thus, the increase of $E2$ by a certain degree will lead to $E1$ being increased by the same degree. For example, an increase in the material input supply elasticity from 0.2 to 0.5 will lead to the decline in price transmission elasticity of the first good by 11.4603 per cent, and in the transmission elasticity to the second good by 11.4592 per cent (Table 12 and Figure 5 below), etc.

Table 12 Impact of price elasticity of supply of material inputs on price transmission elasticities of jointly-produced goods

Scenarios for market power	First jointly-produced good		Second jointly-produced good	
	Price transmission (E1)	Decrease from the first scenario (%)	Price transmission (E2)	Decrease from the first scenario (%)
	(1)	(2)	(3)	(4)
1. $\gamma=0.2$	0.3595	-	0.5393	-
2. $\gamma=0.5$	0.3183	11.4603	0.4775	11.4592
3. $\gamma=1$	0.2673	25.6467	0.4009	25.6628
4. $\gamma=5$	0.1170	67.4547	0.1756	67.4392

Note: for $\mu=0.069$ with 2 firms in the industry, $\rho=1$, $Sa=0.5$, $\eta_1=0.6$, $\eta_2=0.4$, $\theta=0.05$, $k_{1i}=0.3$, $k_{2i}=0.7$, $\delta=1$, $\gamma=0.5$ and $\sigma=0$.

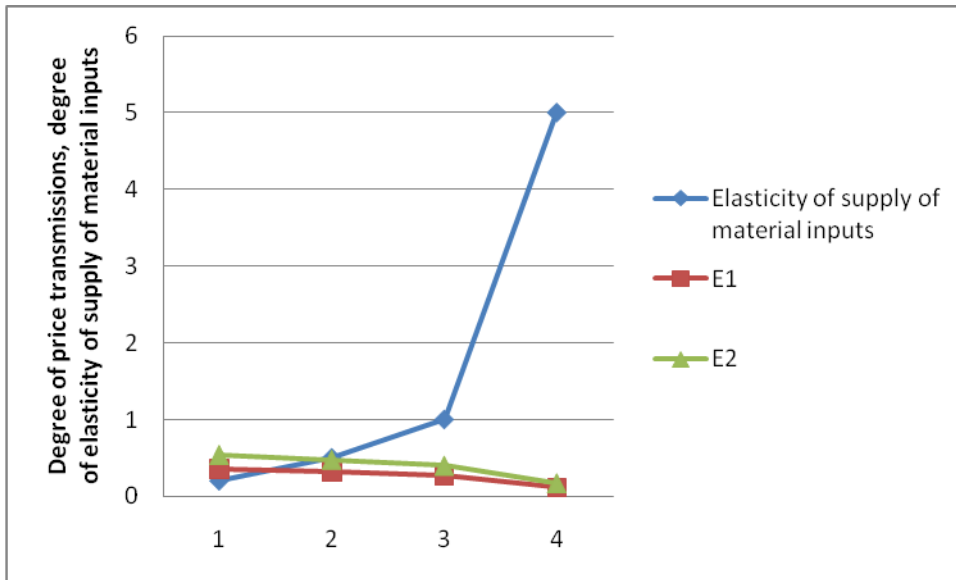


Figure 5. Impact of price elasticity of supply of material inputs on price transmission elasticities of jointly-produced goods

3.a. Elasticities of demand of jointly-produced goods

Elasticity of demand shows the responsiveness of the quantity demanded of a good to a change in its price. Our model considers the responsiveness of two jointly-produced goods, supplied in fixed proportions, to two dependent on each other prices.

Our results show that the elasticity of demand of one good affects not only its own price transmission, but also the price transmission of the other jointly-produced good.

Table 13a demonstrates the impact of the price elasticity of demand of the first output good on price transmission elasticity of this good depending on the values of parameters k_2 and η_2 . From these results we see that with lower values of k_2 price transmission increases when η_1 increases, and with higher values of k_2 price transmission decreases when η_1 increases; the increase in η_2 leads to the decrease in price transmission.

Table 13 The impact of the price elasticity of demand of the first jointly-produced product (η_1) on price transmission elasticity of this product (EI) under the alternative values of parameter k_2 and η_2 when:

a. $k_2=0.3$ and 0.7 ²⁰

Share of the second output in the throughput	$k_1=0.7$ and $k_2=0.3$				$k_1=0.3$ and $k_2=0.7$			
	$\eta_2=0.6$		$\eta_2=1.6$		$\eta_2=0.6$		$\eta_2=1.6$	
Elasticity of demand of the second output	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Elasticity of demand of the first output	$\eta_1=0.4$	$\eta_1=0.8$	$\eta_1=0.4$	$\eta_1=0.8$	$\eta_1=0.4$	$\eta_1=0.8$	$\eta_1=0.4$	$\eta_1=0.8$
Price transmission (EI)	0.1793	0.4344	0.1221	0.1290	0.2570	0.2507	0.2226	0.1891

²⁰ k_2 illustrates the share of the second jointly-produced good in the throughput. The bigger the share of the second good (k_2), the lower the share of the first jointly-produced good (k_1). For example, if the share of the first good is 0.3 ($k_1 = 0.3$), the share of the second good is 0.7 ($k_2 = 0.7$); however, if the share of the first good in the throughput increases to 0.5 ($k_1 = 0.5$), the share of the second good decreases to 0.5 ($k_2=0.5$).

b. $k_2=0.5$ and 0.6

Share of the second output in the throughput	$k_1=0.5$ and $k_2=0.5$				$k_1=0.4$ and $k_2=0.6$			
Elasticity of demand of the 2 nd output	$\eta_2=0.6$		$\eta_2=1.6$		$\eta_2=0.6$		$\eta_2=1.6$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Elasticity of demand of the 1 st output	$\eta_1=0.4$	$\eta_1=0.8$	$\eta_1=0.4$	$\eta_1=0.8$	$\eta_1=0.4$	$\eta_1=0.8$	$\eta_1=0.4$	$\eta_1=0.8$
Price transmission (EI)	0.2112	0.3179	0.1578	0.1534	0.2319	0.2804	0.1847	0.1693

Note: For $\mu=0.069$ that corresponds to 2 firms in the industry, $\rho=1$, $Sa=0.5$, $\theta=0.05$, $\delta=1$, $\gamma=0.5$ and $\sigma=0$.

Table 13b indicates that when the share of the second product is 0.5 and 0.6, with higher values for η_2 , an increase in η_1 leads to the decrease in price transmission; however, with lower values for η_2 , an increase in η_1 leads to the increase in price transmission. An increase in η_2 in all considered cases leads to the decrease in price transmission.

In sum, when the share of the first product is high (0.7), an increase in the elasticity of demand for this product increases its price transmission. When the share of the first product is low (0.3), an increase in the elasticity of demand for this product leads to the decrease in its price transmission. When the share of the first good is equal or close to the share of the second jointly-produced good (0.5; 0.6), the elasticity of demand of the first good increases price transmission if the elasticity of demand for a second good is low, and decreases price transmission if it is high.

In the sensitivity analysis of the single output system, given in Chapter 3, the reaction of the price transmission elasticity τ to the change in the elasticity of retail demand η is determined by the degree of returns to scale ρ . With lower degrees of returns to scale, price transmission decreases when elasticity of demand increases; however, under constant and increasing returns to scale, price transmission increases when elasticity of demand increases. Therefore, in the following we discuss whether returns to scale might have an impact on the price transmission elasticity in a joint products case as well.

Table 14 presents the results of the numerical analysis. Under decreasing and constant returns to scale price transmission of the first jointly-produced good decreases if the elasticity of demand for this good increases. However, under the increasing returns to scale, price transmission starts to increase when the elasticity of demand increases.

Table 14 The impact of price elasticity of demand of the first output good on the respective price transmission under different returns to scale

a. Share of the first jointly-produced good in the throughput is high

	Returns to scale			
	$\rho=0.3$		$\rho=1$	
	(1)	(2)	(3)	(4)
Price elasticity of demand of the first output good	$\eta_1=0.8$	$\eta_1=1.8$	$\eta_1=0.8$	$\eta_1=1.8$
Price transmission of the first output good ($E1$)	0.0859	0.0661	0.2507	0.2363

Note: for $\mu=0.069$ with 2 firms in the industry, $S_a = 0.5$, $\eta_2=0.6$, $\theta=0.05$, $k_1=0.7$, $k_2=0.3$, $\delta = 1$, $\gamma=0.5$ and $\sigma=0$.

b. Share of the first jointly-produced good in the throughput is low

	Returns to scale	
	$\rho=1.1$	
	(1)	(2)
Price elasticity of demand of the first output good	$\eta_1=0.8$	$\eta_1=1.8$
Price transmission of the first output good ($E1$)	0.2759	0.2930

Note: For $\mu=0.069$ that corresponds to 2 firms in the industry, $S_a = 0.5$, $\eta_2=0.6$, $\theta=0.05$, $k_1=0.3$, $k_2=0.7$, $\delta = 1$, $\gamma=0.5$ and $\sigma=0$.

Next consider the cross impact of demand elasticities on price transmission elasticities of both jointly-produced goods. Table 16 illustrates this dependency numerically. When $\eta_1 < \eta_2$ ($\eta_1=0.4$ and $\eta_2=0.6$), price transmission of the first product ($E1=0.2570$) is higher than that of the second one ($E2=0.1713$). When $\eta_1 > \eta_2$ ($\eta_1=0.6$ and $\eta_2=0.4$), price transmission of the first product ($E1=0.3181$) is lower than that of the second product ($E2=0.4775$).

Table 15 The cross impact of the demand elasticities on price transmissions of joint goods

Elasticities of demands of first and second jointly-produced goods	$\eta_1=0.4 \quad \eta_2=0.4$	$\eta_1=0.6 \quad \eta_2=0.4$	$\eta_1=0.4 \quad \eta_2=0.6$
	(1)	(2)	(3)
$E1$	0.2952	0.3183	0.2570
$E2$	0.2952	0.4775	0.1713

Note: For $\mu=0.069$ that corresponds to 2 firms in the industry, $Sa=0.5$, $\theta=0.05$, $k_1=0.3$, $k_2=0.7$, $\delta=1$, $\rho=1$, $\gamma=0.5$, and $\sigma=0$.

When price elasticities of demands on both markets are identical ($\eta_1=\eta_2=0.4$), price transmissions of both jointly-produced goods are also identical. Thus, when two markets are identical the oligopolist sees no reason to consider each of them separately.

An increase in the elasticity of demand of the first output leads to the increase in price transmission elasticities of both joint outputs. An increase in the elasticity of demand of a second joint output leads to the decrease in price transmission of both joint outputs. This points to the fact that jointly-produced products are not independent bodies, but are in a fixed relationship to each other and are even treated as a single product. The producer treats jointly-produced goods as a single product, supplied to a single market, which, however, has two elasticities of demand. Thus, an increase in one elasticity of demand leads to an increase in price transmission, whereas an increase in the other elasticity of demand leads to a decrease in price transmission.

Price transmission is higher on the market of the particular jointly-produced good, which elasticity of demand is lower than another good's. For example, consumers of butter will benefit more from the milk price decline than consumers of skim milk powder, if demand for butter is less elastic than for skim milk powder, and the other way round.

b. Sensitivity with respect to the production technology

Another important set of parameters determining the price transmission elasticities for jointly-produced goods describes the production technology of these goods. We divide these parameters into three groups:

- 1.b. parameters representing inputs combination, i.e., the share of agricultural input (Sa), and the elasticity of inputs substitution (σ);

2.b. parameters representing the throughput separation, i.e., the shares of jointly-produced products in the throughput (k_1, k_2), and the fixed production coefficient (δ);

3.b. and the parameter representing the efficiency of the processing technology, namely the returns to scale parameter (ρ).

1.b. Parameters describing inputs combination

The elasticity of substitution is a measure of the ease with which the varying factor can be substituted by others (Hicks, 1932).

According to equation (71), an increase in σ will increase EI . Thus, the higher degree of inputs substitutability leads to the increase in price transmission elasticity.

$$\frac{\partial E_1}{\partial \sigma} = \frac{\delta \eta_2 Sa \rho a \gamma (1 - Sa) (2 \delta \eta_2 a \eta_1 + \rho b v \eta_1 + \rho \delta \eta_2 + 2 \delta \eta_2 a \gamma \eta_1 + \rho b \eta_1 - \delta \eta_2 a \rho \eta_1 + \rho \delta \eta_2 \mu)}{(Z)^2}$$

where Z stays for a fraction. ²¹ (71)

Table 16 and Figure 6 below indicate that the increase in the elasticity of substitution between inputs increases price transmission elasticities of jointly-produced goods.

²¹ $Z = \left(\begin{array}{l} \rho \delta \eta_2 \mu b + \delta \eta_2 a \rho \eta_1 - 2 \delta \eta_2 a \gamma \eta_1 - \rho b v \eta_1 - \rho \delta \eta_2 + Sa \rho \gamma \delta \eta_2 a \eta_1 + 2 \delta \eta_2 a \gamma \eta_1 Sa - 2 \delta \eta_2 a \gamma \sigma \eta_1 Sa - \\ \rho \delta \eta_2 \mu a - 2 \delta \eta_2 a \eta_1 + Sa \rho \gamma \sigma \eta_2 \mu b - Sa \rho \gamma \delta \eta_2 - Sa \rho \gamma \delta \eta_2 \mu a - Sa \rho \gamma \delta v \eta_1 - Sa \rho \gamma \delta \eta_1 - \rho b \eta_1 \end{array} \right)$

Table 16 The impact of elasticity of substitution on price transmission elasticities of jointly-produced goods

Elasticity of substitution between inputs	Price transmission of the first jointly-produced good ($E1$)	Price transmission of the second jointly-produced good ($E2$)
	(1)	(2)
$\sigma=0$	0.3183	0.4775
$\sigma=0.1$	0.3276	0.4914
$\sigma=0.2$	0.3365	0.5048
$\sigma=0.3$	0.3451	0.5177
$\sigma=0.4$	0.3534	0.5421
$\sigma=0.5$	0.3614	0.5536
$\sigma=0.6$	0.3690	0.5558
$\sigma=0.7$	0.3764	0.5647
$\sigma=0.8$	0.3836	0.5754
$\sigma=0.9$	0.3905	0.5858
$\sigma=1$	0.3972	0.5958

Note: For $\mu=0.069$ that corresponds to 2 firms in the industry, $Sa = 0.5$, $\theta=0.05$, $\eta_1=0.6$, $\eta_2=0.4$, $k_1=0.3$, $k_2=0.7$, $\delta = 1$, $\rho=1$ and $\gamma=0.5$.

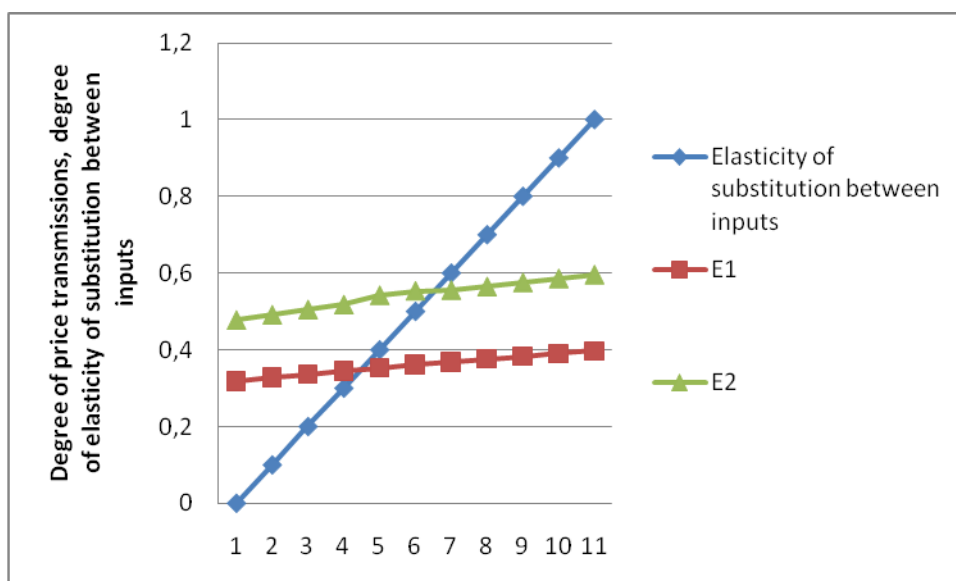


Figure 6. The impact of elasticity of substitution on price transmission elasticities of jointly-produced goods

The next parameter that might determine the extent of price transmission elasticity is the share of agricultural input (Sa). In our case, butter production, the shares of agricultural and materials input are fixed because of the nature of the product. Hence, the sensitivity analysis with respect to Sa is not necessary for our study. However, as these inputs might be slightly substitutable in reality, we conduct a sensitivity analysis with respect to this parameter as well.

As price transmission determines how price changes of the agricultural input feeds through the output, the bigger the share of agricultural input, the higher the price transmission from this input to the output (Gardner, 1975). Thus, the increase in the share of agricultural input should increase the price transmissions of both outputs. Table 17 and Figure 7 present the results.

Table 17 The impact of the increased share of agricultural input on price transmission elasticities of jointly-produced goods

	Price transmission of the first jointly-produced good ($E1$)	Price transmission of the second jointly-produced good ($E2$)
	(1)	(2)
$Sa = 0$	0	0
$Sa = 0.1$	0.0552	0.0828
$Sa = 0.2$	0.1142	0.1713
$Sa = 0.3$	0.1774	0.2661
$Sa = 0.4$	0.2453	0.3679
$Sa = 0.5$	0.3383	0.4775
$Sa = 0.6$	0.3972	0.5958
$Sa = 0.7$	0.4825	0.7238
$Sa = 0.8$	0.5753	0.8629
$Sa = 0.9$	0.6764	1.0146
$Sa = 1$	0.7870	1.1805

Note: For $\mu=0.069$ that corresponds to 2 firms in the industry, $\theta=0.05, \eta_1=0.6, \eta_2=0.4, k_1=0.3, k_2=0.7, \delta=1, \rho=1, \gamma=0.5$ and $\sigma=0$.

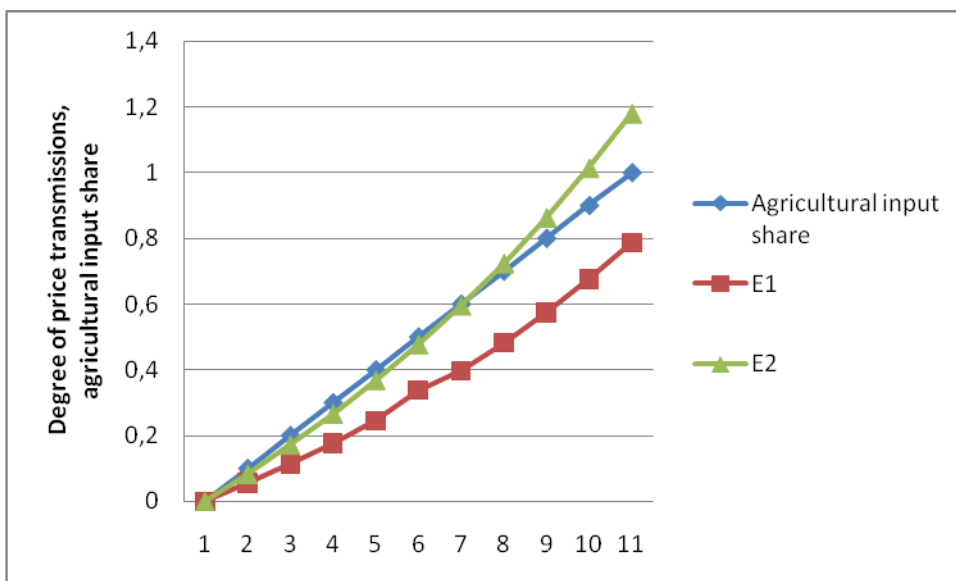


Figure 7. The impact of the increased share of agricultural input on price transmission elasticities of jointly-produced goods

When agricultural input share in production function equals one, change in material input supply no longer has an impact on price transmission. This is because in cases, in which $S_a = 1$, material input is not involved in the production process (Table 18).

Table 18 The impact of the elasticity of supply of materials input on price transmission if $S_a = 1$

	Elasticity of material input supply	
	$\gamma=0.5$	$\gamma=1.5$
	(1)	(2)
Price transmission of the first jointly-produced good ($E1$)	0.7870	0.7870
Price transmission of the second jointly-produced good ($E2$)	1.1805	1.1805

Note: for $\mu=0.069$ with 2 firms in the industry, $S_a=1$, $\theta=0.05$, $\eta_1=0.6$, $\eta_2=0.4$, $k_1=0.3$, $k_2=0.7$, $\delta=1$, $\rho=1$ and $\sigma=0$.

2.b. Parameters representing the throughput separation

The model assumes a throughput, which is further separated into two jointly-produced goods. We accomplish the separation using technical coefficients that determine the share of each jointly-produced good in a throughput. The coefficient k_1 determines the share of the first jointly-produced output, and coefficient k_2 determines the share of the second jointly-produced output. The bigger k_1 is, the more of the first good is produced; as a consequence of that the less of the second good is produced and the smaller the k_2 coefficient is.

We assume that these shares cannot vary substantially because of the nature of the product that we select as a case study; therefore in the frames of our study we do not need to conduct the sensitivity analysis with respect to these parameters.

However, for a general case we conduct the sensitivity analysis with respect to these parameters as well. The differentiation of the price transmission equations $E1$ and $E2$ with respect to the output shares produce cumbersome and unhandy results. Thus, we chose to show the results numerically.

Analysis shows that the impact of the output shares depends on the price elasticities of demand of jointly-produced goods. When these elasticities are identical, e.g. $\eta_1 = \eta_2 = 0.4$ (Table 19), the change in the shares of products supplied to these two markets has no effect on the price transmission elasticities.

Table 19 The impact of the shares of jointly-produced goods on price transmission elasticities when $\eta_1 = \eta_2 = 0.4$

	Shares of the jointly-produced goods in the throughput quantity	
	$k_1=0.1$ $k_2=0.9$	$k_1=0.3$ $k_2=0.7$
	(1)	(2)
Price transmission of the first jointly-produced good ($E1$)	0.2952	0.2952
Price transmission of the second jointly-produced good ($E2$)	0.2952	0.2952

Note: for $\mu=0.069$ with 2 firms in the industry, $Sa=0.5$, $\theta=0.05$, $\gamma=0.5$, $\delta=1$, $\rho=1$ and $\sigma=0$.

However, when price elasticities of demand of two jointly-produced goods differ (see Tables 20a and 20b), then the change in the shares of these jointly-produced goods has an impact on price transmission elasticities. If the elasticity of demand for one good is higher than that for its jointly-produced good, then the increase in the production share of this good will increase its price transmission elasticity. However, when the elasticity of demand of one good is lower than that of its jointly-produced good, - then the increase in the production share of this good will decrease its price transmission elasticity.

The economic intuition is the following: in a more competitive market, an increased number of goods supplied to the market will increase price transmission of these goods. However, in a less competitive market, an increased number of goods supplied to the market will decrease price transmission of these goods.

Table 20 The impact of the shares of jointly-produced goods on price transmission elasticities when $\eta_1 \neq \eta_2$

a. Price transmission of the first jointly-produced good (*E1*)

	Price elasticities of demand			
	$\eta_1=1.6 \quad \eta_2=1.4$		$\eta_1=1.4 \quad \eta_2=1.6$	
	$k_1=0.1 \quad k_2=0.9$	$k_1=0.3 \quad k_2=0.7$	$k_1=0.1 \quad k_2=0.9$	$k_1=0.3 \quad k_2=0.7$
	(1)	(2)	(3)	(4)
Price transmission of the first jointly-produced good (<i>E1</i>)	0.1426	0.1502	0.1619	0.1542

b. Price transmission of the second-jointly produced good (*E2*)

	Price elasticities of demand			
	$\eta_1=1.4 \quad \eta_2=1.6$		$\eta_1=1.6 \quad \eta_2=1.4$	
	$k_1=0.3 \quad k_2=0.7$	$k_1=0.1 \quad k_2=0.9$	$k_1=0.3 \quad k_2=0.7$	$k_1=0.1 \quad k_2=0.9$
	(1)	(2)	(3)	(4)
Price transmission of the second jointly-produced good (<i>E2</i>)	0.1349	0.1716	0.1716	0.1416

Note: for $\mu=0.069$ with 2 firms in the industry, $Sa=0.5$, $\theta=0.05$, $\gamma=0.5$, $\delta=1$, $\rho=1$ and $\sigma=0$.

Another coefficient that describes the output markets regulates the relationship between two jointly-produced goods (δ). It is the ratio of percentage change in the output of one good over the percentage change in the output of the other good (equation 72). In the case of butter and skim milk powder production, or in any other case of goods-complements, - this coefficient equals unity. For instance, an increase in butter production by 10 per cent leads to an increase in skim milk powder production by 10 per cent as well. Thus, we call this measure a fixed production coefficient:

$$d \ln Q_1 = \delta d \ln Q_2. \quad (72)$$

As we assume that the fixed production coefficient does not change in our model, we do not conduct a sensitivity analysis with respect to this parameter.

3.b. Returns to scale parameter

The concept of returns to scale (ρ) refers to changes in output subsequent to a proportional change in all inputs. If output increases by the same proportion as inputs, then there are constant returns to scale in place. If output increases by less than that proportional change, then we deal with decreasing returns to scale. If output increases more than this proportional change, there are increasing returns to scale.

In our model there are two jointly-produced goods. Each output is sensitive to the returns to scale parameter. Equation (73) shows that as increase in the returns to scale leads to an unambiguous increase in the price transmission elasticity of a first jointly-produced good. As the first transmission elasticity is a linear homogenous function of the second one, this result is valid for a second good as well.

$$\frac{\partial E_1}{\partial \rho} = \frac{2\delta^2 \eta_2^2 S a a^2 \eta_1 (\gamma\sigma + 1)(1 + \gamma(1 - Sa) + Sa\gamma\sigma)}{(\Theta)^2}, \quad (73)$$

where Θ is a fraction in denominator²². Table 21 and Figure 7 present the numerical estimates of the price transmission elasticities of both jointly-produced goods under different degrees of returns to scale. While absolute values of price transmission of joint goods are different, their relative changes are identical. For example, when $\rho=0.5$, $E1 = 0.1628$ and $E2 = 0.2442$. When ρ increases to $\rho=1$, both elasticities increase by 95.5 per cent as compared to their previous values, respectively.

Another interesting observation is that increasing ρ by 0.5 units in each scenario leads to the price transmission increase each time by a less percentage (compare columns 2 and 4 of Table 21 under different scenarios). For instance, the change from decreasing to constant returns to scale has a higher impact on price transmission than does the changing from the constant to increasing returns to scale.

²²

$$\Theta = \left(\begin{array}{l} \rho\delta\eta_2\mu b + \delta\eta_2 a \rho \eta_1 - 2\delta\eta_2 a \gamma \eta_1 - \rho b v \eta_1 - \rho\delta\eta_2 + S a \rho \gamma \sigma \delta \eta_2 a \eta_1 + 2\delta\eta_2 a \gamma \eta_1 S a - 2\delta\eta_2 a \gamma \sigma \eta_1 S a - \rho\delta\eta_2 \mu a - \\ 2\delta\eta_2 a \eta_1 S a \rho \gamma \sigma \delta \eta_2 \mu b - S a \rho \gamma \sigma \delta \eta_2 \mu b - S a \rho \gamma \sigma \delta \eta_2 - S a \rho \gamma \sigma \delta \eta_2 \mu a - S a \rho \gamma \sigma b v \eta_1 - S a \rho \gamma \sigma b \eta_1 - \rho b \eta_1 \end{array} \right)$$

Table 21 The impact of returns to scale on price transmissions of jointly-produced goods

Scenarios for returns to scale	First jointly-produced good		Second jointly-produced good	
	Price transmission (E1)	Deviation from the previous scenario (%)	Price transmission (E2)	Deviation from the previous scenario (%)
	(1)	(2)	(3)	(4)
1. $\rho=0.01$	0.0033	-	0.0049	-
2. $\rho=0.5$	0.1628	4833.3333	0.2442	4883.6734
3. $\rho=1$	0.3183	95.5159	0.4775	95.5364
4. $\rho=1.5$	0.4670	46.7169	0.7005	46.7015
5. $\rho=2$	0.6093	30.4710	0.9140	30.4782
6. $\rho=2.5$	0.7456	22.3699	1.1184	22.3632

Note: For $\mu=0.069$ that corresponds to 2 firms in the industry, $Sa=0.5$, $\theta=0.05$, $\eta_1=0.6$, $\eta_2=0.4$, $k_1=0.3$, $k_2=0.7$, $\gamma=0.5$, $\delta=1$, and $\sigma=0$.

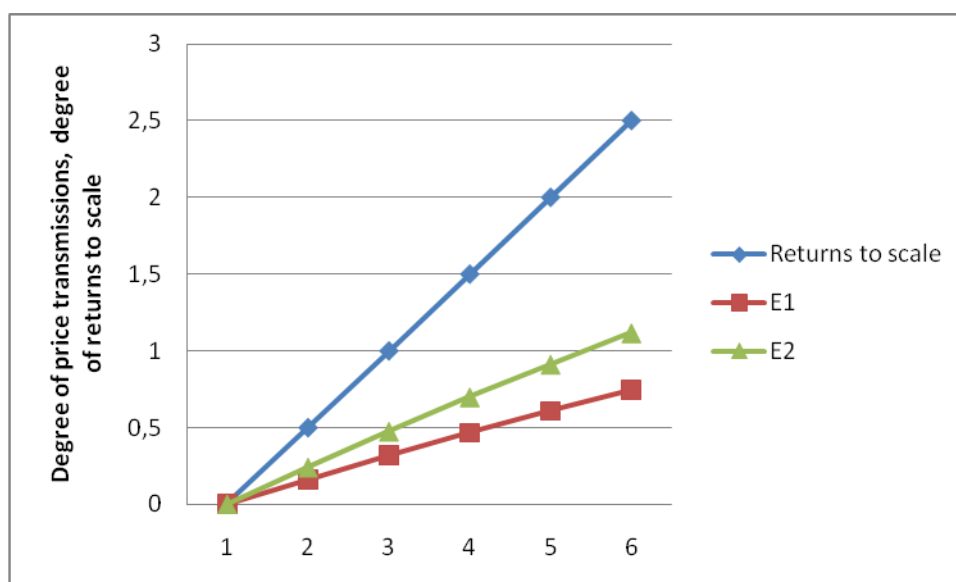


Figure 8. The impact of returns to scale on price transmissions of jointly-produced goods

Summarising research done in this chapter, we conclude that it contributes to the growing body of the price transmission theory on joint output price transmission. This chapter argues that the post-modern theory of price transmission and jointly-produced goods are not unrelated events: both reciprocally feed into each other's inherent interdependences.

We follow the key studies on equilibrium displacement modelling by Gardner (1975) and McCorrison et al. (1989; 2001) in building the basic fundamentals of price transmission

relationships. While both studies use the same method to estimate price transmission, McCorriston undertakes it individually for a single output price transmission; in contrast, the present study offers a model that tackles price transmission for a joint output.

This model examines price transmission in the case of two jointly-produced goods. The dairy industry, producing two goods-complements in production such as butter and skim milk powder, is chosen to illustrate this process. Butter and skim milk powder are produced with single costs and in fixed proportions to each other. These products are produced by the oligopolistic industry, which does not acquire oligopsony power.

Model results show that price transmission of a jointly-produced output is different from that of a single output. Model results show that price transmission of a joint output is not equal to the share of agricultural input, as it is in the case of a single output (McCorriston et al., 1989). Thus, price transmission of a joint output in a case of perfect competition and constant returns to scale depends not only on the share of the agricultural input, as it is in the case of a single output, but additionally on the elasticities of demand of the jointly-produced goods and on a share of the joint output in a gross output. Therefore we conclude that the concept of price transmission of a single output, developed by the whole range of studies working with the EDM approach, is not valid for the case of joint outputs. Hence, it is vital to consider the properties of joint production when estimating price transmission of jointly-produced goods.

Another result is that the price of input is differently transmitted to two jointly-produced goods depending on two independent retail demands of those goods. We show that the price transmission of a first jointly-produced product is governed by the price elasticity of demand not only of a first product, but also of a second product. Similarly, the price elasticity of demand of a first product governs not only price transmission of the product itself, but also price transmission of a second jointly-produced product.

Model results show that the elasticities governing the price transmission of a single output as well as of joint outputs make the same impact. Table 22 indicates that increase in market power, returns to scale and the elasticity of substitution between agricultural and material inputs leads to the increase in the price transmission elasticity of a single good, as well as of jointly-produced goods. Increase in the elasticity of supply of the material input depends on the interaction of parameters ρ, η, σ . However, if the elasticity of supply of material input equals zero, increase or

decrease in the elasticity of substitution between agricultural and material inputs has no effect on joint products price transmission and on a single product price transmission elasticity.

Elasticity of demand increases or decreases price transmission of a single product depending on the value of returns to scale parameter. Elasticity of demand of a first joint product increases or decreases price transmission of its output, depending on the values of such variables as returns to scale, elasticity of demand of a second jointly-produced product and the share of this product in a joint output.

Thus, we may conclude that the sign of change of price transmission of a single product and of a joint product under the impact of certain elasticities is the same (Table 22).

Table 22 Comparison of effects of different elasticities on price transmissions of single good vs. jointly-produced good

	Price transmission of a single output	Price transmission of a first joint output
	(1)	(2)
Market power increase	↓	↓
Returns to scale increase	↑	↑
Elasticity of supply of material input increase	↑↓	↑↓
Elasticity of substitution between agricultural and material inputs increase	↑	↑
Increase in the agricultural input share	↑	↑
Elasticity of demand of a single output increase	↑↓	-
Elasticity of demand of a first joint output increase	-	↑↓

Note: the arrows indicate the sign of the direction of changes.

Finally, the results of the model show that when consumers of one of the jointly-produced goods gain from damping down the market power, consumers of the other good also gain. In addition we found that market power and returns to scale effects are transmitted in relative terms equally to both jointly-produced goods. This implies that consumers in both markets are affected in relative terms equally when changes in market power and returns to scale occur.

Moreover, we also show that a subsequent increase in market power leads to a subsequent increase in price transmission, but a subsequent increase in returns to scale leads to a smaller increase in price transmission elasticity. Hence, the value of price transmission increase has its limit.

We also found that the more effective industry functioning reduces the impact of market power but increases the changes in this impact. Thus, in the industry, characterised by increasing returns to scale market power is damped, but its impact is more pronounced.

This chapter provides a comprehensive understanding of price transmission in joint production in a theoretical context using an example of the dairy industry. However, this study is not limited to the dairy sector. It is a good contribution to the theory of price transmission for all kinds of jointly-produced goods. Cows producing milk and meat, sheep producing wool and meat and the crude oil sector generating motor gasoline and distillate are few examples of production processes that generate two outputs based on common costs.

CHAPTER 5

Conclusions

The central aims of this study are: to define and review the literature on the theoretical aspects of price transmission; to apply the method used to identify the theoretical properties of price transmission and to extend this method to the case of jointly-produced goods. Hence, the main contribution of this study is twofold covering the theory of price transmission and methodology used to identify theoretical aspects of price transmission, and the extension of the theory and methodology for the case of price transmission of jointly-produced goods. The focal points of these study address the following questions:

- (1) Theory and methodology: What is vertical price transmission and what kind of methodology may be used for a theoretical research on price transmission?
- (2) Extension of the theory and methodology: Is the price transmission of a jointly-produced good identical to that of a single output? Specifically, the question is whether results achieved by McCorrison et al. (2001) are valid for the case of a jointly-produced good.

Theory and methodology:

First, a general definition of the term “vertical price transmission” is presented. This background information is then used to review and discuss the literature on theoretical aspects of price transmissions. Reviewed studies are classified according to their findings and the complexity of methodology used. This methodology is the equilibrium displacement modelling (EDM), and it is a major tool employed to conduct theoretical analyses of the mechanisms of price transmissions. Second, a detailed description of the EDM methodology is shown using the example of the McCorrison’s et al. (2001) model. All steps of the modelling framework of this study are discussed, and a detailed description of the mathematical method is given.

Results by McCorrison et al. (2001) are extraordinary and to some extent unexpected. They proved that price transmission might be complete even under imperfect competition. Thus, empirical findings (e.g., Griffith and Piggott (1994); Peltzman (2000); etc.) showing that market power does not necessarily mean imperfect price transmission, and perfect competition in the industry does not necessarily lead to a complete price transmission, now have a theoretical background. Another finding indicates that if the cost function is characterised by increasing

returns to scale, the influence of market power might be offset by the cost effects of scale enlargement, and the level of price transmission may increase relative to the competitive case. Apart from these major results the model by McCorrison et al. produces another finding, which may be successfully used for economic predictions, i.e., - the lower the elasticity of substitution between agricultural and material inputs, the smaller the price transmission elasticity for an agricultural output. Results of the model show that the impact of the elasticity of demand of material input, as well as of the elasticity of supply of material input on price transmission elasticity, is difficult to predict, as it depends on the interaction of several parameters simultaneously. In this chapter we also introduce suggestions for improvement of the results presented in the McCorrison et al. (2001) study. First, it is suggested to expand analysis of the determinants of price transmission, and second, typing errors should be corrected.

Extension of the theory and methodology:

This study argues that the emergence of a post-modern theory of price transmission and jointly-produced goods are not unrelated events: both reciprocally feed into each other's inherent interdependences. Thus, the theory of price transmission is applied to a multiple output hypothesis, and the EDM model is extended to a case of two jointly-produced goods-complements in production. We follow the key studies on equilibrium displacement modelling by Gardner (1975) and McCorrison et al. (1989; 2001) in building the basic fundamentals of price transmission relationships. The EDM model developed by these studies has been extended for price transmission from input to two jointly-produced outputs. The dairy industry, producing two goods-complements in production such as butter and skim milk powder, was chosen as an example, representing the multiple output hypothesis. Butter and skim milk powder are produced with single costs and in fixed proportion to each other. These products are produced by the oligopolistic industry, which does not acquire oligopsony power.

Model results show that it is necessary to consider the properties of joint production when estimating price transmission of jointly-produced goods, because:

1. Price transmission of a jointly-produced output is different from that of a single output.
2. Price transmission of a joint output is not equal to the share of agricultural input, as it is in the case of a single output (McCorrison et al., 1989).
3. Price transmission of a joint output in a case of perfect competition and constant returns to scale depends not only on the share of the agricultural input, as it is in the case of a

single output, but additionally on the elasticities of demand of the jointly-produced goods and on the share of the joint output in a gross output.

4. Price of an input is differently transmitted to two jointly-produced goods depending on two independent retail demands of those goods.

Model results show that it is necessary to consider the properties of joint production when estimating price transmission for multiple outputs. In dairy industry multiple outputs include goods-complements in production (butter and skim milk powder or cheese and whey) and substitutes in production (butter and cheese). In order to estimate price transmission for goods-substitutes in production we first have to incorporate the impact of goods-complements in production into the system. Our results show that the aggregated price transmission of goods-complements in production is not equal to price transmission of a single output, which means that the effect of goods-complements in production should be considered when estimating price transmission for goods-substitutes in production.

There are additional important results, which characterise price transmission in joint production:

1. Elasticities governing the price transmission of a single output as well as price transmission of joint outputs make the same impact.
2. When consumers of one of the jointly-produced goods gain from damping down the market power, consumers of the other good also gain.
3. Market power and returns to scale effects are transmitted in relative terms equally to both jointly-produced goods.
4. A subsequent increase in market power leads to a subsequent increase in price transmission, but a subsequent increase in returns to scale leads to a smaller increase in price transmission elasticity.

Outlook of the research

We considered the case of joint production by the example of goods-complements in production. The obvious extension of the model could be to introduce goods-substitutes in production into the modelling framework.

Some studies (Kinnukan and Forker, 1987; Serra and Goodwin, 2002; Aguiar and Santana, 2002) estimate price transmission of dairy products by regressing farm-gate milk price on a single dairy product, without considering the impact of its joint outputs. Our study results show

that the value of price transmission of one dairy product should include the impact of goods produced in fixed proportions with this dairy product. For example, the value of price transmission of butter should contain the impact of skim milk powder, which should be incorporated into the empirical model. Further research may include an empirical application of this theoretical result.

Next, market structure might be extended for the oligopsony case. Another extension includes incorporating some other shock factors into the model, e.g., the exogenous shift in the demand for one of the jointly-produced goods. This should lead to further development of the conception of joint product pricing. In general, this study could serve as the backbone for further extensions and research directions in this field.

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Appendix 1

The transformation procedure for the output with respect to the input relative change ($d \ln f_A$)

As the output elasticity with respect to the agricultural input is $\alpha = \frac{\partial Q}{\partial A} \cdot \frac{A}{Q}$, we may also write it

$\alpha = f_A \frac{A}{Q}$ and then $f_A = \alpha \frac{Q}{A}$. Converting it into percentage changes gives:

$$d \ln f_A = d \ln \alpha + d \ln Q - d \ln A. \quad (\text{A.1.1})$$

Now we exogenously incorporate the returns to scale parameter ρ and the elasticity of substitution σ into this equation. So we have:

$$d \ln f_A = \frac{\rho\sigma}{\rho\sigma} \cdot (d \ln \alpha + d \ln Q - d \ln A). \quad (\text{A.1.2})$$

Add and subtract the same fraction ($\frac{d \ln Q}{\rho}$) in the brackets:

$$d \ln f_A = \frac{\rho\sigma}{\rho\sigma} \cdot (d \ln Q - \frac{d \ln Q}{\rho} + \frac{d \ln Q}{\rho} - d \ln A + d \ln \alpha), \quad (\text{A.1.3})$$

multiply and divide by parameter ρ , and simplify to get:

$$d \ln f_A = \frac{\rho\sigma}{\rho\sigma} \cdot (\frac{\rho}{\rho} \cdot d \ln Q - \frac{d \ln Q}{\rho} + \frac{d \ln Q}{\rho} - \frac{\rho}{\rho} \cdot d \ln A + \frac{\rho}{\rho} \cdot d \ln \alpha) \quad (\text{A.1.4})$$

$$d \ln f_A = \frac{\rho\sigma}{\rho\sigma} \cdot \frac{(\rho-1)}{\rho} \cdot d \ln Q + \frac{\rho\sigma}{\rho\sigma} \cdot (\frac{d \ln Q}{\rho} - \frac{\rho}{\rho} \cdot d \ln A + \frac{\rho}{\rho} \cdot d \ln \alpha) \quad (\text{A.1.5})$$

$$d \ln f_A = \frac{\sigma(\rho-1)}{\rho\sigma} \cdot d \ln Q + \frac{\sigma}{\rho\sigma} \cdot (d \ln Q - \rho \cdot d \ln A + \rho \cdot d \ln \alpha). \quad (\text{A.1.6})$$

From now on we will continue to transform only the second fraction of the equation above:

$$\frac{\sigma}{\rho\sigma} \cdot (d \ln Q - \rho \cdot d \ln A + \rho \cdot d \ln \alpha) \quad (\text{A.1.7})$$

As $\rho = \alpha + \beta$, and $d \ln Q = \alpha d \ln A + \beta d \ln M$, we have:

$$\frac{\sigma}{\rho\sigma} \cdot (\alpha d \ln A + \beta d \ln M - \alpha d \ln A - \beta d \ln A + \alpha d \ln \alpha + \beta d \ln \alpha), \quad (\text{A.1.8})$$

which yields:

$$\frac{\sigma}{\rho\sigma} \cdot (\beta(d \ln M - d \ln A + d \ln \alpha) + \alpha d \ln \alpha). \quad (\text{A.1.9})$$

If we assume that

$$\alpha d \ln \alpha = -\beta d \ln \beta, \quad (\text{A.1.10})$$

then

$$\frac{\sigma}{\rho\sigma} \cdot (\beta(d \ln M - d \ln A + d \ln \alpha) - \beta d \ln \beta) \quad (\text{A.1.11})$$

and

$$\frac{\sigma}{\rho\sigma} \cdot \beta(d \ln M - d \ln A + d \ln \alpha - d \ln \beta). \quad (\text{A.1.12})$$

Displaying σ as it is offered in Chiang (1967b):

$$\sigma = \frac{d \ln A - d \ln M}{d \ln f_M - d \ln f_A} = \frac{d \ln A - d \ln M}{d \ln A - d \ln M + d \ln \beta - d \ln \alpha} \quad (\text{A.1.13})$$

and putting it into the fraction above will give:

$$-\frac{\beta}{\rho\sigma} \cdot \frac{d \ln A - d \ln M}{d \ln A - d \ln M + d \ln \beta - d \ln \alpha} \cdot (d \ln A - d \ln M - d \ln \alpha + d \ln \beta), \quad (\text{A.1.14})$$

which is equal to:

$$-\frac{\beta}{\sigma\rho} \cdot (d \ln A - d \ln M) \quad (\text{A.1.15})$$

So, $d \ln f_A$ is transformed into the following form:

$$d \ln f_A = \frac{\sigma(\rho-1)}{\rho\sigma} \cdot d \ln Q - \frac{\beta}{\sigma\rho} \cdot (d \ln A - d \ln M) \quad (\text{A.1.16})$$

Following are, first, the σ derivation, and, second, the proof for $\alpha d \ln \alpha = -\beta d \ln \beta$.

The proof for (A1.10): $\alpha d \ln \alpha = -\beta d \ln \beta$:

$\alpha d \ln \alpha = -\beta d \ln \beta$ only if ρ is a parameter, and $d \ln \rho = 0$. As $\rho = \alpha + \beta$, then $d\rho = d\alpha + d\beta$.

Dividing both parts by ρ gives $\frac{d\rho}{\rho} = \frac{d\alpha}{\rho} + \frac{d\beta}{\rho}$. Multiplying and dividing $\frac{d\alpha}{\rho}$ by α , and $\frac{d\beta}{\rho}$

by β gives $\frac{d\rho}{\rho} = \frac{\alpha}{\rho} \cdot \frac{d\alpha}{\alpha} + \frac{\beta}{\rho} \cdot \frac{d\beta}{\beta} = \frac{\alpha}{\rho} \cdot d \ln \alpha + \frac{\beta}{\rho} \cdot d \ln \beta$. As a result we have:

$\rho \cdot d \ln \rho = \alpha d \ln \alpha + \beta d \ln \beta$. If ρ is a parameter, then $d \ln \rho = 0$ and $\alpha d \ln \alpha = -\beta d \ln \beta$.

The $d \ln f_M$ transformation into the form $\frac{\alpha}{\sigma\rho}(d \ln A - d \ln M) + \frac{\sigma(\rho-1)}{\sigma\rho} d \ln Q$ is similarly

derived.

The sigma derivation (A1.13):

$$\sigma = \frac{d \ln A - d \ln M}{d \ln f_M - d \ln f_A} = \frac{d \ln A - d \ln M}{d \ln A - d \ln M + d \ln \beta - d \ln \alpha}$$

This is so because

$$\begin{aligned} (d \ln f_M - d \ln f_A) &= d \ln \beta + d \ln Q - d \ln M - d \ln \alpha - d \ln Q + d \ln A = \\ &= d \ln \beta - d \ln M - d \ln \alpha + d \ln A = d \ln A - d \ln M + d \ln \beta - d \ln \alpha \end{aligned} \quad (\text{A.1.17})$$

If we assume that α and β are variables, then $d \ln \alpha$ and $d \ln \beta$ are not equal to zero, thus, σ is not equal to one.

Appendix 2

The input supply function conversion into the logarithmic form

In order to receive percentage changes of variables, the given agricultural input supply function is converted into a logarithmic form by the following procedure:

$$P=k(A,Z) \tag{A.2.1}$$

$$\ln P=\ln k(A,Z) \tag{A.2.2}$$

$$d \ln P=d \ln k(A,Z) \tag{A.2.3}$$

$$d \ln P=\frac{k_A}{k(A,Z)} dA+\frac{k_Z}{k(A,Z)} dZ \tag{A.2.4}$$

$$d \ln P=\frac{k_A}{k(A,Z)} \cdot \frac{A}{A} dA+\frac{k_Z}{k(A,Z)} \cdot \frac{Z}{Z} dZ. \tag{A.2.5}$$

Knowing that $\frac{dA}{A}=d \ln A$, and $\frac{dZ}{Z}=d \ln Z$ we have:

$$d \ln P=\frac{k_A}{k(A,Z)} \cdot A \cdot d \ln A+\frac{k_Z}{k(A,Z)} \cdot Z \cdot d \ln Z \tag{A.2.6}$$

Knowing that $k_A=\frac{\partial P}{\partial A}$, and $k_M=\frac{\partial P}{\partial Z}$ we have:

$$d \ln P=\frac{\partial P}{\partial A} \cdot \frac{A}{k(A,Z)} \cdot d \ln A+\frac{\partial P}{\partial Z} \cdot \frac{Z}{k(A,Z)} \cdot d \ln Z, \tag{A.2.7}$$

As $P=k(A,Z)$, we have:

$$d \ln P=\frac{\partial P}{\partial A} \cdot \frac{A}{P} \cdot d \ln A+\frac{\partial P}{\partial Z} \cdot \frac{Z}{P} \cdot d \ln Z \tag{A.2.8}$$

and also:

$$d \ln P=\varepsilon d \ln A+\varphi d \ln Z \tag{A.2.9}$$

Supply of material input is converted into the logarithmic form in a similar way.

Appendix 3

The output demand function conversion into the logarithmic form

In order to receive percentage changes of variables, the given output demand function is converted into a logarithmic form by the following procedure:

$$R = h(Q) \quad (\text{A.3.1})$$

$$\ln R = \ln h(Q) \quad (\text{A.3.2})$$

$$d \ln R = d \ln h(Q) \quad (\text{A.3.3})$$

$$d \ln R = \frac{h_Q}{h(Q)} dQ \quad (\text{A.3.4})$$

$$d \ln R = \frac{h_Q}{h(Q)} \cdot \frac{Q}{Q} dQ \quad (\text{A.3.5})$$

Knowing that $\frac{dQ}{Q} = d \ln Q$, we have:

$$d \ln R = \frac{h_Q}{h(Q)} \cdot Q \cdot d \ln Q \quad (\text{A.3.6})$$

Knowing that $h_Q = \frac{\partial R}{\partial Q}$, we have:

$$d \ln R = \frac{\partial R}{\partial Q} \cdot \frac{Q}{h(Q)} \cdot d \ln Q \quad (\text{A.3.7})$$

As $R = h(Q)$, we have:

$$d \ln R = \frac{\partial R}{\partial Q} \cdot \frac{Q}{R} \cdot d \ln Q \quad (\text{A.3.8})$$

and also:

$$\frac{\partial Q}{\partial R} \cdot \frac{R}{Q} \cdot d \ln R = d \ln Q, \quad (\text{A.3.9})$$

We know that $\frac{\partial Q}{\partial R} \cdot \frac{R}{Q}$ is a typical formula for the price elasticity of demand. So, we may write it

down like this:

$$d \ln Q = \eta \cdot d \ln R, \tag{A.3.10}$$

where η is the price elasticity of demand.

As we consider the elasticity of η in absolute terms, $\eta = \left| \frac{\partial Q}{\partial R} \cdot \frac{R}{Q} \right|$, the negative slope of the demand function is reflected by the extra included negative sign:

$$d \ln Q = -\eta \cdot d \ln R. \tag{A.3.11}$$

Appendix 4

The production function conversion into the logarithmic form

In order to receive percentage changes of variables, the given production function is transformed into a logarithmic form by the following procedure:

$$Q = f(A, M) \quad (\text{A.4.1})$$

$$\ln Q = \ln f(A, M) \quad (\text{A.4.2})$$

$$d \ln Q = d \ln f(A, M). \quad (\text{A.4.3})$$

Differentiating $f(A, M)$ by A will be equal to $\frac{f_A}{f(A, M)} dA$. Similarly, differentiating by M , we

have:

$$d \ln Q = \frac{f_A}{f(A, M)} dA + \frac{f_M}{f(A, M)} dM \quad (\text{A.4.4})$$

$$d \ln Q = \frac{f_A}{f(A, M)} dA \cdot \frac{A}{A} + \frac{f_M}{f(A, M)} dM \cdot \frac{M}{M}. \quad (\text{A.4.5})$$

Knowing that $\frac{dA}{A} = d \ln A$, and $\frac{dM}{M} = d \ln M$, and taking alpha and beta equal to

$$\alpha = \frac{f_A}{f(A, M)} \cdot A, \quad \beta = \frac{f_M}{f(A, M)} \cdot M, \text{ we have:}$$

$$d \ln Q = \alpha \cdot d \ln A + \beta \cdot d \ln M. \quad (\text{A.4.6})$$

The equation above is a production function transformed into a logarithmic form.

Appendix 5

The derivation of the output product price

As the upstream market is characterised by imperfect competition, the output product price R is determined by the profit maximisation procedure:

$$\prod_i = [R(Q) \cdot Q_i - C_i(P, W, Q_i)] \quad (\text{A.5.1})$$

which implies:

$$R(Q) + \frac{\partial R(Q)}{\partial Q} \cdot \theta_i \cdot Q_i - \frac{\partial C_i(P, W, Q_i)}{\partial Q_i} = 0, \quad (\text{A.5.2})$$

where

$$\theta_i = \frac{\partial Q}{\partial Q_i} = \frac{\partial Q_i}{\partial Q_i} + \frac{\partial \sum_{j \neq i} Q_j}{\partial Q_i} = 1 + \frac{\partial \sum_{j \neq i} Q_j}{\partial Q_i} = (1 + \theta^*_i) \quad (\text{A.5.3})$$

Then the profit optimization function will be:

$$R(Q) + \frac{\partial R(Q)}{\partial Q} \cdot (1 + \theta^*_i) \cdot Q_i - \frac{\partial C_i(P, W, Q_i)}{\partial Q_i} = 0. \quad (\text{A.5.4})$$

Now sum this equation over the n firms (Cowling and Waterson, 1976):

$$nR(Q) + \sum_{i=1}^n (1 + \theta^*_i) \cdot Q_i \cdot \frac{\partial R(Q)}{\partial Q} - n \frac{\partial C_i}{\partial Q_i} = 0 \quad (\text{A.5.5})$$

$$nR(Q) + \sum_{i=1}^n Q_i \cdot \frac{\partial R(Q)}{\partial Q} + \sum_{i=1}^n \theta^*_i \cdot Q_i \cdot \frac{\partial R(Q)}{\partial Q} - n \frac{\partial C_i}{\partial Q_i} = 0. \quad (\text{A.5.6})$$

Taking $\sum_{i=1}^n Q_i = Q$, and $\sum_{i=1}^n \theta^*_i = \theta^*$ we have:

$$nR(Q) + Q \cdot \frac{\partial R(Q)}{\partial Q} + \theta^* \cdot Q \cdot \frac{\partial R(Q)}{\partial Q} - n \frac{\partial C_i}{\partial Q_i} = 0. \quad (\text{A.5.7})$$

Dividing the whole equation by $R(Q)$ yields:

$$n + \frac{Q}{R(Q)} \cdot \frac{\partial R(Q)}{\partial Q} + \theta^* \cdot \frac{Q}{R(Q)} \cdot \frac{\partial R(Q)}{\partial Q} - n \frac{\partial C_i}{\partial Q_i} \cdot \frac{1}{R(Q)} = 0. \quad (\text{A.5.8})$$

Taking the second fraction as $\left[\frac{Q}{R(Q)} \cdot \frac{\partial R(Q)}{\partial Q} \right] = \left[\frac{Q}{\partial Q} \cdot \frac{\partial R(Q)}{R(Q)} \right] = \frac{1}{\eta}$, where η is the price elasticity of demand, and the third fraction as $\left[\theta^* \cdot \frac{Q}{R(Q)} \cdot \frac{\partial R(Q)}{\partial Q} \right] = \left[\theta^* \cdot \frac{\partial R(Q)}{R(Q)} \cdot \frac{Q}{\partial Q} \right] = \frac{\theta^*}{\eta}$, we

have:

$$n + \frac{1}{\eta} + \frac{\theta^*}{\eta} - n \frac{\partial C_i}{\partial Q_i} \cdot \frac{1}{R(Q)} = 0 \quad (\text{A.5.9})$$

or

$$n + \frac{1 + \theta^*}{\eta} - n \frac{\partial C_i}{\partial Q_i} \cdot \frac{1}{R(Q)} = 0. \quad (\text{A.5.10})$$

Now, multiplying by $R(Q)$ and η , yields:

$$n \cdot \eta \cdot R(Q) + R(Q) \cdot (1 + \theta^*) - n \frac{\partial C_i}{\partial Q_i} \cdot \eta = 0 \quad (\text{A.5.11})$$

and

$$R(Q) \cdot (n\eta + (1 + \theta^*)) = n\eta \frac{\partial C_i}{\partial Q_i}. \quad (\text{A.5.12})$$

Writing $R(Q)$ as R and $(1 + \theta^*)$ as θ , we have:

$$R = \frac{n\eta}{n\eta + \theta} \cdot \frac{\partial C_i}{\partial Q_i}, \quad (\text{A.5.13})$$

where $\frac{\partial C_i}{\partial Q_i}$ are marginal costs. If we write $\frac{n\eta}{n\eta + \theta} = \lambda$, then we may conclude that

$$R = \lambda \cdot C, \quad (\text{A.5.14})$$

where C is marginal costs. Noting that the price elasticity of demand is taken in absolute terms ($\eta = h_R(R/Q)$), we have:

$$\lambda = \frac{n\eta}{n\eta - \theta}. \quad (\text{A.5.15})$$

Appendix 6

The elasticity of the industry mark-up

Appendix 5 indicates the retail price equals marginal costs multiplied by the industry mark-up:

$$R = \lambda C, \quad (\text{A.6.1})$$

which, being transformed into a logarithmic form, is:

$$d \ln R = d \ln \lambda + d \ln C. \quad (\text{A.6.2})$$

Write $d \ln R = -\frac{d \ln \lambda}{d \ln R} d \ln R + d \ln C$, and take $-d \ln \lambda / d \ln R = \mu$, where μ is the elasticity of monopoly mark-up λ (μ also represents a fall (rise) in price-cost margins $\mu = -(d \ln R - d \ln C) / d \ln R$).

This will give:

$$d \ln R = -\mu d \ln R + d \ln C \quad (\text{A.6.3})$$

Simplifying, we have:

$$d \ln R + \mu d \ln R = d \ln C \quad (\text{A.6.4})$$

or

$$d \ln C = (1 + \mu) d \ln R. \quad (\text{A.6.5})$$

Besides, we may also conclude that $d \ln R = d \ln C / (1 + \mu)$, which means that changes in the output price depend on the elasticity of the monopoly mark-up. μ is also equal to $\mu = \omega \theta / (n \eta - \theta)$, where $\omega = d \ln \eta / d \ln R$. This is because μ is the elasticity of monopoly

mark-up λ : $\mu = \frac{\partial \lambda}{\partial R} \cdot \frac{R}{\lambda}$.

Appendix 7

The equilibrium condition for the agricultural input market

Equating the agricultural input demand

$$P = C \cdot f_A \tag{A.7.1}$$

with the agricultural input supply

$$P = k(A, Z), \tag{A.7.2}$$

both transformed into percentage changes, yields:

$$\varepsilon d \ln A + \varphi d \ln Z = d \ln C - \frac{\beta}{\sigma \rho} (d \ln A - d \ln M) + \frac{\sigma(\rho-1)}{\sigma \rho} d \ln Q \tag{A.7.3}$$

and also

$$\varphi d \ln Z = d \ln C - \frac{\beta}{\sigma \rho} (d \ln A - d \ln M) + \frac{\sigma(\rho-1)}{\sigma \rho} d \ln Q - \varepsilon d \ln A. \tag{A.7.4}$$

Noting that $d \ln Q = \alpha d \ln A + \beta d \ln M$, and opening the brackets, we have:

$$\varphi d \ln Z = d \ln C - \frac{\beta}{\sigma \rho} d \ln A + \frac{\beta}{\sigma \rho} d \ln M + \frac{\alpha \sigma(\rho-1)}{\sigma \rho} d \ln A + \frac{\beta \sigma(\rho-1)}{\sigma \rho} d \ln M - \varepsilon d \ln A \tag{A.7.5}$$

Grouping As together and Ms together gives:

$$\varphi d \ln Z = d \ln C + \left(-\frac{\beta}{\sigma \rho} + \frac{\alpha \sigma(\rho-1)}{\sigma \rho} - \varepsilon \right) d \ln A + \left(\frac{\beta}{\sigma \rho} + \frac{\beta \sigma(\rho-1)}{\sigma \rho} \right) d \ln M \tag{A.7.6}$$

$$\varphi d \ln Z = d \ln C + \left(\frac{\alpha \sigma(\rho-1) - \varepsilon \sigma \rho - \beta}{\sigma \rho} \right) d \ln A + \left(\frac{\beta + \beta \sigma(\rho-1)}{\sigma \rho} \right) d \ln M. \tag{A.7.7}$$

Using $d \ln C = (1 + \mu) d \ln R$ (see Appendix 6 for proof) yields:

$$\varphi d \ln Z = \left(\frac{\alpha \sigma(\rho-1) - \varepsilon \sigma \rho - \beta}{\sigma \rho} \right) d \ln A + \left(\frac{\beta + \beta \sigma(\rho-1)}{\sigma \rho} \right) d \ln M + \frac{(1 + \mu) \sigma \rho}{\sigma \rho} d \ln R \tag{A.7.8}$$

or

$$\varphi d \ln Z = -\left(\frac{\beta + \varepsilon \sigma \rho - \alpha \sigma(\rho-1)}{\sigma \rho} \right) d \ln A + \left(\frac{\beta + \beta \sigma(\rho-1)}{\sigma \rho} \right) d \ln M + \frac{(1 + \mu) \sigma \rho}{\sigma \rho} d \ln R. \tag{A.7.9}$$

Appendix 8

The equilibrium condition for the material input market

Equating the material input demand $W = C \cdot f_M$ with the material input supply $W = g(M)$, both transformed into percentage changes, yields:

$$\gamma d \ln M = d \ln C + \frac{\alpha}{\sigma \rho} (d \ln A - d \ln M) + \frac{\sigma(\rho-1)}{\sigma \rho} d \ln Q. \quad (\text{A.8.1})$$

Noting that $d \ln C = (1 + \mu)d \ln R$, and $d \ln Q = \alpha d \ln A + \beta d \ln M$, gives:

$$\gamma d \ln M = (1 + \mu)d \ln R + \frac{\alpha}{\sigma \rho} (d \ln A - d \ln M) + \frac{\sigma(\rho-1)}{\sigma \rho} \cdot (\alpha d \ln A + \beta d \ln M). \quad (\text{A.8.2})$$

Below is the simplification procedure:

$$\gamma d \ln M = (1 + \mu)d \ln R + \frac{\alpha}{\sigma \rho} d \ln A - \frac{\alpha}{\sigma \rho} d \ln M + \frac{\sigma(\rho-1)}{\sigma \rho} \alpha d \ln A + \frac{\sigma(\rho-1)}{\sigma \rho} \beta d \ln M \quad (\text{A.8.3})$$

$$0 = (1 + \mu)d \ln R + \frac{\alpha}{\sigma \rho} d \ln A + \frac{\sigma(\rho-1)}{\sigma \rho} \alpha d \ln A - \frac{\alpha}{\sigma \rho} d \ln M + \frac{\sigma(\rho-1)}{\sigma \rho} \beta d \ln M - \gamma d \ln M \quad (\text{A.8.4})$$

$$0 = (1 + \mu)d \ln R + \frac{\alpha}{\sigma \rho} d \ln A + \frac{\sigma(\rho-1)}{\sigma \rho} \alpha d \ln A - \frac{\alpha}{\sigma \rho} d \ln M + \frac{\sigma(\rho-1)}{\sigma \rho} \beta d \ln M - \gamma d \ln M \quad (\text{A.8.5})$$

$$0 = \left[\frac{(1 + \mu)\sigma \rho}{\sigma \rho} \right] d \ln R + \left[\frac{\alpha + \alpha \sigma(\rho-1)}{\sigma \rho} \right] d \ln A - \left[\frac{\alpha + \gamma \sigma \rho - \beta \sigma(\rho-1)}{\sigma \rho} \right] d \ln M. \quad (\text{A.8.6})$$

Appendix 9

The derivation of price transmission elasticity

Given are percentage changes in the retail and agricultural input prices respectively, followed by the exogenous shock Z :

$$d \ln R = \frac{[\alpha\rho(1+\gamma\sigma)] \varphi d \ln Z}{(\mu+1)\rho(\rho+\alpha\gamma\sigma+\beta\varepsilon\sigma) - \eta(\beta\gamma+\varepsilon\alpha+\varepsilon\sigma\rho\gamma - \varepsilon\sigma\beta(\rho-1) - \alpha\sigma\gamma(\rho-1) - \rho(\rho-1))} \quad (\text{A.9.1})$$

$$d \ln P = \frac{(1+\mu)\rho(\rho+\alpha\sigma\gamma) - \alpha\sigma\eta\gamma(\rho-1) - \rho\eta(\rho-1) + \beta\eta\gamma}{(\mu+1)\rho(\rho+\alpha\gamma\sigma+\beta\varepsilon\sigma) - \eta(\beta\gamma+\varepsilon\alpha+\varepsilon\sigma\rho\gamma - \varepsilon\sigma\beta(\rho-1) - \alpha\sigma\gamma(\rho-1) - \rho(\rho-1))}. \quad (\text{A.9.2})$$

The general expression for the farm to retail price transmission followed by the exogenous shock on the farm level is given by: $\tau = \frac{d \ln R / d \ln Z}{d \ln P / d \ln Z}$. Simplifying yields:

$$\tau = \frac{[\alpha\rho(1+\gamma\sigma)]\varphi d \ln Z}{D} \cdot \frac{D}{[(1+\mu)\rho(\rho+\alpha\gamma\sigma) + \beta\eta\gamma - \alpha\eta\gamma\sigma(\rho-1) - \eta\rho(\rho-1)]\varphi d \ln Z} \quad (\text{A.9.3})$$

or

$$\tau = \frac{\alpha\rho(1+\gamma\sigma)}{(\rho+\alpha\gamma\sigma)[(1+\mu)\rho - \eta(\rho-1)] + \beta\eta\gamma}, \quad (\text{A.9.4})$$

where

$$D = (\mu+1)\rho(\rho+\alpha\gamma\sigma+\beta\varepsilon\sigma) - \eta(\beta\gamma+\varepsilon\alpha+\varepsilon\sigma\rho\gamma - \varepsilon\sigma\beta(\rho-1) - \alpha\sigma\gamma(\rho-1) - \rho(\rho-1)). \quad (\text{A.9.5})$$

Appendix 10

Description of the equilibrium displacement model

“Price transmission of joint products”

The analysis presented below adapts McCorrison, Morgan and Reyner's (2001) analysis of an imperfectly competitive food sector with production function characterised by non-constant returns to scale to the situation where this food industry supplies two jointly-produced products. The dairy industry is taken as an example with its production of butter and skim milk powder (SMP) as jointly-produced goods-complements in production. All three goods are assumed to be homogenous in production. We take McCorrison's assumption about the material inputs and agricultural input to be supplied by competitive industries, and that the food (dairy) sector is unable to exert market power in the purchase of material and milk inputs.

The dairy industry joint production function is

$$g(Q_1, Q_2) = f(A, M), \quad (\text{A.10.1})$$

where Q_1 , Q_2 , A and M are, respectively, first output product (butter), second output product (SMP), agricultural input (milk) and material input. The dairy industry production function is assumed to be homogenous of degree ρ .

The inverse demand functions for the two jointly-produced outputs are

$$P_1 = k_1(Q_1) \quad (\text{A.10.2})$$

$$P_2 = k_2(Q_2), \quad (\text{A.10.3})$$

where P_1 is the price of butter and P_2 is the price of SMP or cheese. Q_1 and Q_2 are the output quantities of the two outputs, respectively.

The inverse input supply functions are

$$X = h(A, Z) \quad (\text{A.10.4})$$

$$Y = h^*(M), \quad (\text{A.10.5})$$

where A and M are agricultural and material input quantities, and X and Y are their prices respectively. The variable Z represents the exogenously occurred shock in the agricultural sector.

Cost minimisation in the food sector gives

$$X = C f_A \quad (\text{A.10.6})$$

$$Y = C f_M, \quad (\text{A.10.7})$$

where C is marginal costs and f_A, f_M are marginal products of agricultural and material inputs, respectively: $f_A = \partial f(A, M) / \partial A$, $f_M = \partial f(A, M) / \partial M$.

Using the profit maximization condition for one firm in the industry and then summing the received condition over all the firms in the industry (n) gives the equilibrium condition in the dairy sector

$$P_1 = \left(\frac{n\eta_1}{nk_1\eta_1 - k_1\theta} \right) C - \left(\frac{n\eta_1}{nk_1\eta_1 - k_1\theta} \right) \left(\frac{nk_2\eta_2 - k_2\theta}{n\eta_2} \right) P_2 \quad (\text{A.10.8a})$$

$$P_1 = \lambda C - \lambda\varphi P_2, \quad (\text{A.10.8b})$$

where $k_1(k_2)$ represents the share of one firm's first (second) output in the throughput of this firm, $\eta_1(\eta_2)$ is demand elasticity for the first (second) jointly-produced outputs, θ is the market power parameter and $\lambda = \left(\frac{n\eta_1}{nk_1\eta_1 - k_1\theta} \right)$ reflects the mark-up of price over costs. In the case of a single output under the perfect competition condition $\lambda = 1$. In the case of a joint output even in perfect competition λ should be greater than one. This is because an oligopolist maximises his profit operating on two markets instead of one. Thus, under the perfect competition the price of a first product could not be equal to marginal costs, but will be equal to marginal costs minus price of the second product. The pass-through coefficient φ represents the share of the second price in marginal costs and is equal to $\left(\frac{nk_2\eta_2 - k_2\theta}{n\eta_2} \right)$.

Totally differentiating the system of equations (A1)-(A8b) and converting to percentage changes in logarithmic form gives

$$d \ln Q_1 = \alpha d \ln A + \beta d \ln M - \delta d \ln Q_2 \quad (\text{A.10.9})$$

$$d \ln Q_1 = -\eta_1 d \ln P_1 \quad (\text{A.10.10})$$

$$d \ln Q_2 = -\eta_2 d \ln P_2 \quad (\text{A.10.11})$$

$$d \ln X = \varepsilon d \ln A + \phi d \ln Z \quad (\text{A.10.12})$$

$$d \ln Y = \gamma d \ln M \quad (\text{A.10.13})$$

$$d \ln X = d \ln C - \frac{\beta}{\sigma \rho} (d \ln A - d \ln M) + \frac{\sigma}{\sigma \rho} (\rho d \ln g_{Q1} - \delta d \ln Q_2) + \frac{(\rho - 1)}{\rho} d \ln Q_1 \quad (\text{A.10.14})$$

$$d \ln Y = d \ln C + \frac{\alpha}{\sigma \rho} (d \ln A - d \ln M) + \frac{\sigma}{\sigma \rho} (\rho d \ln g_{Q1} - \delta d \ln Q_2) + \frac{(\rho - 1)}{\rho} d \ln Q_1 \quad (\text{A.10.15})$$

$$d \ln P_1 = a d \ln \lambda + a d \ln C - b d \ln \lambda - b d \ln \varphi - b d \ln P_2 \quad (\text{A.10.16a})$$

$$d \ln C = d \ln P_1 + a \mu d \ln P_1 - b \mu d \ln P_1 - b \nu d \ln P_2 + b d \ln P_2 \quad (\text{A.10.16b})$$

$$d \ln C = \left(\frac{1 - \mu(b - a)}{a} \right) d \ln P_1 + \left(\frac{b(\nu + 1)}{a} \right) d \ln P_2. \quad (\text{A.10.16c})$$

In the equations above, $a = \lambda C / P_1$, $b = \lambda \varphi P_2 / P_1$, and their difference is equal unity, μ is the elasticity of the industry mark-up and is equal to $\mu = \omega_1 \theta / (n \eta_1 - \theta)$ with ω_1 representing the change in the elasticity of demand of the first product for a given change in the retail price of this product: $\omega_1 = d \ln \eta_1 / d \ln P_1$. ν is the elasticity of the pass-through coefficient and is equal to $\nu = \omega_2 \theta / (n \eta_2 - \theta)$ with ω_2 representing the change in the elasticity of demand of the second product for a given change in the retail price of this product: $\omega_2 = d \ln \eta_2 / d \ln P_2$. The ν coefficient

shows the degree of influence of one of the joint product's price on another. α and β are output elasticities ($\alpha + \beta = \rho$), ε, φ and γ are inverse input supply elasticities and σ is the elasticity of substitution between agricultural and material inputs, all evaluated at equilibrium. The cost shares are equal to $\alpha = f_A A / [g_{Q_1} Q_1]$ and $\beta = f_M M / [g_{Q_1} Q_1]$. Parameter $\delta = g_{Q_2} Q_2 / [g_{Q_1} Q_1]$ or equivalently $\delta = d \ln Q_1 / d \ln Q_2$, which in the case of fixed relationship between two outputs equals unity.

Knowing that the relationship between the first and second outputs is fixed with δ

$$d \ln Q_1 = \delta d \ln Q_2, \quad (\text{A.10.17})$$

we will solve the percentage changes in the nine endogenous variables ($Q_1, Q_2, P_1, P_2, A, M, X, Y$ and C) in terms of the percentage changes in the endogenous variable Z . Substituting equations (A12), (A13), and (A16) into (A14) and (A15) and also (A10) into (A9), taking (A17) into consideration we receive a system of five equations:

$$\begin{aligned} \varphi d \ln Z = & \left(\frac{1 - \mu(b-a)}{a} \right) d \ln P_1 + \left(\frac{b(v+1)}{a} \right) d \ln P_2 + \left(\frac{\alpha\sigma(\rho-1) - \beta - \varepsilon\sigma\rho}{\sigma\rho} \right) d \ln A + \\ & + \left(\frac{\beta + \beta\sigma(\rho-1)}{\sigma\rho} \right) d \ln M - \delta d \ln Q_2 \end{aligned} \quad (\text{A.10.18})$$

$$\begin{aligned} 0 = & \left(\frac{1 - \mu(b-a)}{a} \right) d \ln P_1 + \left(\frac{b(v+1)}{a} \right) d \ln P_2 + \left(\frac{\alpha(1 + \sigma(\rho-1))}{\sigma\rho} \right) d \ln A - \\ & - \left(\frac{\gamma\sigma\rho + \alpha - \beta\sigma(\rho-1)}{\sigma\rho} \right) d \ln M - \delta d \ln Q_2 \end{aligned} \quad (\text{A.10.19})$$

$$0 = \alpha d \ln A + \beta d \ln M - \delta d \ln Q_2 + \eta_1 d \ln P_1 \quad (\text{A.10.20})$$

$$d \ln Q_2 = -\eta_2 d \ln P_2 \quad (\text{A.10.21})$$

$$d \ln Q_1 = \delta d \ln Q_2. \quad (\text{A.10.22})$$

Solving the system of equations above (from (A18) to (A22)) gives solutions for each of the endogenous variables. Focusing on the price transmission from the agricultural input (milk) price to the first output (butter) price, we receive

$$\frac{d \ln P_1}{d \ln X} = E_1 = \frac{\delta \eta_2 S a \rho a (\gamma \sigma + 1)}{D}. \quad (\text{A.10.23})$$

Focusing on the price transmission from the agricultural input (milk) price to the second output (skim milk powder) price, we receive

$$\frac{d \ln P_2}{d \ln X} = E_2 = \frac{\eta_1 S a \rho a (\gamma \sigma + 1)}{D}. \quad (\text{A.10.24})$$

The difference between E_1 and E_2 is as follows

$$E_1 - E_2 = \frac{S a \rho a (\gamma \sigma + 1) (\eta_1 - \delta \eta_2)}{D}, \quad (\text{A.10.25})$$

where

$$\begin{aligned} D = & 2\delta \eta_2 a \eta_1 - \delta \eta_2 a \rho \eta_1 - \rho \delta \eta_2 \mu b + \rho \delta \eta_2 \mu a - 2\delta \eta_2 a \gamma \eta_1 S a + S a \rho \gamma \sigma \delta \eta_2 \mu a \\ & + S a \rho \gamma \sigma v \eta_1 + S a \rho \gamma \sigma \delta \eta_2 + \rho \delta \eta_2 + \rho b \eta_1 - S a \rho \gamma \sigma \delta \eta_2 a \eta_1 - S a \rho \gamma \sigma \delta \eta_2 \mu b \\ & + 2\delta \eta_2 a \gamma \sigma \eta_1 S a + 2\delta \eta_2 a \gamma \eta_1 + \rho b v \eta_1 + S a \rho \gamma \sigma b \eta_1. \end{aligned}$$

As a result we have

$$\frac{E_1}{E_2} = \frac{\delta \eta_2}{\eta_1}. \quad (\text{A.10.26})$$

Curriculum Vitae

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Education:

- 2007 - 2014** PhD Student in Christian-Albrechts-University Kiel,
PhD Thesis: "Theoretical analysis of price transmission: A case of joint production"
- 2009** Humboldt University of Berlin
Doctoral Seminar "Topics in Industrial Organisation"
- 2005-2007** University of Hohenheim/ Stuttgart, Germany
Master of Science in Agricultural Economics
Main interest: agricultural economics, environmental and resource economics, agricultural market policies
The topic of Master Thesis: "A time-series analysis of the beef livestock supply in Russia: Implications for agricultural sector policies"
- 2004-2005** University of Hohenheim/ Stuttgart, Germany
Guest-student in the department of International Economics
- 1996-2001** Kazan State University, Russia
Degree in Economics and Management.
Average grade: 4.7 out of 5 (5 is the highest grade)
Diploma Thesis: "International Companies in Russia: Problems and Development Strategies"
- 2003** Anderson College, USA
Certificate in Management Sciences
- 2000** Summer school for young scientists in Volgograd, Russia
Organized by the Heinz Nixdorf Foundation/Germany
Certificate in Cross-cultural Management, and Project Management

Working experience

- 2013-2014** PhD defence, correction and publication of the dissertation in Christian-Albrechts University in Kiel

2012-2013	Kazan State Agricultural University
2012 - 2014	Internet Project «Success Abroad» / www.success-abroad.ru This Project aims at educating Russian students in terms of winning competitions for international scholarships in order to handle their studies abroad
2007-2011	Scientific assistant in the Christian Albrecht's University in Kiel, Faculty of Agricultural Economics, Department of Agricultural Markets Analysis http://www.uni-kiel.de/marktlehre/ma/mascha.shtml
2006-2007	A helper of a scientific assistant (HIWI) in the project entitled „Bundesmessprogramm Biogasanlagen”, organized by the Bundesministerium für Verbraucherschutz, Ernährung und Landwirtschaft (BMVEL). University of Hohenheim, Department of Agricultural Engineering, Germany
2001-2004	JSC „Tatenergo“ (Energy corporation) / Russia Economist in the Department of Managing Company's Assets
2000-2001	Joint Venture «Synthetic Rubber» / Russia Internship in the department of International Affairs

Scholarships and awards

2013	DAAD scholarship for finishing the Doctoral studies in Kiel University
2010	Financial support granted for attending the 24 th annual IEA Conference 2010 in Belfast, Northern Ireland
2007	Financial support granted for attending the IAAE-EAAE Seminar 2007 in Budapest: “Agricultural Economics and Transition: What was expected, what was observed, the lessons learned”
2006	Financial support granted for the scientific excursion to the University of Northern Thailand
2005	Financial support granted for attending the Green Week Scientific Conference in Berlin: “Managing Economic, Social and Biological Transformations”
2005-2006	Scholarship for Master Program in Hohenheim University from the Rosa-Luxemburg Foundation/Germany
2000	Summer School for young managers organized by the Heinz Nixdorf Foundation/Germany

Teaching experience

- 2012-2014** Online lectures for filling up the documents for international grants and scholarships
- 2010** Christian-Albrechts-University of Kiel
Faculty of Agricultural economics
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Seminar paper supervision: “Neue Formen des Risikomanagements bei Getreide” (“The new forms of the risk management on the cereals market”)
- 2008** Christian-Albrechts-University of Kiel
Faculty of Agricultural economics
Department of Agricultural Markets Analysis
Tutorials in “Grundlagen der Agrarpolitik und Marktlehre” (“Introduction to the Agricultural Policy and Market Analysis”)
- 2008** Christian-Albrechts-University of Kiel
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Department of Agricultural Markets Analysis
Seminar papers supervision:
1. “Allgemeine Gleichgewichtsmodelle: Metaanalytische evaluierung” („General equilibrium models: Methaanalytic evaluation“)
 2. „Overview and perspectives of the world beef market“

Conference and published papers

Antonova M., Loy J.-P., Kapsalyamova Zh., (2010), “Price transmission for Joint Products”, GEWISOLA, September 2010.

Antonova M., Loy J.-P., Kapsalyamova Zh., (2010), “Price transmission in joint production: The case of dairy market”, 24th Annual Conference of the Irish Economic Association, April 2010, Belfast, Northern Ireland

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Union: Aspects of Meat Market”. Polish-German Workshop organized by RLS in Krakow 2004 und Lodz 2008, Manuskripte 67, p. 158

D. Rhodes, Ch. Emery, R. Tian, M. Schurden, S. Tolbert, S. Oertel, M. Antonova, (2004), “A Cross-Cultural Comparison of Leader Ethic”. The Journal of Organizational Culture, Conflicts, and Communications (USA), volume 9, Number 1, 2005

Reviews

Koester U., (2012), Gründzuge der Landwirtschaftlichen Marktlehre. Revision of the book translation in Russian language.

Linguistic skills

Russian
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