3.5 The Economics of Chains and Networks

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1 Introduction

Over the past decade the food and agribusiness industry has shown a trend towards more integrated channels from production to consumers. According to Adam Smith's theory of the 'Invisible Hand'[1] this is induced by the self-interest of people and firms, which in a competitive market will lead to the most efficient use of resources, i.e. the newly developed, more integrated production structures are more efficient in producing particular products than others are. In fact, an empirical study by Zanquetto-Filho et al. (2003) showed that benefits from operating in a more integrated manner range from cost savings and improved customer service to more effective marketing and sales growth. Unfortunately, these results were (as is most often the case) based on surveys on managers' opinions on the benefits of integration and not on hard economic data. So, it is generally agreed upon by business managers that more integration yields benefits in one form or another. But is this always true? Consider the following two cases:

The case of the Greenery International
In the early 90s the Dutch greenhouse vegetables growers faced a major crisis, due to decreasing prices. They became aware that restructuring the greenhouse sector, by enlarging, modernising and reallocating firms became necessary to face the competition from countries with low cost of production like Spain. Beside growers, the marketing channel, dominated by about 20 auctions and more than 150 wholesalers, had to restructure because it could not accommodate the demand side, made up of large international operating retailers. The answer to this mismatch was a merge of the majority of the Dutch vegetable auctions into the 'Greenery International' in 1996, marketing 90% of Dutch greenhouse vegetables. The Greenery aimed at being an active and responsive marketing organization and increasing the producers' share in the consumer expenditures. Therefore, the Greenery experimented

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1 Adam Smith (1723-1790) is most often recognized for the expression 'the invisible hand', which he used to demonstrate how self-interest guides the most efficient use of resources in a nation's economy, with public welfare coming as a by-product.

by unilaterally setting a price for cucumbers and inviting buyers to make a bid for specified quantities. The main competitors, the auction ZON and the Belgian auctions, reacted by offering the cucumbers at a price that was just a fraction lower. As second movers, these auctions could completely sell their stock. The Greenery, however, was forced to function as a market clearance organization. It had to bear the costs of the mismatch between production and consumption, an activity traditionally carried out by the auction. The economic performance of the Greenery, as first mover and dominant supplier, became weaker than that of its competitors (based on Bijman, 2002).

The case of the Dutch pork industry

The Dutch pork industry exports around 65% of its production, making the Netherlands one of the world's five largest pig and pork exporting countries in terms of absolute metric tons of pork exported. About 85% of all pork is produced according to a chain quality assurance scheme, efficiency gains are made through improvements in IT and global per capita consumption of pork is on the rise. These factors should point to a successful Dutch pork industry with opportunities to consolidate or increase the export position. However, environmental policy is becoming stricter and there is increased attention to animal welfare and changing consumer demands. Consumers not only want convenient, economical, tasty and healthy meat, but also information that verifies animal production practices and food safety. Furthermore, because the larger part of exports is in carcasses, the main value-adding part of the supply chain is exported as well. There has also been increased competition among the pig meat exporting countries. At the same time the Netherlands has experienced an increase in the cost of production, which has resulted in the loss of the position of low-cost producer in Europe. A restructuring of the industry took place. The genetics and feed industries consolidated, the number of pig farmers and pigs decreased considerably, and the slaughter and processing industries restructured through merges and take-overs. Nonetheless, the Netherlands, being one of the top 8 European pig meat producers, has seen a decrease in production over the past ten years and is projected to be the only top 8-country to show a further decline from 2001-2002 (based on Boston et al., 2003).

So, is it true that reconfiguration of production and marketing structures to replace arm's length pricing is always more efficient? According to the cases above, it is not. If not, is there something we, as economists, can do about it? Or is the Invisible Hand actually visible? Is there one or more stakeholder in the production chain who actively stimulates reconfiguration of production so he can seize more gains, likely at the expense of other stakeholders who do not yield such power? To answer these questions, we need to define chains and networks and look at the economics behind them. The most commonly used term to denote chains and networks involved in production is the term 'supply chain', which will be used in the remainder of this chapter.

According to Chopra and Meindl (2001) a supply chain can be defined as the collection of stages involved, directly and indirectly, in fulfilling demand. This definition implies that not only producers and suppliers but also transport businesses, warehouses, retailers, and customers themselves are part of the supply chain. This definition does not say anything about how these stages are or should be organized. This implies that the stages in a supply chain can use any form of product exchange (e.g. markets, contracts) to get the product to the end-user, or they can choose to incorporate specific tasks, like transport or marketing or even go as far as incorporating all stages down- and upstream the supply chain (excluding consumption of course). For the remainder of this chapter we thus need to keep in mind that a supply chain structure can range from a collection of competitive firms, using the price mechanism on markets, to fully integrated companies, that incorporate the entire supply chain.

While supply chain management is a well-known concept and covered in several textbooks (e.g. Stadler and Kigler, 2002; Chopra and Meindl, 2001, Christopher, 1992), the topic of the economics of production chains is a collection of theories and research allies that covers (or tries to cover) the economic reasoning behind supply chain activities. Trying to explain the organization and operations of supply chains requires a thorough understanding of the economics involved. Nonetheless, a theoretical framework for the economics of supply chains does not exist. The goal of this chapter is therefore to give an overview of relevant theories and to try to identify the gaps therein, so we can (begin to) explain why the whole is sometimes more and sometimes less than the sum of its parts. To accomplish this, we take a production economic approach, focussing on the decisions the production chain as a whole and participants in a supply chain must make. Other alternatives would be neo-institutional economics, which attempts to incorporate institutional restrictions into theory, or industrial organisation (IO), originated by Coase (1937) among others. Even though the latter is closely related to the topic of this chapter and thus highly relevant for explaining production chain organization, it focuses on the cost of transactions as the source of reconfiguration rather than the chain's and firm's objectives and performance. While the IO approach has provided, and still is providing us with important insights,

> '... the focus (of contemporary theory) in this effort has led to the neglect of information problems that do not involve agency relationships. These are associated with planning in a world in which the future is highly uncertain, and they include problems of product choice, investment and marketing policies, and scope of operations' (Demsetz, 1997).
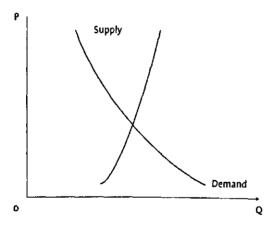
While economic growth has led to specialization and differentiation, it has also led to the emergence of complicated structures of production chains and networks. As Demsetz states, the focus on the configuration of these chains

and networks has resulted in a collection of explanations for more or less integration, all more or less based on the premises of transaction costs. So far, it has omitted to thoroughly address issues of product and process choice, risk and uncertainty in chains and networks, investment analysis and so on. This chapter shall provide an overview of the neo-classical and business economics of supply chains and the opportunities for further research in this area.

2 Economics of supply chain production

2.1 Supply and demand

There would be no need for production if there were no demand for a particular product. Market demand is represented by the quantities of a commodity that all customers in a particular market are willing and able to purchase, depending on price. This curve, represented in figure 1, is the summation of individual demand curves and includes customers who drop out as price increases and who enter the market as the price declines. Thus, a change in price affects the number of customers, as well as the quantity each consumes (Tomek and Robinson, 1990).

Figure 1   Market supply and demand

The supply curve, like the demand curve, is the aggregation of the supply curves of individual firms. It represents the effect of a price change on aggregate output. Note that the curves are drawn as being rather inelastic, i.e. supply and demand quantities are rather independent of price. This is the case in the food- and agribusiness, especially in the short run. As the time period under study increases, supply and demand become more elastic due to the possibility for adjustment. In the case of demand this is due to imperfect knowledge, the time that is needed to make changes, behavioural factors, etc. (Tomek and Robinson, 1990). Adjustment in supply refers to the time horizon

needed to make production decisions, ranging from which product to choose (long run) to sell or store (short run).

It is the supply side that is of interest in this chapter, and the relationship between the market supply curve and individual supply curves. In a simple one-stage producer-consumer market, at a given price, aggregation of the quantities of individual producers adds up to total market supply (figure 2a). In the case of more stages of production, e.g. in the case of a producer, wholesaler and retailer, market equilibria need to exist on the farm output, wholesale and retail market. Gardner (1975) described simultaneous market equilibria under perfect competition; Heien (1980) extended this research by including sector dynamics, and Holloway (1991), in his models, allowed for imperfect competition. Simply stated, individual supply curves need to be aggregated vertically (figure 2b). In that case, for a given quantity, partial prices add up to the final price.

Figure 2a Horizontal aggregation of supply
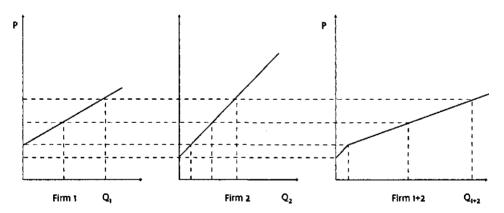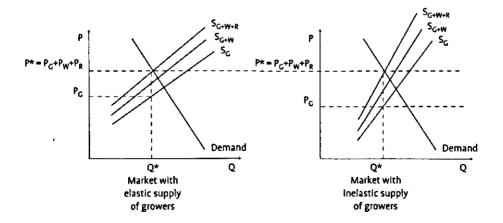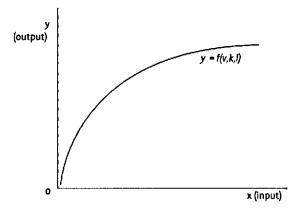

Figure 2b   Vertical aggregation of supply

Consider tomato growers, who offer the amount of Q_G tomatoes at price P_G, wholesalers who offer the trade of Q_W tomatoes at price P_w and retailers who offer the shop floor for Q_R tomatoes at price P_r. The aggregate is market supply Q^* which meets market demand at P^*, that represents the aggregated price P_{G+W+R}. In the left panel of figure 2b a situation with elastic supply is shown, the right panel gives a situation with more inelastic supply at the level of the grower. This is a typical situation for tomato growers in the Netherlands. Wholesalers and especially retailers are more and more becoming players on a world market for tomatoes, which means that they are very flexible in responding to consumer demand. Growers on the other hand, generally operate in national markets with investment terms of fifteen years. This asset specificity restricts their production possibilities in the shorter run, making supply at the level of the grower rather inelastic. When the supply curve of the wholesaler and retailer remain the same, the end- result is a steeper (more inelastic) total supply curve.

In the second case in our introduction the cost of production for pork increased due to environmental and welfare regulations. Due to poor marketing of the increase in environmental protection and animal welfare, the consumer does not recognise any added value and will not pay for it. Therefore, the price will remain the same, while costs have increased. The supply curve in figure 2b shifts to the left and consumers will want to maintain P^*, so demand will decrease as well, resulting in a lower volume of pork being produced and sold.

2.2   From supply curves to production functions

Individual supply curves are dependent on the underlying input-output relationship the producer faces, also called production function. The production function determines the shape of the marginal and average cost functions and thus the level of output where marginal revenue (i.e. price in a competitive market, where the Decision-Making Unit, DMU, is a price-taker) equals marginal cost. As is common with micro-economists, one could look at a production or network (the DMU) as one single entity with a clear goal that it pursues without any wasted effort. In that case we can apply the neo-classical economic approach and draw up a production function for our production chain analogue to any other production unit. In figure 3 the Supply Chain Production Function (SCPF) is presented as the relationship between input x and output y.
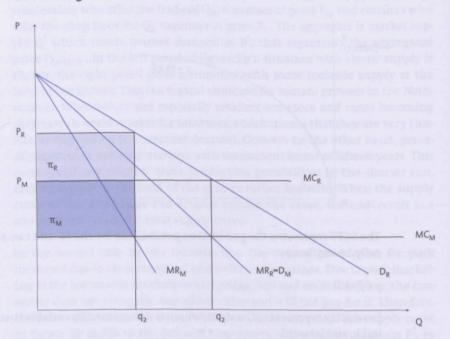
Figure 3 **Supply Chain Production Function (SCPF)**

The SCPF represents the production possibilities for the SC and can algebraically be written as:

$$y = f(v,k,l) \qquad (1)$$

in which y represents SC output, which is determined by variable costs v, capital k, and labour l.

The neo-classical production chain is assumed to maximize profits, in a competitive market. This means that it controls the levels of input, and hence output. Furthermore, in the neo-classical world, the chain produces on the production frontier, not subject to any form of inefficiency. Up to here, the neoclassical approach as used for firms suits a production chain fine. Nonetheless, when trying to define the SCPF, we run into several problems. First of all, a supply chain is really made up out of several firms, all producing on their own PF. Even if we maintain the assumption of profit maximization, it is highly likely that not every stage of a production chain operates in a similar competitive environment. Input, or, in the case of monopolies, output and pricing decisions are therefore not equal for all stages. Moreover, these decisions, especially those of monopolists and oligopolists affect the performance of other participants in the chain. Spengler (1950) first explained why everyone suffers from the inefficiency of successive monopolies or oligopolies due to 'double marginalisation' (Spengler, 1950). The phenomenon is explained in figure 4.

Figure 4   Double marginalization

D_R represents the demand faced by a monopolist retailer, MR_R the corresponding retail marginal revenue curve. Assuming that the retailer has a fixed cost of retailing and his only variable cost is purchasing product Q (i.e. he purchases the product from the manufacturer, turns around and sells it to consumers), then the retailers' marginal cost is the manufacturer price p_M. The retailer, in a neo-classical world, wants to maximize his profits and will therefore pursue a quantity q_2 at which $MR_R = p_M$. The manufacturer is aware of this and consequently MR_R is the demand curve he faces. Since he is in a monopoly position, he will mark up his price to p_M, where $MC_M = MR_M$. Subsequently the retailer will mark up his price where MC_R (or p_M) = MR_R. The manufacturer makes a profit P_M given by the dark shaded area, the retailer earns a profit P_R represented by the light shaded area. This is called double marginalization because each successive monopoly causes a price distortion. This calls for better integration of production chains since the consequence of better integration would be that more of the product would be offered at a lower price (increase in consumer welfare), while at the same time profit for the integrated firm is greater than the sum of the two monopolies (increase in 'producer' welfare) (Cotterill, 2001). While integration through for instance co-ordination of pricing practices can benefit successive monopolies or oligopolies, this does not help those levels of the production chain that are in a situation of perfect competition horizontally. The latter case is close to reality in the food- and agribusiness (Giraud-Héraud et al., 1999). For producers in competitive environments, the optimal solution would be

perfect competition for all levels of the chain so that mark-ups do not occur. This would also increase consumer's welfare. Policy-makers opt for the second solution to the double marginalization problem by means of antitrust regulations. In 1995 Gaudet and Van Long reported that the increase in profit as a result of integration is dependent on the number of players and the type of interaction that is allowed between integrated and non-integrated players. This is where the Greenery International (in our first case) misjudged its power. Not all auctions had joined the Greenery and no restrictions existed on interactions with Greenery-integrated growers or retailers. The decision-making behaviour of the Greenery was therefore wrongly based on the assumption of being a monopolistic upstream supplier. In a recent empirical study Cotterill et al. (2001) showed that the problem described above is even more complex. First of all, the interaction between firms in a supply chain varies considerably with the type of product considered. Second, they empirically show that proportional mark-up behaviour of (monopolistic) retailers and linear demand curves do not describe the market reality well. A more product (or product category) specific approach is therefore needed (Cotterill, 2001).
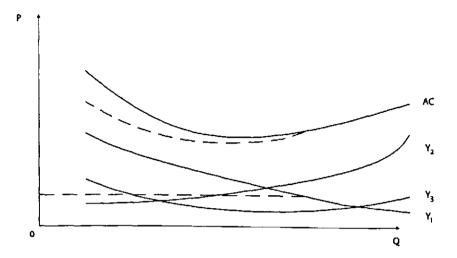
Secondly, some of the output of one SC member serves as some of the input for another. These intermediate outputs and inputs are associated with two SC members, and while one tries to maximize revenues, the other one strives to minimize costs. Besides intermediate inputs and outputs, members of a SC use inputs and produce outputs that are solely related to that specific SC member. These direct inputs and outputs can simply be treated as inputs and outputs of the SC, while the intermediate inputs and outputs cannot.

Thirdly, the production function for a supply chain faces additional costs compared with firms. Beside costs associated with production, a supply chain is faced with information costs (i.e. the costs associated with information exchange between SC members), inventory carrying costs (i.e. the costs associated with carrying a quantity of stored inventory; capital costs, inventory service costs, storage space costs and inventory risk costs), physical flow costs (i.e. the costs of distribution), and transaction costs (i.e. the costs associated with transactions between SC members) (LaLonde and Pohlen, 1996). These costs have both fixed and variable characteristics and should be included in the SCPF.

2.2.1 Studies on neo-classical supply chain production

Not many people have looked at a neo-classical solution to modelling production chains. George Stigler (1951) was the first, and for a long time the only one, to look at vertical organization within the neo-classical boundaries of firm and market behaviour. He states that a firm is made up out of production processes rather than the classic input output relationship. He further assumes that these processes are cost-wise independent and produce fixed proportions so all cost functions can be drawn into one graph (Stigler, 1951).

This implies that the cost of total production is simply the sum of the independent cost curves as is shown in figure 5.

Figure 5   Aggregate cost curves (Stigler, 1951)

In figure 5, process Y_1 shows increasing returns, Y_2 decreasing and Y_3 both. The U-shaped average cost curve is the sum of the three separate cost-functions. The question now is, when will process Y_1 spin-off from the firm to become a separate industry? According to Stigler this happens when the demand for a product is large enough to support a specialised firm, thus following Adam Smith's theorem that the division of labour is limited by the size of the market. If Y_1 is produced separately at a cost indicated by the dotted line, then the remaining average costs curve is represented by the dotted AC-curve; the spin-off reduces costs. Stigler's theory is flawed in that it is incomplete with regards to a demand curve, the determination of industry supply and an equilibrium price. It assumes that the minimum cost combination determines the structure of the production chain, inherently implying perfect markets. He makes this assumption because initially, the new firm may be a monopoly but the price it can charge is limited by the costs of in-house production of the old industry. Output will expand until process Y_1 starts to see decreasing returns to scale and entry into this new industry will follow, leading to a competitive structure.

Recently, Cotterill (2000, 2001) extended Stigler's model to study the reasons behind the organization of a food-marketing channel and how a particular organization affects the channel's performance. He focuses on imperfect competition and market power either as a determinant of or a result of the structure of a production chain. He uses game theory to calculate farm-to-retail price transmission rates, for production chains with different organizational structures. The different structures are due to differences in

competitive characteristics of participants, some operating in a competitive market, others in an oligopoly or monopoly. The games show that vertical structures other than perfect competition depress price transmission. This means that consumers do not get signals to alter consumption to abundant products. At the same time, upstream producers (farmers in Cotterill's case) suffer because their supply situation is ignored (Cotteril, 2001).

2.3 *Production functions and efficiency*

Most SC management textbooks refer to efficiency of supply chains (e.g. Chopra and Meindl, 2001). They often discuss a so-called cost-responsiveness efficiency frontier, which reflects the relationship of the responsiveness of the SC to meet consumer's demand and the cost the SC makes to do so. The SC must make a trade-off between cost and responsiveness (figure 6).
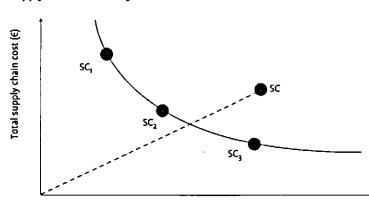
Figure 6   Supply Chain Efficiency

In neo-classical economic theory all firms are assumed to produce on the production frontier as is the case with SC_1, SC_2, and SC_3 in figure 6. In practice this is generally not the case as can be seen from the numerous efficiency and productivity studies that have been done. One may assume that full efficiency in supply chains is even further off the mark since there are several decision-making units that have their own objectives and operate in different competitive environments. The other SC in figure 6 is not on the frontier and could, by either decreasing cost, increasing response time or both, move toward a more efficient production situation. The problem with respect to efficiency in supply chains is that beside direct outputs, which are delivered straight to the market, a firm also produces output, which is input to a firm in the next stage. These intermediate outputs are intermediate inputs to the firm in the adjacent stage, next to the direct inputs this firm acquires from other suppliers not involved in the chain (Zhu, 2003). Each firm in each stage has its own goals and optimization criteria for the intermediate in/outputs.

They also produce under different forms of competition within and between stages due to the number of firms and power distribution. This does not necessarily contribute positively to the performance of the SC as a whole because of counterproductive decision-making, i.e. the producer wants to maximize his revenues, while the wholesaler intends to minimize his inputs. Contributions of Zhu (2003) in this field are a first step towards measuring SC-efficiency (Zhu, 2003). The method is strongly related to analyses on intermediate goods done by Jaenicke (2000) and Färe and Grosskopf (1996), that look at intermediate goods over time-periods rather than levels in a SC. The big advantage of this method is that even though the supply chain is viewed as a black box, efficiency in terms of response time, transaction costs and even environmental and social parameters can be included. Only a few empirical studies have been conducted so far. Talluri et al. (1999) used efficiency measurement to determine which suppliers and manufacturers were most efficient before making combinations of them into supply chains (Talluri et al., 1999). The problem with this method is, and Talluri et al. also indicate this, is that the initial selection based on optimization may lead to sub-optimal solutions, because a combination with an inefficient partner may result in a relatively more efficient supply chain because of better compatibility characteristics of partners. A more extensive study, done by Talluri and Baker (2002) focuses again on the design of an efficient supply chain but also includes distribution characteristics of the SC. Even though the paper aims to design '... efficient production and delivery of a variety of products at low cost, high quality, and short lead times', it suffers from the same problem as the paper by Talluri et al. (1999). Thus, even though the efficiency of supply chains is considered highly important, the study of the topic lacks both theoretical and empirical research. Research that covers the trade-off between cost efficiency, quality and delivery, is therefore needed.

2.4   Supply chain accounting and investment analysis

To assist supply chain members in supply chain decision-making, planning, control and performance measurement activities, it is imperative that they have information on management and cost accounting across the chain. Even though Stigler (1951) assumed independent cost-curves for the different processes in a chain, it is recognised here that these processes are interdependent activities in which the performance of one activity affects the performance and cost of other activities. It is comparable with a multi-divisional company, where each division works more or less independently. Accounting theory for those types of firms will therefore be helpful in the development of accounting systems for the supply chain. Saunders (1994) noted that cost is an important part of supply chain performance and should therefore be managed 'on an integrated basis' (Saunders, 1994). He further emphasised the potential for management accounting in the supply chain but failed to show how accounting techniques such as activity-based-costing (ABS) or

target costing should be implemented, nor who would be responsible for it. Furthermore, issues of ownership of information and the distribution of expenses were not addressed (Berry et al., 2000). In order to overcome this, and to achieve a more strategic approach towards the classical make-or-buy decision, Gietzmann (1996) proposes trust and commitment. Attempts are made to design accounting systems for supply chains: e.g. Supply Chain Costing, a method closely related to ABC (Goldbach, 2000, LaLonde and Pohlen, 1996), target costing (Lockamy III and Smith, 2000; Seuring and Von Ossietzky, 2001; Kato, 1993), and total cost management (Quillian, 1991). Berry et al. (2000) give an overview of systems in place and found that supply chain thinking had changed management accounting practices but the focus was still intra, rather than inter-firm.

Another issue in supply chains, and closely related to accounting, is investments in capital assets (quasi-fixed inputs). They make the adjustment path of an SC sluggish rather than instantaneous. They also involve risk, because firms may become dependent on the existence of the chain they operate and invested in (asset specificity). Current static efficiency analysis is based on the assumption that a firm is able to adjust immediately and ignores the intertemporal linkage of production decisions. An additional complication of dynamics in an SC context is that each level of the supply chain has different periods of investment, resulting in differences in adjustment costs, likely making the chain as slow to adjust as the level with the highest adjustment costs. This can be crucial in a time when flexibility of production is needed.

3   Conclusion and outlook

This chapter describes the theoretical foundations of an economic approach to supply chains and networks based on neo-classical and business economics. This approach to supply chain production is rather underdeveloped, even though it could provide highly useful insights into the production dynamics behind supply chains. Obviously, much needs to be done to answer questions of how to theoretically and empirically assess the efficiency of production chains and networks and how to improve this efficiency if necessary. Moreover, this knowledge is imperative if we want to urge the participants in a production chain to operate in a manner that would be more beneficial to them and to society as well, through increased consumer welfare. The current issues of trust, as in the case with the Dutch pork supply chain, and the unfamiliarity with theoretical principles, as was the case with The Greenery International, would no longer have to occur.

As Demsetz (1997) indicated, many issues not concerning agency relationships could be addressed using neo-classical and business economics. This chapter has provided an overview of theory and the sparse literature

available in this field. A further extension would be to look at risk and uncertainty in chains, and the effect this has on, for instance, investments in chain-specific assets or co-operation between chain partners (e.g. Huirne and Hardaker, 1998). Extending production functions to include stochastic elements (e.g. Hardaker et al., 1997) or using a state-contingent approach (Chambers and Quiggin, 2000) could provide valuable insights into the effect of risk and uncertainty on chains and chain performance. Performance measurement of supply chains is an important issue because it provides insight into the relative performance of different organizational structures and helps decision-makers with their supply chain decisions. There is a large array of measures available (for an overview see Gunasekaran et al., 2001; Lapide, 2002 and Beamon, 1999) but unfortunately most indicators and/or scorecards focus on process optimization and product flow. Furthermore, they are based on the goals of individual actors in the chain rather than the optimization of the entire chain. Product portfolio-analysis is necessary to explain the different structures and performance of supply chains in relation to the nature of the demand of the product. According to Fisher (1997) these are primarily functional or primarily innovative. Primarily functional products satisfy basic needs, predictable demand and long life cycles, which invites competition and low margins. Innovative products have a volatile demand and high margins (Fisher, 1997). Finally, institutional constraints may affect all the above. The effect of e.g. taxes on supply chain production and the transfer of prices between chain partners can be evaluated using general equilibrium analysis incorporating taxes (e.g. Mas-Colell et al., 1995).

In conclusion, the authors would like to argue that this overview of neo-classical and business supply chain economics represents a beginning of a promising new research area. The fields of Institutional Economics and Industrial Organisation focus on the relationships between chain partners, and as such have contributed much to the understanding of the emergence of supply chains. Expanding neo-classical and business economic theory shall provide an understanding of decision-making from a production point of view.

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