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**Technological development in the
fruit and vegetable industry:
A property rights perspective**

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Executive Summary

- 1) There are two paths of technological development in the Danish fruit and vegetable industry: one which can be characterized as a production-cost-minimization path and another which can be characterized as a transaction-cost-minimization path.
- 2) Technological opportunities within the production-cost-minimization path can be easily understood from an artefact perspective of technology, while the transaction-cost-minimization path requires a supplementary perspective which can be found within theories on transaction costs.
- 3) The set of technological opportunities underlying the production-cost-minimization path consists of opportunities for improving the efficiency of firms' processing technology and opportunities for optimizing the cultivation and harvesting of the crops used in processing.
- 4) Firms' incentives for technological development of the opportunities underlying the production-cost-minimization path stem both from price competition within the industry and the rising cost of labour and other inputs needed in the production process.
- 5) The set of technological opportunities underlying the transaction-cost-minimization path consists of improvements in the control of the production processes, development of measures and measurement technology, and sorting techniques for reducing quality variations in the final products, including reducing quality variations by improving crop and harvesting methods.
- 6) Firms' and farmers' incentives for technological development of the opportunities underlying the transaction-cost-minimization path stem from competition on quality within the industry.
- 7) The incentive structure will be dependent on the specific distribution of property rights between the different agents within the chain of production.
- 8) Product development, understood here as quality improvement, will be strongly influenced by firms' transaction cost considerations, since the different transaction-cost-minimization standards that have emerged in the industry may make it more attractive to develop products in some ways than others.

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1. Introduction

As in other industries, much of the technological development in the fruit and vegetable industry is motivated by a desire to increase profits and improve competitiveness. Competition on price has, for example, led to continuous improvements in machines and production routines. Increased competition from East European countries has also influenced technological development. Among other things, it has given added impetus to the development of product *quality*, including efforts to reduce the costs associated with producing and selling goods of a given quality.

Technological development has also been motivated by a number of other factors, however, including the rising cost of electricity, water, and labour¹, and taxes on waste water and refuse. These industry-external changes have resulted in a variety of new developments in and adaptations of production. For example, higher wages and new electricity, water and refuse rates have led to more automation, a better utilization of waste products, and water recirculation and purification schemes.

While all such economic incentives are important elements of technological development, as Rosenberg (1985) points out, they are too *general* to explain the process of technological development in a particular industry:

“.. the ultimate incentives are always economic in nature; but economic incentives to reduce cost always exist in business operations, and precisely because such incentives are so diffuse and general, they do not explain very much in terms of the particular sequence and timing of innovative activity” (p 110).

In order to understand concrete technological developments at industry and firm level, therefore, we must first examine how incentives which result from socioeconomic changes are transformed into technological problems and solutions (Dosi, 1988; Laudan, 1984; Constant, 1984). In other words, it is necessary to look at the internal technological dynamics which creates the basis for new technological opportunities. Dosi (1988) has captured much of this dynamics with his concept of “technological paradigms”:

“A “technological paradigm” defines contextually the needs that are meant to be fulfilled, the scientific principles utilized for the task, the material technology to be used. In other words, a technological paradigm can be defined as a “pattern” for solutions of selected techno-economic problems based on highly selected principles derived from the natural sciences. A paradigm is both a set of exemplar - basic artefacts which are to be developed and improved - and a set of heuristic - “where do we go from here?” “Where should we search?” “On what sort of knowledge should we draw?”” (p 224).

¹ These cost increases have provided incentives for cost-saving technological developments. Savings don't necessarily have to be made in areas directly affected by the cost increases, however. For example, if the price of labour increases, it doesn't necessarily lead to rationalizations in production. The firm might choose to make savings elsewhere, eg by increasing efficiency and reducing wastage (Rosenberg, 1985).

The technological paradigms constitute, together with firms' institutional characteristics, the basis for an incremental technological development along specific paths.

In the following, I will argue that changes in competitive conditions in the fruit and vegetable industry can lead to two different technological paths, one of which must be seen in a "production perspective" while the other must be seen in an "exchange perspective". The first technological path is characterized by incremental improvements in productivity arising from both improvements in production processes and, to some extent, the introduction of new process capabilities. The technology internal dynamics is thus related to the physical characteristics of the production processes used by the firm. The choice between different development priorities will therefore be influenced by changes in the cost of raw materials, labour, water and electricity, but also by changes in the regulations governing the discharge of waste water and directives on the use of waste products.

The second technological path is characterized by incremental reductions in transaction costs, which are due to the relatively large differences in the quality characteristics of fruit and vegetables. Within this path, technological development will take the form of improvements in quality measures and process control, together with a gradual reduction in product variation through breeding and improvements in growing, harvesting and handling methods. In particular, the internal technological dynamics behind the emergence of technological solutions to transaction cost problems is related to the physical (biological) characteristics of the products. But both measuring, controlling, sorting and breeding techniques and harvesting and handling methods will have an effect on the technological possibilities which can be identified. These kinds of development are especially influenced by changes in demand for particular product qualities and by changes in the economic organization of the transactions, since the actual development depends on which party has the incentive to reduce the variability. Technological development is regarded here as a relevant alternative to institutional innovations, which, through a more effective organization and protection of rights, is also able to reduce transaction costs. In both paths, the knowledge accumulated through the development of previous solutions is also an important "technology-internal" factor.

2. An evolutionary explanation of technological paths

A lot of theories about technological change at industry level focus on the explanatory role of historical factors, with the internal dynamics behind incremental technological development as a central feature. Nelson and Winter (1982), Dosi (1988), Rosenberg (1976, 1982, 1985), and Sahal (1981) use the term "technological trajectory" to describe a cumulative and self-generating pattern of incremental developments independent of external economic conditions.

Technological paths can be studied from two different - but not incompatible - points of view, namely a knowledge perspective (based on studies of technological development within the sociology of knowledge) and an artefact perspective (based on studies of the development of products and processes within the history of technology). Both approaches stress that technological development is characterized by a connected and systemic set of changes resulting

from technology internal factors. These technology internal factors include both the physical characteristics of the techniques, the accumulated knowledge, and the methods used in the developments.

Within the *knowledge perspective*, technological development is seen as a process of knowledge accumulation which occurs when technicians - organized in hierarchies of “technological communities” (Constant, 1984; Laudan, 1984) - solve technological problems. Technological paths emerge when this accumulation of knowledge is controlled and limited by the set of traditions and heuristics which characterize the technological community concerned, ie technicians (engineers, food technologists, agronomists, etc.) who, by virtue of their education, have acquired a common core of knowledge and practice. Alternatively, technological paths can be seen from an *artefact perspective*. Here, paths emerge because the physical characteristics of the artefacts, including their complexity and systematic dependency, makes bigger changes more difficult. But the cumulative character of knowledge which underlies technological solutions is also given here as one of the reasons for the existence of technological paths.

Inspired by Dosi and Orsenigo (1988), the often different definitions of and explanations for technological paths can be classified into four factors, which together explain the emergence of technological paths in an industry. These are:

- 1) Technological opportunities created by an historically-determined dynamics. This dynamics will be limited to particular technologies, since the technological opportunities which can be identified are highly dependent on both existing technologies and the technological knowledge accumulated by firms, public research institutions and technological communities. In particular, the emergence of technological guideposts (a both technologically and commercially feasible product or process design) will create the basis for a technological path at industry level.
- 2) The existence of conventions, routines, norms, and other forms of behaviour-shaping institutions². These institutions, which influence the choice of technological opportunities, will often support the incremental development of existing technologies rather than the development of new alternatives. This tendency will be reinforced if, in addition to behaviour-shaping institutions, there also exist limitations in the form of appropriability opportunities, sunk costs, legislation, and quality standards which make the incremental development of existing technologies (or quality characteristics) more attractive than alternatives.
- 3) A market selection working in favour of specific technological solutions. Competition activities in the selection environment can favour innovations which are based on incremental improvements of existing technologies.
- 4) Lastly, in any industry, technological development is dependent on the resources of individual agents and firms’ profitability. As Metcalfe and Boden (1990) point out:

² These behaviour-shaping institutions can either be planned or spontaneous (North, 1990).

“Insofar as technological change is resource dependent, profits provide the basis for advancing technology so that the terms of competition are continually redefined” (p 156).

Thus, in any industry, technological development is directed by the most profitable firms, since they are the ones with the most resources to develop and invest in new technology. However, the resources channelled into public research must also be presumed to have some influence on technological development.

As presented here, the empirical analysis of technological development in the fruit and vegetable industry is restricted to a description of: 1) some of the factors which could lead to technological opportunities, and 2) some of the standards which, at industry level, define what are attractive technological opportunities. Technological opportunities and industry standards constitute a large part of the frameworks which determine the choice of technologies in public research institutions, firms, and among technicians in the various technological communities. The “frameworks” for technological development outlined here are, of course, the result of previous decisions made by the innovative agents. How this has occurred in the fruit and vegetable industry lies outside the scope of this report, however.

Future developments in the industry will be influenced by the routines, norms, traditions, and other important institutions which shape the innovative agents’ decisions. These, like firms’ “fixed sunk costs” in production plant, routines, and appropriability mechanisms, etc., which make investments in some technologies more interesting than in others, are not included in the empirical description, however. Likewise, there is no analysis of innovative agents’ economic resources for technological development.

3. Technological opportunities

This section begins with a brief clarification of the concept of technological opportunities, followed by an account of the dynamics which created the set of technological opportunities and which, in turn, will gradually change it. Here, technological opportunities are defined as:

1. A problem which has been identified as being technological in nature by firms or other technological actors in the industry.
2. The identification of technological solutions, or solution models, which consist of applications of known solutions to new problem areas or new solutions to known problem areas. The solutions can be an integrated part of an ingredient, a raw material, a machine, or it can be a formula, method, patent, or other form of knowledge.

I don’t make a sharp distinction between technological problems and solutions here because problems are often only defined as technological problems when technicians and researchers have an idea of how they can be solved (Wojcick, 1984).

Technological problems and solutions are identified by R&D institutions (Research Association for processed fruit and vegetables; ATS institutes - Academy of Technological Science. ATS institutes, which are partly self-financing and partly state financed, were set up to carry out applied research and transfer knowledge to firms in different industries - The Danish Agricultural Advisory Centre; The Royal Veterinary and Agricultural University; Biotechnological Institute; and grower's associations, etc.), suppliers of production technology and raw materials, and by firms in the industry. Thus, in order to get a true picture of the set of technological opportunities in the fruit and vegetable industry, it is necessary to include both the entire chain of production and associated research institutions.

The set of technological opportunities is in constant flux, since solutions to one set of identified problems creates new knowledge and thus a new basis for identifying new technological problems. According to Kline and Rosenberg (1986), the knowledge on which the identification of new technological opportunities is based is a result of the interplay between research-based and empirical knowledge. Their "Chained Link Model" shows this interplay as a complex process, in which technological knowledge, scientific knowledge, and problem-solving interact at various stages in the process, giving rise to feedback between the individual stages. Thus, contact between technicians, who develop the concrete products and processes, and researchers, who expand scientific knowledge, is extremely important during the innovation process, both for the identification of technological opportunities, for seeking and developing concrete solutions to problems, and for the accumulation of new technological knowledge.

As mentioned above, the dynamics underling changes in the set of technological opportunities is also one of the factors which contributes to the emergence of technological paths at industry level. Compared with market selection, this dynamics will, *ex ante*, contribute to a certain ordered and coherent development, because the technological solutions developed by technicians often form the basis for an incremental cumulative expansion of knowledge. Thus there is a dialectic relationship between the expansion of knowledge and the development of products and processes, since investments in development projects not only result in new products and processes, but also in new knowledge, which in turn forms the basis of future product and process developments (Dodgson, 1990). One of the characteristics of development in the set of technological opportunities, therefore, is that "... the condition of the industry in each time period bears the seeds of its condition in the following period" (Nelson & Winter, 1982 p 19).

This continuity, which often characterizes development in the set of technological opportunities, is also due to the fact that the accumulation of knowledge within a particular area eases the accumulation of new knowledge in that area (Cohen & Levinthal, 1990). These learning advantages create a form of "lock in" in certain technologies, since, over time, so much knowledge is accumulated about them that, perhaps independently of changes in economic conditions, they become more attractive alternatives for further development than other technologies. In addition, the new knowledge is often both tacit and based on experiences of specific products and processes, and therefore inaccessible to all but those involved in the development activities. However, as regards the development of new techniques, it is not only diffusion problems and learning advantages which help "lock in" particular solutions, but also

actual improvements in the functional characteristics and efficiency of the techniques themselves. These improvements also lead to irreversibility in the technological development process, since the chosen techniques often remain the most attractive alternatives even when the market, or the competitive conditions under which they were chosen, change (David, 1975).

Notwithstanding the lock-in mechanisms described above, changes in competitive conditions are still an important factor in inducing technological development. Dosi (1984) thus proposes distinguishing between changes in competitive conditions (mechanisms which induce technological development) and the actual outcome of the technological development process. The interesting thing about evolutionary theories, however, is the fact that they regard changes in the technological development process and changes in competitive conditions as endogenous processes, in the sense that technological development in the firm (the selection unit) is accompanied by changes in competitive conditions (the selection environment). This is because changes in the firm's production methods lead either to changes in the market's price structure, as more and more firms produce both cheaper and better (Nelson & Winter, 1982), or to changes in demand (Penrose, 1959)³. At the same time, changes in competitive conditions create incentives for new technological development, because firms' technological competitive advantages continuously change in line with changes in factor prices and demand. In this sense, therefore, the factors which induce technological development cannot be completely separated from the internal technological factors which create the opportunities for new technological development. These factors can be separated analytically in the short run, however, which is what has been done in the empirical analysis. But first, the following section will give an account of three different theoretical perspectives of technological opportunities in the fruit and vegetable industry.

4. Different perspectives of technological opportunities in the fruit and vegetable industry

Nelson and Winter (1982) suggest that a first step towards describing the development of any industry is to classify the technological opportunities in that industry according to whether they can be found among a given set of possible solutions, or whether these solutions must be developed by the firm itself.

The first type of technological opportunity consists of, for example, technology transfers from firms' suppliers, technological solutions which firms can imitate by examining competitors' products (and perhaps also their production methods), and the more or less fully-developed analytic methods available from R&D institutions. The set of technological opportunities can thus be described by collecting information on all the alternatives which, in principle, are open to the firm. If the firm has to develop technological opportunities itself, however, it becomes much more difficult to form an impression of the set of technological opportunities in the industry. Here, however, theories of paths of technological development can be of help,

³ Penrose claims that supply and demand are endogenous factors because, in supplying goods, firms also partly influence the demand for them..... "For if entrepreneurial notions about what consumers ought to like have some influence on what is offered to consumers, and therefore on what they in fact like, or learn to like, a mere inquiry into the "state of demand" will not enable us to understand the productive activity of entrepreneurs and, in particular, their innovation activity" (p 8).

since, among other things, these focus on factors which create the basis for new technological opportunities. In the next section, an artefact and knowledge perspective are presented as complementary contributions to an understanding of technological opportunities. Later, I will explain why these two perspectives are insufficient to understand the technological opportunities in the fruit and vegetable industry, and must therefore be supplemented by a third.

An artefact and knowledge perspective of technological opportunities in the fruit and vegetable industry

Both the knowledge and artefact perspective stress that the adaptation of technology to changes in demand, factor prices, etc., are limited by a number of historical factors in the development of technology.

The *artefact perspective* seeks to explain the dynamics behind the process of technological development by taking a starting point in a specific product and its historical development. Here, technological paths consist of incremental (as opposed to radical) technological changes in the products or production processes, resulting in an improvement of their functional characteristics, or performance, over time. The system view of technology which underlies the artefact perspective means that technological development is seen in terms of systems of increasing complexity. For example, Sahal (1981) claims that technologies are often developed into more and more complex systems of mutually dependent components. This complexity often sets an upper limit for growth in such a system. Paths emerge because the physical characteristics of products and processes, especially their complexity, make it difficult to make more extensive changes in the technology.

The technological opportunities are considered to be closely connected with the physical characteristics of the product or production process. Rosenberg (1976) uses the term “technological imperatives” to describe how the nature of the products and production process constantly creates new opportunities for technological development. The scale, complexity, materials and structure of the technology are of crucial importance in determining which innovative activities can improve the functional characteristics of products and production processes over time. Sahal (1981) argues that, in particular, changes in scale of a product or in production function as such imperatives. The desire to change the scale of a product or production process most often appears as a consequence of changes in, for example, demand (technology-external factors). However, the scaling process itself leads to a number of technological “bottleneck problems”, eg problems with capacity adjustments between individual machines and problems of timing and flow. Sahal divides these types of problems into three general types:

- 1) Problems due to uneven development in the components of the technology;
- 2) Problems which arise because of the need for new materials; and
- 3) Problems caused by a more complex structure.

The amount of technological opportunities in an industry often depends on the degree of “imbalance” between components in the technological systems which characterize the indus-

try's production and products. The development of new materials and other complementary inputs or technologies strongly influences the possibilities for solving technological problems.

The *knowledge perspective* sees paths as a process of knowledge accumulation, which occurs when technicians in firms and research institutions solve technical problems. Paths of technological development emerge both because this accumulation is controlled and limited by the traditions and heuristics of technicians from different technological communities and because knowledge accumulation becomes easier when new knowledge builds on existing knowledge. This perspective attaches more weight to how technological problems and solutions are identified than to the factors which cause the problems. It is argued that problems are only seen as technological opportunities after sufficient knowledge about the physical or biological causes of the problem has been accumulated. It is also argued that actual scientific knowledge play a certain role in the identification of technological problems. Such knowledge can, for example, help identify the limits to which a particular technology can be applied or improved. Scientific knowledge is also regarded as an important means of solving technological problems - though it is emphasized that, for firms, scientific knowledge is abstruse, and often requires a great deal of modification before it can be used in problem-solving on a practical level (Rosenberg, 1985; Kline & Rosenberg, 1986; Laudan, 1984).

Both the knowledge and artefact perspectives stress the fact that adjustments of technology to changes in demand, factor prices, etc., are limited by a number of historical factors surrounding the development of the technologies themselves. Future developments in the fruit and vegetable industry will therefore not occur at random, but will follow specific paths, dictated both by technologies already in use and the accumulated knowledge and current practice in the technological communities.

However, both perspectives focus primarily on technological development aimed at making production more efficient and improving a product's functional characteristics. They therefore reflect a system view of technology - though this is most pronounced in the artefact perspective. It is often remarked how the mutual dependency and complexity of the technical systems themselves limit incremental improvements in products and techniques. Technological opportunities are thus most often perceived as optimization problems within a closed system of technologies, or as problems of adapting one system to another.

This system approach seems to be particularly good at explaining the emergence of technological opportunities for improving productivity and developing new product variants. The most frequent incentives for this type of development in the fruit and vegetable industry are price competition and industry-external changes in relative factor prices, legislation, etc. This applies especially to developments in firms' production plant which result from changes in the price of water, raw materials, and labour, together with developments which result from new taxes on refuse and waste water.

On the other hand, the two perspectives are not so good at explaining the appearance of technological opportunities which reduce transaction costs which result from the nature of the product itself. Incentives for this type of development come especially from internal compe-

tition in the industry (including international competition). For the most part, these incentives seem to channel technological development in the direction of producing more uniform products. Apart from this, considerable efforts are made to develop faster and more precise methods for measuring the different quality characteristics of raw and final products; competition also provides an incentive to develop these characteristics.

Neither the knowledge nor the artefact perspective are particularly good at explaining and understanding the dynamics behind this technological development. The next section thus introduces yet another possible complementary perspective of technological development - *the transaction cost perspective*. It should be noted, however, that the link between the transaction cost perspective and technological development is rarely seen in the literature. One of the few to have dealt extensively with this link is Teece (1987), though in another way than the one discussed here.

While the knowledge and artefact perspectives largely originate from more inductive, empirical studies of the historical development of products and processes, the transaction cost perspective is primarily a deductive, theoretical perspective. Transaction costs in themselves do not cause technological problems, however - it is the product's characteristics, which are empirical in nature, that give rise to transaction costs.

Transaction cost theory takes a starting point in the individual transaction - ie not necessarily a market exchange between two or more agents of goods or services - and seeks to identify the costs of transacting between individual agents in an economy. The transaction cost perspective is used here as a means of understanding the kind of technological development which is aimed at ensuring and improving products' quality characteristics, and, in addition, to increase the understanding of the function of industry norms and product standards in facilitating trade between agents, together with the role these standards and norms play in technological development. First, however, a number of examples of technological developed aimed at reducing firms' production costs.

5. Production-cost-minimizing technological opportunities

As mentioned above, changes in competitive conditions in the fruit and vegetable industry pave the way for the emergence of technological paths, where the one path can be understood from a production perspective, and the other from an exchange perspective. Within the first path - here called the production-cost-minimizing path - incentives for technological development result from, among other things, changes in firms' production costs. Some of the biggest cost items in the fruit and vegetable industry are water, raw products, labour, and taxes on refuse and waste water. In addition, firms express a general desire to reduce the costs of producing final products of a given quality. Developments aimed at reducing these costs include general improvements in production plant, a better utilization of raw products, automation, reduction of water consumption, cheaper and better purification of waste water, and better utilization of by-products and waste products. The following section describes some of the initiatives which firms have introduced in order to reduce their production costs.

Technological opportunities which help reduce production costs

General cost reductions

Gradual increases in productivity and better organization of the production process are two of the most common technological improvements within the production-cost-minimizing path which lead to general cost reductions. Many firms have either carried out, or are in the process of introducing such improvements. Some firms have embarked on an ISO certification process as a step in the streamlining of their production.

Improvements in machine performance, together with the introduction of new process capabilities, are also some of the technological opportunities which contribute to reducing production costs. Improvements to machines have most often been carried out by the firms themselves, while new equipment has been purchased from suppliers. The great majority of firms used standard machines, though a few had such specialized productions that there were no standard solutions. These firms therefore designed and made their own equipment. But even firms which had more standardized production often employed mechanics and other technicians - partly for repair and maintenance, partly to improve the machines, and partly to solve any bottleneck problems which might occur in trying to match the capacities of different machines, or as a result of the physical limitations of the factory buildings.

Reduction of water consumption

Water is used in both the washing, blanching, cooling, and transport of the raw products, and in cleaning. Firms which both wash, blanch and cool the raw materials often consume large volumes of water, which thus also represents one of their biggest outlays. Firms have tried different ways of limiting their water consumption. Many have introduced water-saving methods and routines (eg reminding workers to turn off taps), while others have collaborated with their suppliers to convert their machines so that the water from cooling and blanching is used to rinse the raw products. Standards for microbiological pollution set limits to how much water can be recirculated, however. One firm had developed a method for cooling vegetables which was based on air cooling rather than water cooling, while another firm was examining the feasibility of using rainwater.

Reduction of labour and raw materials costs

Firms seek to reduce wage costs primarily by gradually automating parts of the production process and, in one case, by introducing computer-monitoring of production. Several firms said that, while further automation was technically feasible, it was economically unjustifiable. Two factors seem to limit the extent of automation in production: flexibility and reliability. Reliability is especially important for firms which process perishables and firms which compete on delivery. Reliability is so important for the latter that they used a large portion of the money saved through automation on employing mechanics, engineers, and other skilled wor-

kers to quickly repair the machines as soon as they developed problems. In two other cases, considerations of flexibility also set limits to the extent of automation. One firm mentioned that further streamlining of their production would impair their ability to produce different kinds of raw products, while another mentioned the packing department as being an especially labour-intensive area. This firm had no plans for further automation here, because it would affect their ability to pack products according to customers' specifications.

One of the ways in which firms can reduce the costs of raw products is to utilize them better. Waste in production can often be traced to waste in storage due to loss of, for example, weight, aroma, vitamins, the discarding of raw products which don't live up to the quality standard, peeling, the pressing of fruit and berries, together with raw products which fall off the conveyor belt during transport. Firms try to reduce losses due to the discarding of poor quality raw products partly through specifications and control of the raw product on delivery (more about this below), and partly through process control, to avoid damaging the product during the process itself (eg burning during deep-frying). The specifying of varieties and sorting by size reduces much of the losses sustained during peeling. In addition, the development of new peeling methods has contributed to a more "delicate" peeling. In vegetable production, losses also occur in changing from one type of product to another. Many firms therefore try to ensure a large batch size. At the same time, a better utilization of the raw product also reduces the firm's waste problems considerably.

A few firms have developed new process methods. For example, one firm has installed a hydrocutter, which turns potatoes along their long axis, thus reducing wastage during slicing. Another firm reversed root and top removal in their production of onions, so that a smaller part of the onion was peeled away during the subsequent peeling process.

In the pressing of berries for juice, the introduction of refrigeration technology and enzymatic pressing has increased the yield of juice. The heating of the pulp also increases yields, but this increases the risk of loss of brix (dry matter content) at the same time, which is one of the parameters by which juice is measured. The profitability of fruit juice production thus rests on the firm's ability to both obtain high juice yields and maintain the brix content of the raw product throughout the production process. The firm is working on developing more gentle production methods which avoid brix loss (such methods will also help to maintain the level of aromatics in the juice).

Taxes on waste water

The tax on waste water has just been changed from a tax determined by the level of pollution to a tax per cubic metre of discharge water. This charge has partly given firms a strong incentive to reduce water consumption and partly increased their interest in recycling waste water. In spite of the change, however, firms are still faced with certain demands to limit water pollution. Most firms have developed methods and routines for collecting product remains which are flushed out when the machines are cleaned, and the majority of firms either have, or are introducing, some form of sewage treatment plant or other. As a rule, the standard solution

recommended by suppliers and consultants are adopted, though one firm had developed its own filter for filtering water, making investment in a biological plant unnecessary.

By-products and other waste

By-products consist of peel, remains from the pressing of fruit and berries, discarded pieces of raw products from production, cherry stones, product remains due to the changeover from one product line to another, and the scum from jam. The remains of fruit and berries are used in animal feed or in biogas plants. Most peel (except onion peel) is either used in feed or is composted. The firms try to limit waste as much as possible: by utilizing as much of the raw product as possible; by producing as large batch sizes as possible; and by giving growers a bonus for specific sizes and varieties of crops so that the least amount possible has to be thrown away during production. Apart from organic waste, earth, stones, and other impurities are also mixed in with the deliveries of raw products. The firms bear the cost of removing this waste themselves. They try to limit the waste primarily by paying growers a bonus for clean deliveries.

Summary

The production-cost-minimizing technological path is a result of firms' and suppliers' efforts to improve machine performance, automate production, and reduce the cost of water, waste water, and by-products. This path will be characterized by incremental improvements in the production routines and methods used. From an artefact perspective, there is not likely to be just one path for the Danish fruit and vegetable industry, since firms use different production methods. However, there will be a certain overlap across products in some of the methods used, eg sorting technologies, refrigeration technologies, packing machines, and water purification plants. Since the methods used in the fruit and vegetable industry are relatively simple (as opposed to complex), it is not so much the systemic complexity which will set the limits of technological development so much as considerations of flexibility and the wage costs of skilled technicians connected with guaranteeing production continuity in a more integrated and complex system. The relatively simple production (batch production) possibly also implies that the opportunities for incremental improvements in productivity are relatively limited - unless firms change the form of production - since there are no serious bottlenecks or scaling problems. The set of technological opportunities seems to be broader within the transaction-cost-minimizing path, which I will return to in chapter 7. Before that, however, I turn to the set of technological opportunities connected with the development of new product varieties.

6. Development of new product variants

Much of the product development in the fruit and vegetable industry consists in finding new variants of existing products. The set of technological opportunities connected with the development of new variants of the same type of product can partly be seen as a supplement

to the production-cost-minimizing path. Problems which crop up in connection with adapting different production parameters to new raw product variants can be easily describe by the systems approach to technological opportunities, which also underlies the production-cost-minimizing path. But while the technical success of the development efforts described in the previous chapter could be measured by production costs, it is more difficult to formulate (non-market) success goals for the development of new product variants. Most firms try to ensure that the new variants don't fluctuate more in quality than the firm's other products, however. This often means adapting the production plant and routines to the new ingredients.

Incentives for this type of product development come partly from competition between firms and partly from the requirements of retailers. There is a big difference in the organization and content of this type of development activity between firms, however. A lot of the larger firms have established product development teams, where the marketing, sales, and production departments collaborate in the development of new product variants. In some of the group-owned firms, part of the sales or marketing activities were placed under group control. Product development wasn't as formalized in the smaller firms, however.

While the organization of activities seems to depend on a firm's size, the content of the development activities depends on whether the firm is an order producer of intermediate products or a batch producer of both semi- and final products. In job-producing firms, which supply intermediate products to other firms, new variants are developed in close collaboration with customers, since the customer often has specific requirements. A few firms stressed precisely the ability to develop customized products as one of their competitive strengths, while others regarded job production more as an adjustment of the standard range in volume and possibly also taste. The latter especially regarded price and the ability to deliver products of a consistent quality as their most important competitive parameter, and they attached great importance to increasing both the efficiency of the production process and the quality of their products. The former firms also regarded the development of new products as a competitive parameter, and they attached great importance to developing the knowledge to enable them to create new product variants.

The job-producing firms mostly felt that they had been chosen as partners because of their knowledge of raw products, production techniques, the production process, and their production capacity. The firms' knowledge of suppliers and their ability to evaluate suppliers' expertise and product quality also appear to be important factors, because, among other things, they can limit the spectrum of variants which the firms develop.

Batch-producing firms, which make finished products under their own label, considered the label as their prime asset. But keeping a label in the public eye requires a big advertising effort and a well-developed sales strategy to coordinate marketing campaigns and select and care for sales channels. For these firms too, the development of new product variants was one of the ways in which the firm could defend its market segments, or even expand into new segments among end users. This didn't necessarily mean that product development was based on an exhaustive knowledge of consumers, however. Collaboration with retail chains was often more or equally as important. Common to firms which produce finished goods under their

own label and firms which produce under the label of a retail chain is the necessity of being able to produce at a consistent level of quality. Once the idea for a new product variant had taken shape, therefore, a considerable part of the subsequent technical development consisted in determining the level of quality characteristics, so that the technicians (often together with marketing) could ensure that quality variations in the new product variants didn't exceed those of the firm's other products.

Some examples of the development of product variants are given below, together with the corresponding set of technological opportunities.

New product variants are created by:

- 1) Changing the way the raw product is cut up. Some examples of new variants are sliced and cubed carrots, sliced and cubed pickled beetroot, new potato products, with and without peel, and varying the size of the chopped onions in crisp-fried chopped onions.
- 2) Changing the spices used, eg developing new types of jam by adding rum and almonds. Taste variants of sour products are created by changing the vinegar and sugar content of the pickle and the spices used. The taste of crisp-fried chopped onions can be changed by using a different batter for frying.
- 3) Using new raw products. New variants of frozen mixed vegetables and new types of jam, stewed fruit and fruit juice can be developed by using other vegetables and berries. For example, variants of concentrated fruit juices are made by changing the characteristics of the pressed juice (eg colour, clarity, acidity, and dry matter content).
- 4) Changing the shape or size of the packaging. Packaging solutions come mainly from suppliers of packing machines and packaging (eg Tetra Pak and Shur), while the development of new sizes and design adaptations are often the result of a collaboration between suppliers and buyer. In a very few cases, firms have attempted to develop new forms of packaging themselves, eg vacuum-packed potatoes, and spinach in multiple tear-off packets, both of which are complex technological solutions and represent a significant change in the product's character.

New variants are often developed in a test kitchen, followed by a pilot production, and, subsequently, full-scale production. The shift from test kitchen to full-scale production is often problematic, because not all the important parameters, influencing eg taste and consistency, are known. In jam and stewed fruit production, for example, it is necessary to adjust infusion times and the quantity of pectin used to the characteristics of the new products. The success of this adjustment often depends on the firm's experience, together with measurements of the acid, dry matter, and calcium content of the berries. The way in which the berries, sugar and pectins interact is not completely known, however.

In addition to the above, the firms also mentioned a number of specific problems in developing new variants. For example, it was mentioned that, in the production of crisp-fried

chopped onions, it was difficult to both increase the size of the onion pieces and maintain a water content that was low enough to enable the product to be stored without the need for refrigeration.

The development of new potato products required the development of new cutting machines, and, as with carrots, it was also necessary to make sure that the new products didn't result in an increased loss of the raw product. In one case (diced and sliced beetroot), the new variants enabled both small and large raw products to be used.

Summary

As can be seen from the above, the commonest way of creating new variants is by varying the size (search characteristics) and taste (experience characteristics) of the final product. The choice between different types of berries for jam, the determination of a product's shape, and the various sizes of ingredients in vegetable mixes, together with the shape and size of the packaging, is heavily influenced by firms' expectations of buyers' preferences for new variants. Once the idea for a new variant has taken shape, and the initial problems concerning its production have been solved, a period of technical product development begins, in which the batch-producing firms try to limit variations in quality between deliveries and the job-producing firms try to fulfil buyers' requirements and specifications. As the following chapter will show, it is difficult to separate completely the set of technological opportunities connected to the development of product variants from those connected with the transaction-cost-minimizing path, since technical product development must be presumed to be influenced by considerations of transaction costs.

7. A transaction cost perspective of technological opportunities in the fruit and vegetable industry

The transaction cost perspective embraces a relatively broad spectrum of theories about different sources of the cost of *transacting*. Transaction cost theory seeks to explain why the classical market exchange is replaced by more complex forms of contracts. The explanation is based on an assumption of efficiency. Williamson (1985) distinguishes between a number of different theories which all deal with the question of why and how more complex forms of contracts increase the effectiveness of the exchange.

These include the property rights and measurement schools, both of which are the prime source of inspiration for the following analysis of transaction costs and technological development. The work of *Yoram Barzel* (1982, 1985, 1989) is particularly important here.

Property rights theories argue that the actual ownership of an asset influences how effectively that asset can be used. Therefore it is essential that property rights are assigned to those who can best use the asset. In some cases this will mean that they have to be traded, and in other cases shared between partners. In such cases, more comprehensive contracts can be necessary

to ensure an effective transfer or sharing of property rights. The property rights approach defines transaction costs in relation to a perfect - Walrasian - market. In such a perfect market, the transfer of property rights will take place smoothly and the protection of them will be straightforward. There are therefore no transaction costs⁴. Barzel defines transaction costs as costs due to “the transfer, capture and protection of rights”, where

“...the rights in question are property rights. Property rights of individuals over assets are the power to consume, obtain income from, and alienate the assets” (Barzel, 1989, p 2).

The measurement school attaches particular weight to the fact that the characteristics of exchanged property rights are often difficult to specify. This approach to transaction costs is therefore well suited to analysing how the character of a specific product influences the transaction itself. According to Barzel, transaction problems arise precisely because it is difficult and costly to obtain precise information about all the characteristics of a product:

“It is my contention that costly (intermediate and final) product information is the central problem of transacting, leading to all other transacting problems” (Barzel, 1985, p 6).

Product information is broadly defined as information about the level of a characteristic per unit, eg the sweetness of a cherry, plus the number of products in a group with the same level (eg the number of sweet cherries in a basket)⁵. If the information was free, berries and vegetables with the same quality characteristics would be sold at the same price. If, for example, it was costly for a seller to precisely measure the quality of every single cherry, then high-quality cherries would probably be sold at the same price as cherries of a lower quality. By not measuring the quality of and grading the cherries, the seller also forgoes the possibility of earning the full value placed by buyers on each cherry. In other words, he has placed some of the value of his product in the public domain, because it was too costly for him to specify the quality of each cherry. The value which the seller fails to specify, and which is thus placed in the public domain, is captured by the buyer, who use resources to find cherries of a higher quality than their price. For example, buyers spend time in queues, and use time and energy on selecting cherries of an especially high quality. The important point, however, is that the seller will increase his income if he can measure and grade cherries into uniform groups better and more cheaply. Buyers will also save time and energy, because they will be save the trouble of sorting through a lot of cherries of different quality and size. On the whole, buyers will often win more from a better sorting of the cherries than they lose by not searching for undervalued cherries. If it was possible to obtain information about each fruit and vegetable easily and cheaply, therefore, both parties should benefit. It is thus my contention that the technological development of

⁴ Williamson (1985) points out that property rights theories often implicitly assume that those who own the rights can easily enforce them through, for example, the courts. Williamson, however, asserts that the courts are often inadequate for enforcing contracts. This is due to the fact that people are only rational to a limited extent, and thus often cannot stipulate all the circumstances which are relevant for effectuation of the contract. Opportunism and asset specificity thus often result in an uncompensated use of assets. Williamson therefore stresses the importance of “ex post support institutions of contract matter” (Williamson, 1985, p 29).

⁵ Information about production factors is defined as information about the output of the production factors.

measurement methods and sorting techniques is **one** of the ways in which information costs can be reduced. As an alternative to technological development, there are several different ways of organizing the transaction itself so as to reduce transaction costs.

In the fruit and vegetable industry, *caveat emptor* is the most widespread form of organizing transactions between retailers and final consumers, though some transactions in input and raw products⁶ are also organized in this way. In *caveat emptor* transactions, the seller's obligation to the buyer ends when payment and the goods change hands. In transactions with raw products, a lot of growers and their organizations use contracts as a means of organizing their transactions, especially those with the processing industry. These contracts form the basis of *caveat emptor* transactions, since they commit both parties to certain obligations for shorter or longer periods. A contract, after all, is precisely a promise to supply a service or product at some point in the future.

In some cases, transactions are carried out by means of order contracts, while in other cases, proper grower contracts are used. Order contracts contain a promise of the future supply of a product with certain specifications. Order contracts are used, for example, in transactions involving input products such as fruit juice, concentrates, berries for jam and stewed fruit, etc. Grower contracts differ from order contracts in that they also contain a promise to produce the product according to special instructions. Grower contracts are used solely between growers and food processing firms.

Figures 1 and 2 show how growers and their organizations organize the trade in vegetables, fruit and berries.

Figure 1. Economic organization of the vegetable trade

Type of economic organization	Sale to Industry	Sale to the retail trade
Direct contractual cultivation	Some potato growers including Flensted	
Contracts negotiated by a joint growers' association	Frigodan's pea and vegetables growers' association	
Sales organization (order sales)	Nordgrønt (growers' association)	Nordgrønt (certain products)
Auction sales through a joint organization		GASA (growers' association)
Direct sale		Several fruit, berry and vegetable growers

⁶ For example, fruit juice concentrates and cucumbers for the production of cucumber salad.

Figure 2. Economic organization of the fruit and berry trade

Type of economic organization	Sale to Industry	Sale to the retail trade
Direct contractual cultivation	Some berry growers (among others KV Saft)	
Contracts negotiated by a joint growers' association		
Sales organization (order sales)	Sjælland's berry growers' association	Fyn's berry growers' association
Auction sales through a joint organization		GASA (growers' association)
Direct sale		Several apple growers

One of the fundamental assumptions of transaction theories is that there is an economic rationale behind the differences in the economic organization of transactions, which, for example, characterize the fruit and vegetable industry⁷. Barzel (1989) and Cheung (1983), for example, assert that the economic rationale behind the choice of economic organization is the desire to minimize the dissipation of rent. Williamson (1985) is a bit more specific, stating that agents “organize transactions so as to economize on bounded rationality while simultaneously safeguarding them against the hazards of opportunism” (p 32). Transaction cost theory was primarily developed to analyse which form of economic organization is the most effective, given specific product characteristics and production technologies. The following analysis of technological opportunities in the fruit and vegetable industry approaches this from the “opposite” direction, and asks the question: given the economic organization of the industry, which technological developments will reduce transaction costs?

⁷ Williamson (1985) thus argues that “A predictive theory of economic organization requires that the factors responsible for differences among transactions be identified and explicated” (p 52). When this is done, it will be possible to predict which form of economic organization will come to characterize a particular transaction. As Williamson himself points out, such an argument is based on a different perception of individuals' rationality than that underlying evolutionary theories. In evolutionary theories, such as the one presented by Nelson and Winter (1982), individuals are primarily attributed a “procedural rationality”, which implies that their actions, including their “choice” of economic organization, can only be predicted on the basis of the decision routines open to them. These routines are in turn a product of an historical development, in which various routines have been tried and either adopted or rejected. In Williamson's transaction cost theory, individuals have only a limited rationality, in the sense that they don't have all the important information about future events, but they are attributed such a high degree of intentionality that they are not only able to perceive their limitations, but are also able to judge which form of economic organization is best able to “solve” the transaction problems facing them. The perceptions of rationality which underlie measurement theory has many similarities to that presented by Williamson. However, measurement theory attaches more weight to individuals' costs of obtaining information about product characteristics than to their uncertainty about changes in transaction conditions. I will return later to the problems caused by this difference in rationality perception when I discuss the use of transaction cost theories in an evolutionary perspective of technological development.

Williamson (1985) points out that different transaction cost theories attach different weight to the costs of making contracts (the so-called ex ante transaction costs) and the costs of carrying them out (ex post transaction costs).

Like Williamson's "governance" theory, measurement theory attaches particular importance to the costs which occur after the contract has been signed. The latter theory deals primarily with problems connected with ensuring a closer relation between a product's value and its price, however. Governance theory, on the other hand, focuses on the way transactions are organized to protect them against opportunism in the face of unexpected events. In governance theory terminology, this involves the creation of "efficient control mechanisms". As developed by Williamson, governance theory is especially relevant in the analysis of recurring transactions between the same parties. Such transactions are much more common between growers and firms than in the consumer market. In a later section on transaction costs in raw product and input product markets, governance theory and measurement theory are employed as two complementary perspectives of transaction costs⁸. The following section on consumer markets employs solely the information cost approach. The discussion concentrates on the interplay between transaction costs and technological development in so-called caveat emptor transactions.

8. Transaction costs and technological opportunities in caveat emptor transactions

What are the causes of transaction costs? According to Barzel (1982), variations in product characteristics are one of the most important sources of information problems, and thus also of transaction costs. Information problems occur because:

- 1) There are differences in the level of different quality characteristics from one product unit to the next;
- 2) The distribution of quality characteristics changes over time; and
- 3) There are differences in the various suppliers' quality distribution.

However, it seems reasonable to assume that information problems also depend on how easy it is to measure products' quality characteristics, and not all characteristics of fruit and vegetables are equally easy to measure and evaluate. Generally speaking, a product's quality characteristics can be divided into three categories:

⁸ Williamson also draws attention to this complementarity, and particularly emphasizes the fact that both theories deal with the transaction problems which occur as a result of asymmetric information. He argues that, unless agents are characterized by either limited rationality or opportunism, neither measurement theory nor governance theory is relevant. Furthermore, he asserts that information costs don't create problems if neither party in a transaction tries to exploit their own information opportunistically. Barzel (1985) doesn't wholly agree with this, however. He points out that "...Whereas, no doubt, some dissipation will be eliminated when agents keep their promise, a major problem remains. For the same reason that contracts are incomplete, agents cannot possibly know in full detail to what their word applies. They are likely to err, then, when attempting to keep their word, even though sometimes breaking a promise is preferable to keeping it. People cannot costlessly tell when their behavior is dissipating" (p 10).

- 1) Search characteristics,
- 2) Experience characteristics, and
- 3) Credence characteristics,

depending on how easy it is for the consumer to experience the characteristic at the time of purchase (Tirole, 1988)⁹.

Search characteristics can be observed directly. In the case of fruit and vegetables, this means size, shape, colour, and the regularity of and impurities in the deliveries or products. Experience characteristics can often only be evaluated or measured after the product has been consumed or used in the production process. Consistency and taste are the two most important experience characteristics of fruit and vegetables. Finally, credence characteristics are characteristics which cannot be observed or experienced directly by looking at or inspecting the raw or final product. The use of crop sprays is one such example of credence characteristics. Search and experience characteristics are often measured according to an ordinal scale, with a range from especially valued (eg a good taste) to undesirable (bad taste). Credence characteristics, on the other hand, are often a question of either/or.

The example of peas is used below to illustrate how a product's characteristics can be a source of transaction costs. Based on the above two categories of information problems (types of variation and quality characteristics), a number of these are presented to explain the occurrence of transaction costs in the fruit and vegetable industry. Technological development and the organization of transactions are discussed as two alternative ways in which transaction costs can be reduced. The next section discusses how variations in the level of search, experience, and credence characteristics in a seller's products result in transaction costs. Then follows a section on how changes in the quality characteristics of a seller's products over time result in transaction costs. Finally, there is a section that discusses how differences in quality characteristics between different sellers result in transaction costs.

Differences in the level of quality characteristics between products

Variations in search characteristics

We can start by making the realistic assumption that consumers prefer small peas to large peas. Since pea size is relatively easy for both buyer and seller to judge, both parties have the same information. Peas have different sizes when they are picked, so the seller has two options: he can either sell the peas sorted or unsorted. If he chooses the second option, his packets will contain both high-value and low-value peas. Moreover, some packets will contain more small peas than other packets, so these will be more valuable to buyers than other packets. Since sellers want as high a price for their peas as possible, they will try to price

⁹ Tirole (1988) actually classifies products into groups of search, experience, and credence goods. The concept of search and experience goods was introduced by Nelson (1970), while the concept of credence goods is attributed to Darby and Karni (1973). I have chosen to regard a single product as having all three characteristics, however.

them so that the price reflects the value buyers ascribe to different sizes of pea. The price they can charge for a packet containing 100% small peas is lower than the value buyers ascribe to such a packet, however, because of the costs¹⁰ of trying to find it. Buyers' costs consist partly of the time and energy they use in estimating the size of the peas in a single packet, and partly of the time they use in trying to find a packet containing 100% small peas among all the other packets. The more packets they have to search through, the higher their costs.

In the above example, the seller will have to reduce his prices every time a packet containing the smallest peas is sold. To avoid this, he can try to sell them at a fixed price (which reflects the mean value and variation in size of his peas¹¹). If the seller still allows buyers to choose freely between packets, some buyers, by using resources to search for the best packets in the refrigerated counter, will get a better bargain than others. Their gain will be at the seller's expense, however; as the best packets gradually disappear, the seller is left with a lot of packets which can only be sold at a lower price, because customers don't consider them to be worth the asking price.

The seller can do two things to prevent buyers getting a bargain at his expense. He can sell the peas in bags containing two or more packets, thereby restricting the consumer's choice, or he can pack the peas in opaque packets, thus making it more difficult (more costly) for consumers to sort them out. From a social welfare point of view, this restriction would be to the benefit of both parties, since they will both use fewer resources in trying to ensure the value of the transaction. Buyers (en masse) would use fewer resources in sorting, and the seller would use fewer resources to protect the value of his peas. In principle, limiting buyers' free choice gives the seller two advantages: he avoids having to cut his prices as the best packets are gradually sold, and he acquires a certain share of the resources which buyers would have used in searching for the best peas.

For the buyer, it is another story altogether, however. Those buyers who got the packets containing the most small peas will regard the product as being of a higher value than buyers who got packets containing the most large peas. The "unlucky" buyers might become suspicious of the seller's offering, however. If buyers suspected sellers of cheating, the price (under competition) would fall to a level which reflected buyers' expectations of quality. Honest sellers would then be punished economically. To prevent the bad reputation of dishonest sellers from ruining the value of the honest seller's products, however, he has to somehow signal to buyers that, if they buy from him, they are guaranteed a random selection of packets of peas from an optimally¹² sorted supply. Brands can function as such a signal, since systematic shortcomings in the seller's products undermine the value of the brand (Klein & Leffler, 1989).

Not all sellers have brands or other assets which they can use to convince buyers of their honesty and credibility, however. Others again simply have no possibility of limiting buyers'

¹⁰ These are opportunity costs, which can vary from customer to customer.

¹¹ The mean value and variation reflects buyers' expected value of a packet of peas chosen at random.

¹² Here, optimally means that the seller's marginal costs of sorting are equal to his marginal profits.

free choice. But these sellers can sort the peas themselves, and thus prevent buyers from gaining value from the transaction at their expense¹³. This is due to the fact that grading the peas allows the seller to differentiate the price, so that packets containing the most small peas fetch a higher price than packets containing most large peas. Thus the seller secures more of the value which the buyer ascribes to the small peas for himself. Sellers who want to maximize their value of the transaction will grade their peas to the point where the costs of further grading is equal to the gain. Sellers' costs of supplying peas of uniform size depend on the variety and on the production and sorting technology. His economic gain depends on how easy it is for buyers to find the best packets. The lower the buyer's sorting costs, the more the seller stands to lose. On the other hand, when buyers' sorting costs are low, the seller ought to become more interested in developing cost-saving sorting methods. If, for example, the development of new sorting methods or new varieties of peas of uniform size reduce the costs of producing packets containing 100% small peas, then the producer will be able to secure a greater share of the value which these packets represent.

This example is made more complicated, however, if buyers prefer packets of peas of uniform size to packets which contain 90% small peas and 10% medium-sized and large peas. The seller who sorts peas into uniform sizes before they are packed can thus get a higher price per pea.

If the assumptions behind this theory are correct, the following conclusions can be made: When buyers' sorting costs are low and it is also to their advantage to sort (because of in the distribution), sellers have an incentive to: 1) either reduce their costs of producing peas of uniform size, or 2) limit buyers' free choice. Since sellers of a brand are in a better position to limit buyers' free choice, they don't need to sort their peas as intensively as sellers without a brand. The latter can compete with brand producers by having lower sorting costs, however. If buyers prefer homogeneous products, eg peas with little variation in size, then sorting costs will be considerable for both groups of sellers¹⁴.

Variations in experience characteristics

Variations in the taste, consistency, and perishability of peas could be due to the fact that they are grown under different conditions, are picked at different times, that they are handled differently from harvest to delivery to the firm, and that firms have different ways of processing and freezing the peas. These characteristics are often very difficult for both seller and buyer to judge before purchasing (experience characteristics). In such cases, uniformity can be a cha-

¹³ As long as the seller's costs of sorting are lower than the buyer's, then he will do it - and he'll even do it in cases where seller and buyer have the same sorting costs. This is because the seller has a form of advantages of scale in sorting, since he only estimates pea size once, while the buyer has to do it at least once, and sometimes two or more times (Barzel, 1982). The seller is therefore the one with the incentive to develop methods which make it cheaper to sort. The seller who develops a cheap sorting method will even gain a profit advantage vis-à-vis competitors - though only if the method doesn't spread quickly.

¹⁴ Resenman and Wilson (1991) have shown that, in a quality differentiated market for cherries, in which unsorted cherries are sold in the lowest quality class together with cherries which are sorted into this class, firms which, because of their higher sorting costs, do not carry out sorting can obtain a higher price for their unsorted cherries than firms which do sort - if, that is, they have a brand which signals to buyers that they sell a more favourable distribution of cherries.

racteristic of the product which buyers are willing to pay extra for (Barzel, 1982). Sellers who market peas which are known for their identical taste should therefore be able to get a higher price than those who market peas with more dissimilar tastes.

Variations in taste or other experience characteristics cannot always be reduced through cultivation or changes in production methods. Experience characteristics are special, however, in that, when the buyer has consumed the product, he can evaluate its characteristics without cost. Sellers can exploit this “free” information by giving buyers a product guarantee, offering to refund the price of a “bad” packet of peas. This reduces buyers’ risks’ At the same time, the buyer will use fewer resources in trying to evaluate the quality of the product and in comparing it with competitors’ products before the purchase. The consumer should therefore be willing to pay more for peas which carry a guarantee. With this, the seller is both able to realize a larger share of the value of the taste characteristic and secure a share of the resources which consumers use in comparing different sellers’ products. Technological developments which result in a more uniform taste can still be an attractive alternative, however, especially where it is costly for the seller to provide a product guarantee.

If neither buyer nor seller can obtain a higher value by sorting the peas, the price should, in time, reflect buyers’ expectations of the peas’ taste and supply (or the product guarantee given). While the guarantee reduces the buyer’s risk, it doesn’t reduce the seller’s risk, since the difficulties of evaluating experience characteristics means that he might unwittingly be selling extraordinarily good-tasting peas at a much too low price.

However, differences in taste and consistency can be reflected in the peas’ search characteristics. In many cases, therefore, both seller and buyer use search characteristics (eg colour, size) as a proxy measure by which they sort products into groups of homogeneous taste. Price will then come to reflect differences in proxy measures, since they will be associated with a particular taste or consistency. However, unless there is an unambiguous relation between, for example, taste and colour, then peas will not necessarily be similar in taste¹⁵ when they are sorted by colour. The more tenuous the relation between colour and taste, the greater the heterogeneity in taste. Since sorting by the proxy measures of colour and size doesn’t precisely reflect the taste distribution of the peas, the price which the seller can get for them will be lower than that which reflects a mean value and spread in colour or size. Thus the seller still has an incentive to develop methods for measuring and grading peas into groups of more identical taste¹⁶.

Sellers also have an incentive to develop proxy measures, however, since it is these which buyers use when they decide which seller to buy from. If, for example, growers can cultivate a pea with an especially intense colour, without it affecting taste in any way, then buyers will choose sellers which offer this pea rather than ones which don’t. Gradually, however, colour will lose its value as a proxy measure of taste. In time, therefore, buyers will pay less and less

¹⁵ Some of the variations can be due to problems in determining the precise relation between colour (proxy measure) and taste. Added to this is the fact that there can be some uncertainty connected with measuring and sorting peas by colour.

¹⁶ If all producers have the same variations in taste within each quality class, and if all consumers, for practical reasons, are prevented from selecting the packets with the best taste, then peas will not be sorted, and there will be no choice between producers.

for peas of a particular colour - though the greenest peas will still command a higher value than less green peas. Improvements in pea colour through cultivation will cease when the extra effort is no longer rewarded by higher earnings, ie when marginal benefit no longer exceeds marginal costs. The less value buyers ascribe to colour, the quicker this point will be reached.

On the basis of the above arguments, it can be concluded that the seller has an incentive to develop products of identical taste as long as it is costly to provide a product guarantee. Sellers can achieve a homogeneous taste through the development of new varieties and improved production processes, or by grading peas by proxy measures. The latter can create incentives to develop proxy measures rather than characteristics.

Variations in credence characteristics

Credence characteristics differ from search and experience characteristics in especially two ways: Firstly, credence characteristics are mostly *either present or not present*. For example, peas cannot be grown more or less ecologically. In such cases, the price of the characteristic “ecological” is inelastic, since buyers won’t pay more for a “more ecological” pea. This also implies that buyers have no incentive to sort, since they won’t obtain a higher value by choosing between ecological peas. Sellers who can guarantee that their peas are ecological will therefore be able to obtain the full value of the characteristic “ecological”, minus the costs of providing a credible guarantee. On the other hand, the seller risks losing the entire value of “ecological peas” if buyers find out that, for example, he mixes ecological peas with ordinary peas. It should be noted, however, that some credence characteristics can be measured on an ordinal scale, eg nutritional value, in which case sorting can be an important means of protecting the value of these characteristics.

Secondly, credence characteristics are characterized by persistently asymmetrical information. The seller has privileged access to information about peas’ cultivation, variety, production, or other factors which determine whether a pea can be called ecological or not. Buyers, on the other hand, can rarely be completely sure that the peas they have just bought really are ecological. The information which the seller possesses is often difficult and costly to communicate. Sellers who want to realize the value of their ecological peas must therefore achieve credibility in other ways.

There are several ways in which the seller can achieve credibility. For example, he can sell ecological peas under his own brand, or join a trade association which controls quality on behalf of the consumer. Sellers who want to maximize the value of “ecological peas” will choose the solution which is least costly and which at the same time gives them the greatest credibility with buyers (provided that credibility - though not necessarily credence characteristics - has a certain price elasticity). The credibility of the various signals the seller can send depends on the buyer being confident that the seller can’t cheat on quality - or at least that he won’t gain economically if he does cheat. No matter which solution the seller chooses, however, some sort of control mechanism is necessary to ensure that the products actually possess

the credence characteristics they are alleged to have, so there will be some control cost in any case. Guaranteeing credence characteristics thus provides an incentive for a technological development - including the development of measurement and control methods - aimed at reducing these costs. If the seller chooses to signal credibility by joining a trade organization, then control costs depend not only on the methods used, but also on other sellers' incentives to cheat¹⁷. Incentives to cheat are greatest where credence characteristics are costly to provide. The development of special disease-resistant peas and sorting and production technology which reduces production costs can be decisive for incentives to cheat, and thus also for control costs¹⁸.

This leads to the following conclusions: guaranteeing credence characteristics results in the development of control systems and measurement techniques which guarantee product characteristics. Incentives to develop cheap ways of producing these characteristics will be greatest where the seller employs an industry standard as signal. The lower the costs of supplying the credence characteristics, the less the incentive to cheat (free-riders), and the lower the control costs.

Changes in sellers' quality

If a seller's product changes unpredictably from one delivery to the next, buyers must use a great deal of time and energy in trying to find out whether the products they buy are representative of the offering or not. If, however, sellers can supply a uniform quality and a consistent distribution every time, then customers will gradually use less and less time on controlling products. Transaction costs (the resources buyers use to evaluate the product's quality) will thus fall over time, because buyers will have more confidence in the seller's products.

The seller who can guarantee an offer for packets of peas with a small variation in size should therefore be able to get a higher price for his products than sellers whose offerings change from season to season. This will give the seller an incentive both to develop varieties whose quality characteristics are unaffected by changes in growing conditions and production methods which ensure as stable production conditions as possible.

Sellers who want a share of the resources which customers use to inspect their products must often provide customers with a guarantee of their credibility (commit themselves to a certain quality¹⁹). The producer's or distributor's brands, together with ISO or other certificates, can function as a signal to buyers that the distribution of the product contains a constant number of the desired quality attributed.

¹⁷ If the same quality standard is used by everybody in the industry, any attempt by individual producers to cheat will hurt the other producers, since exposure will reduce the credibility of the standard in consumers' eyes (negative externalities as a result of free-riders). To prevent cheating, firms must be willing to pay for an independent control.

¹⁸ Incentives to cheat also depend on how much the seller stands to lose if he is discovered.

¹⁹ If the sum of the resources which consumers use in comparing different sellers' products is greater than the producer's costs of ensuring a standard distribution of products, it will be economically advantageous for the producer to offer this guarantee.

Differences in individual sellers' offerings

Consumers don't only use resources to control individual sellers' offerings, however. They also use time and energy on comparing the products of competing sellers. It will be easier for consumers to compare different sellers' offerings of peas of different sizes, colour, or other search characteristics if general quality classes are established. If they wanted small peas, they would then only have to compare the distribution and prices of small peas offered by different sellers. The criteria on which the quality classes are based will, in all likelihood, influence the priority sellers give to their development efforts. These efforts can be presumed to be directed towards the development of methods which make it cheap to grade peas according to the criteria used in quality classification. In addition, the development of a product's quality characteristics can be influenced by the criteria adopted for the standard.

Since it is costly for consumers to directly compare individual seller's distribution of experience characteristics, sellers can more easily entice buyers to purchase from them, even though the price is high compared with other sellers' offerings. Credence characteristics constitute a special problem, since neither at the time of purchase nor consumption of the product can the buyer be sure of the quality. This means that the buyer cannot compare different sellers' credence characteristics either.

The setting of specific standards for production routines which guarantee credence characteristics does give buyers an indirect possibility of comparing different sellers' products, however, because they can just compare the standards. The comparison then depends on buyers' evaluation of the credibility of these signals. The choice between sellers can thus hang on buyers' knowledge of the existence of production methods which effectively guarantee a product's credence characteristics, plus their knowledge of the effectiveness of a seller's control system. Technological development can be important here. For example, the development of production technology and control systems, including proxy measures for credence characteristics (pesticide residues, microbiological tests, etc.), effective spot checks, etc., can contribute to an increase in the credibility of the signals.

Summary

The above discussion leads to the following theses on how variations in the level of the search, experience and credence characteristics of fruit and vegetables give rise to transaction costs, which in turn provide incentives for a technological development aimed at reducing these costs.

1) Search characteristics

When buyers' sorting costs are low, and, at the same time, they benefit from sorting (because many of the peas are worth a lot more than their price), sellers have an incentive to: 1) produce identical products, or 2) limit buyers' free choice. Since sellers who have a brand are in a better position to limit buyers' free choice, they don't have to grade their peas as much as

sellers who don't have a brand. The latter can compete with brand producers by having lower sorting costs, however. If buyers prefer homogeneous products, eg peas with insignificant variations in size, then sorting costs will be high for both groups of sellers.

2) Experience characteristics

The seller has an incentive to develop products which have identical tastes as long as it is costly to provide a product guarantee. This can be achieved through the development of new varieties and improvements in production processes, and by sorting the product according to proxy measures. The latter provide an incentive to develop proxy measures rather than characteristics (though this reduces the value buyers ascribe to these measures).

3) Credence characteristics

These are characterized by consistently asymmetric information. The seller must therefore win credibility with buyers either through a brand or by subjecting himself to the control of a trade organization. Incentives to develop cheap ways of producing the characteristics will be greatest if sellers signal their credibility through an industry standard brand. The lower the costs of supplying the credence characteristic, the less the incentive to cheat (free-riders), and the lower the costs of control. Irrespective of how the seller chooses to gain credibility, guaranteeing credence characteristics will provide an incentive to develop control systems and measurement methods which can guarantee product characteristics.

4) Variations in search, experience, or credence characteristics of sellers' products over time

These variations result in transaction costs, because buyers have to use resources to check that the price actually reflects the level of quality and variation of each delivery. This should give the seller an incentive to reduce the quality variations in his deliveries.

5) Differences in search, experience, or credence characteristics between different sellers

Such differences lead to transaction costs, because buyers use a lot of resources in comparing the offerings of different sellers. This should give an incentive to standardize the way in which sellers sort their products into different quality classes.

An analysis of transaction costs can only indicate incentives to develop particular technologies which, with the level of technical knowledge that exists today, are considered able to reduce these costs. Which technologies will form the basis of future incremental developments within the transaction-cost-minimizing path depends on the physical and biological characteristics of the products and production processes used in the fruit and vegetable industry. This is the subject of the next section.

9. Technological opportunities which reduce transaction costs in the production of the final product

In the previous section, we saw how products' characteristics could lead to information problems and thus also transaction costs. The following briefly discusses how the interviewed firms try to reduce these costs by technological means.

Minor variations in quality characteristics from one product to the next

Variations in products' search, experience and credence characteristics within a single delivery can be due to both differences in the quality of the raw products and differences in production methods. Since such variations, as mentioned above, constitute one of the sources of transaction costs, producers are interesting in developing sorting or production methods which will enable them to produce more homogeneous products. This interest must be presumed to be greatest, however, if it is easy for buyers to select the best products and if, at the same time, there are big variations in the most sought after of the product's quality characteristics.

As far as the production of peas is concerned, there is a direct relation between the quality of the raw product and that of the final product. Here, sorting the peas into three categories - small, medium and large - ensures that the producer gets the whole value which buyers ascribe to peas of different sizes. The firm ensures a certain uniform consistency and taste by enforcing their rights to control the harvesting. The optimal harvest time is determined on the basis of a relationship between the number of thermal units, AIS figures, and tenderometer values²⁰. Since the most important ripening parameters are known, the harvest can be computer-controlled. Since, by virtue of its harvest plans, the firm thus has the most influence on the peas' consistency, it also bears the cost of variations which result from "bad" planning (it becomes what is known as the "residual claimant", Barzel, 1989). After the harvest, the firm carefully sorts the peas by means of optical screening technology, eliminating any discoloured and irregular-shaped peas. The firm also bears the loss of these peas.

Berries which are used for freezing, jam, and stewed fruit ripen at different times. Since the picking machines can't distinguish between ripe and unripe crops or variations in colour, deliveries will contain variations in colour. The berries are therefore sorted in the firm using optical screening technology²¹. In jam production, different qualities of berries are used for making high-quality and ordinary jams²². Apart from differences in raw product quality, the number of whole berries in jam is also a search criterion which distinguishes high-quality

²⁰ Thermal units refer to the number of degrees Celsius which the average temperature has been over 5 degrees/day throughout the growing season. AIS figures express peas' starch content, while the tenderometer value expresses their firmness.

²¹ In this case, the firm was a residual claimant, since growers were not paid according to berries' colour differences. The firm also bore the loss of rejected berries.

²² In some cases, the raw product is sorted into categories which are used in various types of products. This applies, for example, in the production of crisp-fried and pre-fried chopped onions, as well as in the production of frozen berries, fruit juice and pulp. However, this sorting is more aimed at ensuring a certain level of quality in the final product, and, at the same time, making the most out of differences in the quality of the raw product.

from low-quality jam. Producers of high-quality jam are putting their efforts into developing more gentle methods of transporting the berries between the various stages in the process, and stirring the jam as gently as possible during heating in order to minimize the amount that has to be sold as low-quality jam.

Homogeneity of ingredients is an important search characteristic of frozen mixed vegetables, jams, and other products containing whole or sliced fruit and vegetables. Firms therefore have an interest in developing methods which make the production of homogeneous products cheaper. The cost of ensuring a certain homogeneity in the final product depends on the product. Most firms made sure of certain regularity in ingredient size, shape and colour through their choice of varieties and control of the raw product, but a number of initiatives in the production process also contributed to homogeneity, eg a lot of irregularities are removed after chopping, slicing, cutting, etc., by means of optical or manual screening. Any pieces which are discoloured or have spots, and irregular pieces such as the tops and bottoms of carrots, are also removed at this stage. Together, these constitute a large part of raw product loss during the production process. In the production of chips, the method used to cut the potatoes is extremely important for the uniformity of the final product. The problem of cutting potatoes for chips is overcome by using a hydrocutter, which turns the potato lengthways before cutting so that the chips in each bag are roughly equal in length. The alternative would have been to throw away all the chips which didn't meet the specifications, which would have resulted in a much bigger wastage.

Blemishes in the raw product, such as cuts and bruises, can also lead to a certain non-uniformity in the search characteristics of the final product. This can be remedied to some extent in the case of potatoes and beetroots by adjusting the peeling process, so that any blemishes in the top layers of the raw product are removed. Such deeper peeling also increased wastage, however.

In products such as fruit juice, where the colour and shape of the individual pieces can't be seen, any colour differences in the berries can be partly offset by mixing berries and juices from different growers. This requires a large storage capacity, however.

Ensuring quality characteristics over time

The interviews showed that a lot of the initiatives in the industry are aimed at maintaining a particular quality standard, ie efforts to ensure that firms make products which don't change from one delivery to the next. Such efforts should, as remarked in the previous section, lead to a reduction in transaction costs over time. Sellers who develop raw product varieties and production methods which ensure a uniformity in the products should therefore be able to get a higher price for their products than sellers whose deliveries are more varied in quality. Thus firms have an incentive to develop methods which make this uniformity cheaper and easier to achieve.

For some products, it is often difficult in practice to distinguish between development efforts aimed at creating more identical sizes of ingredients in the final product, and those aimed at

ensuring an identical output every day. For example, if a better and cheaper method for separating discoloured vegetables is developed, then this contributes both to raising the level of the products' search characteristics (it results in a more uniform product) and to reducing variations in the products over time. Some activities are aimed solely at ensuring quality uniformity, however, eg specifications and control of raw product characteristics, control of the various production processes, and control of the final product. But ensuring the raw product's quality characteristics can lead to a lot of transaction problems. These will be discussed more thoroughly in chapter 10. The next section focuses solely on how production methods and the control of raw and final products contribute to a uniform offering. The section is divided into three subsections, which deal with the way in which firms ensure the search, experience and credence characteristics respectively of the final products.

Ensuring search characteristics over time

Three of the most important search characteristics of final products are the shape, colour and homogeneity of the ingredients. Seasonal differences in the raw product's search characteristics are one of the main reasons for quality differences in firms' product offerings over time. These differences are due to the use of new varieties, growing methods, harvesting and handling methods, and, not least, variations in growing conditions, including the weather. Some of the costs of this variation in raw product quality is absorbed by the growers, but firms also shoulder part of the costs themselves.

For frozen peas and products made from berries and fruit, differences in the ripeness and growing conditions (including weather conditions) of the raw product are an important source of the colour variation of the ingredients. As mentioned above, firms attempt to reduce differences in colour by sorting the raw product. This isn't always enough to ensure identical products from season to season, however, which is why all the firms whose products were made from fruit and berries also had extensive knowledge of the raw product quality of suppliers in other countries, thereby enabling them to "control" their products' colour characteristics through the suppliers. These suppliers were chosen mainly on the basis of the firms' experiences from previous purchases, together with their general knowledge of the climate and other important growing conditions in the suppliers areas. The final choice of supplier was based on comparisons of different suppliers' samples. Samples and experience are thus of great importance to firms that want to "control" the quality of their deliveries, which is partly due to the fact that, as yet, there are no reliable measuring methods which allow suppliers to specify the colour of the berries they can deliver.

Raw products which change in some way or other during storage can also lead to changes in a firm's products over time. This applies to, for example, potatoes and onions. The dry matter content in potatoes seems to influence the colour of both chips and vacuum-packed pre-cooked potatoes, while the dry matter content of onions is thought to affect the colour of crisp-fried chopped onions. The dry matter content is measured at regular intervals in order to calculate the optimal time for harvesting. Apart from this, storage can affect the biological process in onions and potatoes, and thus affect the quality of the raw product, making them

turn brown during deep-frying. This can be prevented through specifications in growers' contracts concerning the handling of the raw products.

Control of critical production parameters can be of major importance for the firm's ability to ensure a homogeneous appearance of its products. This applies to, for example, the production of jam and stewed fruit, where the distribution of berries in the jam is one of the search characteristics which can vary from production to production. An even distribution is ensured by letting the berries absorb sugar, so that the density of the preserve and the berries is the same. Drawing times depend on the characteristics of the raw product, including the variety and size of the berries²³. Drawing times are "controlled" on the basis of sorting (or the purchase of sorted berries) and test productions.

The distribution of ingredients in the jar is also an important search characteristic of sour products. It is reasonably easy to achieve an even distribution of vegetables in the pickle, because they are cut up and put in the jars before the pickle is poured over them. An exception is whole cucumbers, however, where it is necessary to prick a hole in the cucumber to ensure an equal distribution of cucumber and pickle. This is automated today.

In addition, control of the frying process (and, in the case of crisp-fried chopped onions, a good knowledge of the relation between the batter and frying) is also an important element in the control of colour variations in final products. Finally, sorting the products after frying can reduce the number of discoloured pieces.

Ensuring experience characteristics over time

It was argued above that product uniformity can mean that the firm can get a higher price for its products. This is especially likely in the case of experience characteristics, such as taste, consistency and perishability, which are difficult for buyers to evaluate. Precisely which factors lead to variations in these characteristics depends on the product concerned. However, variations in the taste and consistency of a large number of final products are mainly due to variations in the quality characteristics of the raw product - but also here, there are a number of cases in which the production process itself influences products' experience characteristics. Several of the interviewed firms had also introduced procedures in their production aimed at ensuring a uniformity in precisely these characteristics. As the following will show, firms ensure experience characteristics primarily through the specification and control of the raw products' taste and consistency characteristics, and through control of the production processes. A few firms also carried out organoleptic tests of the taste characteristics of the final products.

In the production of, for example, fruit juice, squash, and jam, the taste and aroma of the final product depends to a very great extent on the variety and growing conditions of the fruit and berries. Neither the taste nor aroma can be measured directly, but it is known that the taste of berries and fruit - and thus also of the final product - depends on their dry matter and acidic content. Both of these can be measured, and both growers and producers of intermediate

²³ Drawing times are also thought to influence the jam's taste.

products are paid according to these proxy measures. Product homogeneity is ensured by blending berries or fruit with different amounts of acid and brix, thereby enabling firms to achieve the same quality level production after production, season after season. This requires large stocks of raw products, however. Since, as already mentioned, the taste and aroma characteristics of the raw product are hard to measure²⁴, firms must use proxy measures²⁵ instead, which can complicate their efforts to ensure a uniform quality in the final product.

Taste variations in the final product can also be due to unfortunate characteristics of the raw product. For example, cucumbers grown for pickling can develop bitter substances if they are subjected to extreme growing conditions. Firms try to prevent this partly by requiring growers to water frequently and partly by means of random checks (tasting) of the cucumbers. If any of the sampled cucumbers are bitter, the whole consignment is rejected²⁶.

Finally, variations in taste can also occur as a result of the interplay between the raw product's characteristics and the firm's production processes. The production of crisp-fried chopped onions, for example, suffers from the problem of ensuring a stable oil content in the raw product, because the dry matter content changes during storage. As yet, no satisfactory solution has been found to this problem.

Consistency is an important experience characteristic of stewed fruit, jam, and sour products. The consistency of jam depends on the interplay between the pectins and starch components of the berries. The exact relationship between the berries' characteristics and the jam's consistency is still not fully understood, however. What is known, however, is that both the natural pectin content of the berries and their content of known pectin reactive substances, such as calcium, is influenced by growing conditions. One firm analysed the berries' calcium content so that it could adjust the addition of "artificial" pectins, thereby obtaining a uniform consistency every time. Another method used to prevent variations in consistency is to mix the berries with different amounts of calcium.

Consistency is also an important experience characteristic of sour products. The consistency of large pickling cucumbers depends on how well firms can control the heat treatment process. This relationship between consistency and heat treatment also applies for beetroots and pumpkins. In order to control the process precisely, however, the ingredients have to be roughly the same size, which is sometimes achieved through the choice of variety and sometimes by sorting the raw products. "Consistency problems" can also arise in beetroots towards the end of the season because they become chewy when boiled. When this happens, the whole batch must be discarded. This is a rare problem, however, and there is still no explanation for it.

Perishability, which is an important experience characteristic of all products in the fruit and vegetable industry, is a quality attribute which only becomes noticeable after a certain period.

²⁴ A number of specific aroma and taste components in berries have still not been analysed, so as yet there are no analytic methods for measuring berries' sensory quality.

²⁵ It is important to realize that sellers can have an incentive to give a higher priority to improvements in the level of proxy measures than hard-to-measure experience characteristics. There is a limit to the "utility" of such efforts, however, since, with time, proxy methods can lose their value as indicators of the aforementioned characteristics.

²⁶ The problem of bitterness in cucumbers has been solved through cultivation.

Control and sampling are two of the most important ways of ensuring a uniform perishability of the final product from delivery to delivery. Firms took samples of their products to test their perishability. Perishability can be measured in days, and variations in this can be ascertained by examining how many of a sample of products have the specified perishability.

A number of different preserving methods are used - depending on the firm's expertise and the products concerned - including freezing, pasteurization, autoclaving, sterilisation, and vacuum packing. The causes of variations in perishability depend both on the product in question and the preserving method used. With preserving and autoclaving, control of the process temperature and packaging are two of the methods most frequently used to avoid variations in perishability. In jam and stewed fruit production, differences in the sugar content of the raw products are also a source of perishability variations in the final product. Sugar is a good preservative in sufficiently high concentrations, but in lower concentrations it is necessary to add preservatives in order to guarantee a specific perishability²⁷. Water evaporation and a high acid content ensure the perishability of squash, while the sterilized bottling of both squash and purée ensures perishability without the need for preservatives. Sulphuric acid is added to apple purée for customers who are unable to store it in sterile conditions. Variations in perishability can occur in the case of technical failures or careless cleaning in the bottling plant.

Ensuring credence characteristics over time

Compliance with microbiological standards is an important credence characteristic of the final product. All food processing firms are subject to strict food inspection standards. Food control inspectors regularly visit and inspect firms' final products and production processes. Some firms had even established their own standards which went further than the official ones, while other firms used standards set by their customers. Some firms again had changed some of their production processes in connection with the introduction of quality control systems or ISO certification.

There were big differences between the firms as to whether they controlled the raw product, the production process, or just the final product, and in the extent to which they regarded control as a means of identifying sources of microbiological contamination, or whether it was just a means of ensuring that variations in microbiological levels were within the required standards.

The two firms which produced vegetables for use in pre-cooked meals expressed the desire to be able to document the bacterial count and the absence of listeria and salmonella bacteria in vegetables.

The following are some of the most important ways in which firms tried to limit microbiological contamination during production:

²⁷ Both jam and stewed fruit can be made without preservatives, but this requires a sugar content of 60%, which none of the interviewed firms wanted in their products.

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- Separation of crops, traceability from final product to raw product.
 - Improved cleaning routines and the possible introduction of automatic cleaning, so that the production machines clean themselves (eg by installing automatic cleaning in the juice tanks).
 - Keeping unwashed raw products separate from the production. All the firms washed their raw products outside the production area - in one case, in the field.
 - Keeping blanched and non-blanched products apart.
 - Analysing the microbiology of the raw products, and keeping an eye on changes during production.
 - Fractionation of recycled water, so that water coolant is only used in the first washing of the vegetables.
 - Checking that the packaging is tightly sealed.

Summary

The fruit and vegetable industry uses a lot of resources to prevent variations in output and in ensuring a certain level of search, experience and credence characteristics. Part of this resource use could be reduced if new and better methods were available for measuring the quality characteristics of raw and final products and for controlling the production processes.

An analysis of transaction costs can only identify incentives to develop technologies which, with today's technological knowledge, are considered likely to reduce these costs. However, the actual technological development in the fruit and vegetable industry can only be understood by taking a starting point in the physical and biological characteristics of the products and production processes used in the industry. The data collected so far doesn't allow us to be more specific about the direction of this development because of the lack of an historical dimension. It is thus not possible to identify a technological path for those development efforts which result in a reduction of transaction costs. Information from the interviews can only be used to indicate which techniques such a path could involve.

As mentioned previously, the transaction cost analysis is based on the assumption that both buyer and seller are rational to a limited degree, in the sense that they don't have all the relevant information about the products. They are not limited as far as their ability to work out an optimal search or sorting strategy is concerned, however. They are thus able to protect their rights to a point where the costs of searching and sorting correspond to the economic benefit of ditto. This is a fairly presumptuous and somewhat unrealistic assumption to make about individual agents' decision-making capacity. It is therefore also interesting to examine what importance it would have for "identified" technological opportunities if agents had a more

limited ability to work out an optimum and thus had to rely on familiar search and sorting routines. One possibility, for example, is that buyers only made the effort to choose between alternative sellers if the quality level of the goods they bought fell drastically vis-à-vis their price, or that they were getting bargains (ie paying less for the same quality) more often than before. This would imply that sellers charging the same price, but having different distributions of quality, could exist side by side as long as they could all ensure that their products didn't change over time. If this were the case, it could no longer be assumed that individual sellers were always forced to make incremental improvements in the quality level and distribution of their products, because as long as they could avoid changes in the quality and range of their products, their market share would be guaranteed. Another possibility is that buyers didn't sort to the point where their marginal utility of sorting corresponded to the marginal costs, but relied on a search routine. The value which a buyer acquired from a seller by sorting would then depend on the buyer's searching routine. Buyers could eg search among ten products and select the one whose quality corresponded roughly to the price. But this only means that the seller will not have to sort his products as extensively as when the buyer can calculate his utility of an extra effort.

Only in the event that buyers' choice between sellers and their choice of individual products was completely random would the above analysis of transaction costs be completely irrelevant to technological development.

10. Transaction costs and technological opportunities in caveat vendor transactions

The previous section focused on the interplay between transaction costs and technological development in so-called caveat emptor transactions. This form of economic organization of transactions is costly, however, and is only used under certain conditions (Barzel, 1989). It is eg important for both buyer and seller to have some knowledge of products' quality characteristics prior to the transaction so that they can each be sure of getting the highest possible value from the transaction. Furthermore, it is important that, through the market, the buyer can exercise some degree of control over the seller by not buying from him. If the buyer incurs costs in exercising this control, then the market is not functioning effectively as a control mechanism (which, among other things, applies to experience and credence characteristics).

However, the market may not be functioning properly as a control mechanism because there are too few suppliers of the same product. This often appears to be the case in the market for raw products. The use of specialized production equipment and a desire to differentiate final products might explain why firms can't just buy their raw products on the market. Contracting with growers or suppliers of input products gives them access to products which are more suited to their specific requirements. This is the gist of caveat vendor transactions, in which the trade in specialized raw and input products is organized by means of contractual specifications which commit both parties to specific obligations over a shorter or longer period. The rights specified in the contracts are enforced primarily through the courts.

In the following, the order or grower contracts, used in the fruit and vegetable industry are regarded as a reallocation of property rights between the contracting parties (Barzel, 1982). This takes place because input suppliers or growers can best utilize their rights to obtain income from their assets - in the form of capital, land and labour - by transferring the user rights (or part of them) to the firm rather than using them themselves to produce what they want.

There are big differences in how far-reaching the reallocation of property rights is. In order contracts, the agreement between the parties includes a promise from the seller to use his assets to produce a product with certain specified characteristics. The reallocation is more far-reaching in actual contractual cultivation, however. Here, the agreement between firm and grower specifies both the characteristics which the raw product must have (and by which the grower is paid) and various factors concerning the cultivation, harvesting, and handling of the crop. With this, the grower also transfers part of the use of his land and labour to the firm.

From a property rights point of view, this difference in contracts can be explained by differences in efficiency as regards the utilization of property rights. Put another way, order contracts are used when the buyer (often a firm) can be sure of getting the highest value from raw and input products solely by specifying which “types” of raw product and input product, eg land, labour and capital, to use in production. The seller, who is the formal owner of the land, labour and capital, is then free to maximize the yield from these assets by using them as effectively as possible²⁸. Grower contracts, which involve a much more far-reaching division of the ownership of land and capital, are used when buyers either cannot specify their rights or cannot ensure the highest value of the raw products unless they also acquire the right to (in part) decide how the growers use their land and labour. But even though growers’ user-rights over their land and labour are limited, they still have sufficient freedom, within the framework of the contract, to maximize production by using their remaining part of their rights over labour and land in the best possible way.

When rights are traded, or divided by means of contracts, the parties protect the value of these rights by specifying them in the contracts up to the point where the benefits correspond to the costs. The costs consist of 1) specifying and measuring all the characteristics of the assets; 2) determining the value of the characteristics; 3) protecting the rights; and 4) enforcing the rights. The higher these costs, the more rights are placed in the public domain, and both parties will then use resources to acquire this value.

The rights over the assets which are specified in the contracts are not fully protected, however, if one or both parties can influence the value which the assets can generate.

If the parties can influence the value of traded or divided rights, then the maximum value of the assets will only be ensured unless the specific division of the rights in the contract also

²⁸ The use of order contracts presupposes that it is relatively easy to specify and control the quality characteristics the buyer wants. The existence of a particular set of technical standards (after which search and experience characteristics can be specified) or behavioural standards (after which credence characteristics can be specified) in the industry will make it easier for the buyer to communicate his specific requirements. This will also make it easier for sellers to say which requirements they are able to meet.

takes into account the various possibilities of the parties to influence the value, or income flow, which the assets can generate. The rights should be generated in such a way that the party which has the best chance of influencing an asset's economic value also has the rights to that part of the asset's income flow which the party's actions can influence (Barzel, 1989). For example, the value of the assets is influenced where buyer and seller have the possibility of biased selection of the products on offer ("adverse selection"), or when one of the parties limit their contribution ("shirking"). If one of the parties has made a specific investment, whose value outside the transaction is very low, it gives the other party to the transaction a unique opportunity to influence the value of the parties' assets (investments) without compensating the first party. "Hold up" from the one party means that this party appropriates the quasi-rents which would otherwise have accrued to the party which had invested in the asset.

In some cases, the income flow is only influenced by one of the parties in the transaction. In such cases, the value of the assets can be protected by making this party economically responsible for variations in the value the asset can generate ("residual claimant"), so that the party's incentive to make uncompensated use of the rights is limited. In other cases, the income flow is influenced by both parties. This is often the case where the rights over an asset are shared by the parties. Again, the asset's value is best protected if each of the parties is made economically responsible for that part of the income flow which they can influence.

However, completely protecting the rights can cause problems if the value which the asset can create is difficult to measure or varies unpredictably, since it is hard in such cases to determine the parties' possibility for influencing the income flow. This also means that neither party can say with certainty whether anything of value has been captured in the transaction (Barzel, 1989). For example, when the parties share rights to land, it can be difficult to establish whether variations in the raw product's quality are due to the weather, the cultivation methods used, or the crop varieties which the buyer wants grown.

Transaction costs in caveat vendor transactions thus consist of the resources which, if product information had been freely available, are "unnecessarily" used in specifying and protecting property rights. These include, for example, resources used in finding trading partners, in determining the value of the assets, and in determining the parties' influence on this value. Even when the rights have already been optimally divided, there will still - given the problems of determining each party's possibility for influencing the income flow - be transaction costs. These consist of the resources used in making sure that the specifications have been met and in acquiring the value placed in the public domain - including excessive searching and sorting. Also included are the costs of enforcing the rights specified in the contracts. These costs will be high if the parties are able to utilize the property rights placed in the public domain in an opportunistic way, either because they are not stipulated in the contract or because they can only be enforced with difficulty.

Technological opportunities which reduce transaction costs in caveat vendor transactions

In order to understand the relationship between transaction costs and technological development in the caveat vendor transactions typical of much of the trade in raw products and input products in the fruit and vegetable industry, it is first necessary to give a more detailed description of the factors which give rise to transaction costs in order and grower contracts respectively.

Inspired by Williamson (1985), transaction costs can be divided into ex ante and ex post transaction costs. These include the following kinds of costs²⁹:

Ex ante transaction costs:

- 1) Search and information costs
- 2) Costs of negotiating contracts
- 3) Costs of enforcing a contract

Ex post transaction costs:

- 4) Costs resulting from a poor adjustment of trade (“misalignment”)
- 5) Negotiating costs incurred from adjusting trading conditions to external changes (“haggling costs”)
- 6) Costs of ensuring that both parties remain in the transaction (“bonding costs”)

In the following, it is argued that ex ante transaction costs are primarily costs of procuring precise information about the quality characteristics and yields of products and product factors. Ex post costs are argued to be a result of the fact that the uncertainty connected with extended transactions makes it impossible to draw up complete contracts in which all rights are fixed and their value discounted under alternative market conditions. This enables the parties to use resources to acquire those property rights that are placed in the public domain, because they are not stipulated in the contract and therefore can only with difficulty be enforced through, for example, the courts³⁰. The different types of costs are discussed in greater detail below.

²⁹ The classification is a combination of Williamson (1985) and Dahlman (1979).

³⁰ Asset specificity is one of the factors which can make enforcement difficult. Asset specificity gives one or both parties a special opportunity to influence the value of the parties' assets (investments) without compensating the other party. “Hold up” from one of the parties namely means that this party appropriates the quasi-rents which would otherwise accrue to the party which had invested in an idiosyncratically specific asset.

Ex ante transaction costs

1) Search and information costs

Before the contract is signed, the buyer often uses time and energy in evaluating possible contract partners. This corresponds to a consumer choosing the seller with the best offer. For example, it seems reasonable to assume that the greater the differences in quality and price between potential contract partners, and the more difficult it is to account for differences in the products themselves, the more extensive the search for a partner and thus the higher the search costs.

When transactions are organized by means of contracts, the buyer is unable to compare the various suppliers' product qualities, because the contracts are signed before the input or raw product is produced. The buyer does have recourse to various "proxy measures", however, since he can compare the quality of different sellers' samples and, partly, their expertise and production machinery. Samples only give information about the level of a product's search and experience characteristics, however³¹. A comparison of different sellers' credence characteristics often requires the direct inspection of the seller's production facilities.

In the interviews, a few of the order-producing firms mentioned that potential buyers of their products did, in fact, insist on such inspections - of, among other things, the firm's quality control systems and their documentation. These firms also mentioned that their competitive advantages over other order-producing firms were due to such factors as the ability to deliver, capacity, and production plant. Reputation was also cited as an important asset, which can perhaps be attributed to the fact that buyers' search costs will be reduced if they can base their search on order-producing firms' reputations. A firm's reputation thus functions as a kind of brand. Firms also often use resources to check up on growers before entering into agreements on contractual cultivation. In some cases, this involved checking the quality of the soil, while in other cases it just involved checking whether growers' irrigation systems were sufficient to meet the firm's cultivation stipulations³².

Despite inspection, the selection of contract partners in both grower and order contracts is still somewhat risky, because buyers often don't have access to all the relevant information about the seller's capabilities. Furthermore, evaluating the suitability of every potential partner can be a costly affair. For example, it is relatively easy for a firm to check whether the grower has an irrigation system, but it's another thing altogether to evaluate the quality of the soil or labour. The latter are experience characteristics which often only become apparent after the firm has received one or more deliveries from the seller.

³¹ Furthermore, the buyer naturally cannot be certain that the quality of the delivered product will be the same as the quality of the sample.

³² In the case of cucumbers for pickling, extreme cultivation conditions can cause bitterness. The firm can check for bitterness by taking test samples, however. Deliveries with a certain number of bitter cucumbers are rejected, and the grower bears the loss. Nevertheless, the firm tries to limit the problem by specifying growing conditions in the contract, eg by requiring growers to have an irrigation system.

Credence characteristics are the most difficult of all for the firm to evaluate because they are characterized by asymmetrical information in the seller's favour. One example of this is land which hasn't been fertilized using artificial fertilizers for years, and which can therefore be approved for ecological cultivation. The grower will often know whether the land has been sprayed or not, but the firm will have great difficulty in making sure of this. If there is a prospect of extra payment for non-sprayed land, growers will have an incentive to keep quiet about their knowledge. This presents the firm with a potentially moral hazard problem.

2) Negotiation costs

Negotiations costs consist of the resource used to determine the price of the product characteristics and user rights specified in the contract.

The contract specifies the criteria by which the products are paid. Price determination, which is the outcome of an offer and eventual negotiation between the parties, can thus be more resource demanding than with caveat emptor transactions. Some of the purchasing firms said that they bought part of their raw products at auctions at market prices. Thus the price of various search and experience characteristics of raw or input products can be influenced by the market price for raw products.

The costs of drawing up contracts depends not only on the extent of the negotiations, but also on how easily the parties can communicate their wishes and requirements. These communication costs fall with successive contracts, as a common language and understanding are developed. In time, the ability to communicate at low cost can become an asset, the value of which depends on the two transacting parties continuing to do business with each other (Williamson, 1985).

3) Costs of enforcing property rights

The costs of enforcing property rights consist of the resources used by the parties to ensure that the products actually have the characteristics specified in the contract. This doesn't mean that all a product's characteristics are specified and valued in the contract, however. The higher the costs of measuring and evaluating the products' characteristics, the fewer the characteristics that will be specified, and the harder it will be to protect their full value in a transaction. The producer's situation is similar to that of the pea seller in the previous section, though with the crucial difference that the product's value is determined in negotiations between an order producer and a buyer rather than through direct competition in the market.

When transactions are organized by means of order contracts, the buyer safeguards his property rights over the product's quality characteristics by checking whether they correspond to the contract specifications. Here, as in other transactions, what counts is that the buyer protects his rights to an extent determined by the costs of evaluating the products he receives. Most often, the buyer makes do with testing a sample of the deliveries. If there is any doubt as

to the accuracy of the measurements, the contract usually specifies what action to take in the event that the buyer and seller have different measures of quality. Several firms mentioned that, if the correctness of the measurements was in doubt, then it was the buyer's measures that decided the issue. The buyer also makes certain that the contract contains a clause stipulating that he can get a refund for products which don't live up to his quality specifications. This right of complaint has the same function as a product guarantee. Out of consideration to the seller, however, such rights are often weighed down by a number of restrictions³³.

Order-producing firms also protect themselves against buyers' uncompensated use of their assets. Such a situation could arise, for example, if it were normal practice for a buyer to contract with different suppliers, wait until the products were ready, and then buy from the supplier with the lowest price³⁴. This kind of adverse selection of business partners leads to transaction problems, because one of the parties in the transaction is not fully compensated for having used his assets to produce a specified product. The order-producing firm can prevent this form of uncompensated use of his assets by inserting a clause in the contract which guarantees him a certain compensation if the order is cancelled or if there is a breach of contract³⁵. The way in which property rights are divided in order contracts primarily gives order-producing firms an incentive to develop raw products and production methods which enable them to deliver products with the specified characteristics, while buyers primarily have an incentive to develop control methods.

Grower contracts are like order contracts in that property rights are specified and their value determined in the contract through negotiations between the parties. They differ from order contracts in that the growers transfer part of their user rights over the land and their labour to the firm. In grower contracts, uncompensated use of rights is limited by making the growers economically responsible for variations in those search and, in part, experience characteristics of the raw products which are due solely to their efforts, while the buyers are made economically responsible for those variations in yield and quality which are solely due to the fact that the growers followed the cultivation, harvesting and handling specifications laid down in the contract.

In grower contracts, too, the possibility of the parties to realize the full value of their rights depends on the costs of specifying and evaluating the value of all the characteristics of the rights concerned. Growers safeguard the value of the rights they transfer to the buyer by making sure they get compensation for the opportunity costs incurred in following the firm's instructions regarding labour and land. Examples of the opportunity costs incurred by growers as a result of being under contract to grow particular varieties of peas, potatoes, carrots, etc., are lower yields or a higher input of labour. In principle, growers must be compensated for the

³³ The seller keeps part of the property rights over those product characteristics which he has had a particular hand in creating, and which he is therefore responsible for. This responsibility lasts until the product is accepted, and eventually consumed, by the buyer. However, the seller often has to stipulate various restrictions in the way the buyer handles the product during the period in which he can be held responsible for its quality. Such restrictions aren't meant to limit the buyer's property rights in any way, only insure the seller against unwarranted complaints which are due to the buyer's careless handling of the product (Barzel, 1989).

³⁴ This depends on how easy it is for the buyer to find alternative producers with better product quality.

³⁵ For a more detailed discussion of this, see Williamson (1985, chpts. 4 and 5).

opportunity costs of using their assets for the specific uses stipulated in the contract. If, on the other hand, they could have obtained higher economic value by leaving the land fallow, then they should also be compensated for this.

What is important here is that the way in which the parties divide property rights over joint assets influences their incentives for technological development. One example of this is the production of frozen peas. Here, the parties have divided the property rights over the grower's land and labour, since the contract specifies which varieties of pea the grower must cultivate and when they are to be harvested. Growers are paid according to the quantity, or weight, delivered. All those variations in quality and quantity which are solely due to the fact that the growers followed the firm's instructions in the contract are compensated. For example, growers get a higher price for growing peas which give a lower yield. This gives the firm an incentive to develop varieties of peas and cultivation and harvesting methods which will insure them against variations in quality, while growers primarily have an incentive to develop cultivation methods which increase the yields of the varieties they have undertaken to grow.

It is not always necessary for the parties to divide property rights in order to ensure certain search or experience characteristics in the raw products (or deliveries), however. In such cases, the parties ensure the highest economic value of the assets by making the growers economically responsible for quality variations in the raw product. This is done by offering them a share of the income flow corresponding to the effort they put into creating it (residual claimant). A right of return clause can also be inserted in the contract, stipulating that growers' responsibility only extends to those quality characteristics which they have a particular influence on. The value of both land and labour is thus maximized by inserting a carrot (bonus) or stick (right of return) clause in the contracts which reduces the parties' incentives to acquire value without compensation in the transactions. In practice, growers are made economically responsible for variations in quality characteristics by making the price they can get for the raw product dependent on its quality characteristics. Three characteristics in particular are specified directly in the contract, and it is on the basis of these that the price is agreed between firm and grower:

A) Search characteristics of the raw product, eg the variety, size and shape of the raw product, and the care with which it has been handled during harvesting (whether it is bruised or has any other blemishes caused by crushing, tearing, cutting, etc.).

B) Search characteristics of the delivery, eg the amount of earth, stones, leaves and other material in the deliveries.

C) Experience characteristics of the raw product, eg the cooking properties of onions and potatoes.

When growers are economically responsible for quality variations, the buyer safeguards his rights by evaluating the quality of the raw product. The following subsections discuss how the above three factors provide incentives for both growers and buyers to develop technological solutions.

A) Search characteristics of the raw product

As previously mentioned, firms ensure the search characteristics of the raw product by evaluating size, shape, foreign matter in deliveries, colour, bruising and discolouration. Firms either screen the products or carry out spot checks to control the raw product's search characteristics. The scale of control depends on whether it is a supplier whose quality and distribution are known, or whether it is a new supplier.

The size and shape of the raw product are particularly important:

1) Where size determines a quality's category (small, medium and large peas). The grading of peas into quality categories depends on the variety, but optical sorting after the harvest is also important, because the firm receives a higher price for an identical final product. Increased demands on size often makes increased demands on the sorting technology.

2) Where the vegetable is chopped into different shapes (eg sliced and diced carrots and beetroots), or used to make different products (eg crisp-fried chopped onions and soft-fried onions). Some varieties of carrot and beetroot have a shape which gives a better utilization of the raw product during chopping/slicing than other varieties. These varieties are specified in the contracts. Onions are mechanically sorted into large and small onions. (The firm has a bonus scheme which favours big onions over small onions, since the large ones are easier to handle.)

3) Where a uniform final product is an important search characteristic for the buyer (this applies, for example, to gherkins and large pickled cucumbers, chips, and Samsø potatoes in jars). The uniformity of large pickled cucumbers and potato products is ensured by sorting the raw product on arrival at the factory (though Samsø potatoes are sorted during the harvest)³⁶.

4) Where the consistency/taste of the final product depends on size. For example, pumpkins and large cucumbers become coarse above a certain size. Pumpkins are sorted and paid for according to how much of the flesh can be used. Large cucumbers are sorted during harvest, since they are picked by hand.

5) Where vegetables undergo subsequent heat treatment (eg beetroots used in pickled beetroot). The beetroots are graded into four sizes, three of which are used in production. The smallest is rejected and is the grower's loss.

6) Where the vegetable is peeled mechanically, as with large cucumbers. A manual grading by size during the harvest ensures an optimal use of the raw product.

As can be seen from the above, in some cases firms can select a particular variety and thus get more identical raw products, or raw products which are easier to process. The firm's possibilities for selecting this or that variety often depends on the success of previous breeding efforts to develop varieties with particular proportions. These efforts have resulted in the develop-

³⁶ The uniformity of ingredients in cucumber salad is ensured through the selection of the "giant" variety of cucumber, which gives long, straight cucumbers. These are bought at auctions, however.

ment of special characteristics in, for example, carrots, beetroots, cucumbers, potatoes, and peas. Breeding often takes years before the desired results are achieved, however. It also has natural limitations, since it is not possible to develop all the desired characteristics in all types of vegetables. Thus variations in size can't be completely eliminated through breeding.

There are variations in size in most varieties of vegetables and berries, depending on, for example, their growing conditions. If such variations have an influence on the characteristics of the final product, or on the degree of utilization of the raw product, then payment is based on the processing firm's sorting of the raw product on delivery³⁷. Payment is specified beforehand, in the grower contract. In some cases, eg pumpkins, large cucumbers and beetroots, growers are paid according to the quantity of crops of minimum specified size they deliver. The growers bear the loss of unusable sizes. In other cases (potatoes for chips and vacuum-packing, onions, beetroots), the raw product is divided into size classes, and growers receive a bonus for growing those sizes which the firm wants the most. Growers thus have an incentive to develop varieties or cultivation methods which result in reduced variations in size, while the firm primarily has an incentive to develop cheaper sorting methods.

Size and shape aren't the only search characteristics specified in the contracts. Bruising and other blemishes are an important search characteristic in, for example, potatoes and beetroots, because such marks are visible in the final product, whether in the form of chips, vacuum-packed potatoes, tinned potatoes, or pickled beetroot. In the latter, wounds also make them more difficult to peel - not only does it take longer, but the peel has to be thicker, thus increasing wastage.

The damage to potatoes and beetroots occurs during harvesting and transport. Small new Samsø potatoes are particularly vulnerable because they have a very thin peel, so careful harvesting is necessary to limit damage. Test samples are taken of both potatoes and beetroots on delivery. Growers are made automatically responsible for their handling of the raw product through bonus payments for deliveries which are free from defective raw products. Growers of small new Samsø potatoes receive even more, because the firm pays a higher price for these small potatoes.

As regards onions, it is known that an outbreak of mould fungus during storage can lead to discolouration during frying. Growers can reduce fungal attacks by crop-spraying and through storage in dry, cool conditions. The growers are economically responsible for storage and thus also for onion quality, including the detection of mould fungus. The onions are sorted on arrival at the firm so that growers can be paid according to the quality of deliveries.

Colour changes are an important experience characteristic of potatoes. Here, the dry matter content is thought to influence potato colour during frying. To avoid discolouration, the dry matter content is measure, and boiling and frying tests are carried out on all deliveries of potatoes, which takes about half an hour. The results of both methods determine how much the grower is paid.

³⁷ An exception is Samsø potatoes, however; growers deliver the "big" potatoes to the fresh food market because they are harvested manually.

B) Search characteristics of the deliveries

Foreign matter in the deliveries is an important search characteristic of many raw products, and the contract often specifies a limit for how much soil, stones and leaves a delivery can contain. The way berries, potatoes and beetroots are harvested affect the quantity of foreign matter in the deliveries, eg most berries and fruit are harvested by machines which shake the bushes and trees, which brings down a lot of leaves and twigs at the same time. A lot of these are removed by sending the berries past a fan, however. Efforts are still being made to solve the problem through the development of harvesting methods³⁸. The amount of foreign matter in deliveries is judged by means of visual inspection. Some firms give a bonus for “clean” deliveries, while others reject deliveries with too much foreign matter.

The harvesting of root crops also results in a lot of stones in the deliveries. These are eliminated before production, since there are a lot of harmful bacteria in the soil. Furthermore, stones, etc., both damage machines and the overall quality of the final product. In most cases, it is the firm which bears the costs of removing stones and other foreign matter. In all cases, stones were removed mechanically by means of a rotating riddle. Firms use different methods of reducing the number of stones in the deliveries, ranging from bonus schemes for stone-free deliveries to the mandatory use of rotating riddles. Newly harvested root crops still have a lot of soil clinging to the roots. This is washed off on arrival at the firm (the risk of soil bacteria getting into production is also greater when the soil is washed off in the factory). (The exception is leeks, since the development of a leek harvester has moved the washing process out to the field.) In all cases, the firm bears the costs of washing root crops. The costs of rinsing green vegetables is also borne by the firm. In order to preserve the aroma and vitamins of the raw products, they should be rinsed as quickly as possible before being used.

It is growers who get the most out of technological solutions to the problems of damage during harvesting and foreign materials in the deliveries, because they bear the costs of rejection. But the firms also get something out of it, because new harvesting methods which reduce the amount of foreign material in the deliveries also reduce firms’ costs of visual inspection and removal of the “rubbish”. Similarly, firms will have an interest in preventing damage to the raw products during harvesting, because their control and sorting costs will decrease if they can be sure of getting the qualities they want.

C) Experience characteristics of the raw product

Taste is an important experience characteristic of raw products, since the taste of the final products largely depends on the taste of the ingredients. For both jam and fruit juice, the taste of the final product depends on the dry matter and acid content of the berries and fruit used. Both are measured, with growers being paid according to the dry matter content. A press test is used to calculate the level of these characteristics for every delivery. Aroma is another important taste component, which, however (according to the companies themselves), cannot

³⁸ The primary efforts are, however, directed towards improving mechanical harvesting methods which avoid damaging the crop.

be measured objectively today. Aroma depends, among other things, in the variety of berry used. The aroma of different varieties of berry and fruit can be bought separately and added to fruit juice, squash and jam, thereby compensating for variations in taste. Variations in taste in the final product can also be due to unfortunate characteristics of the raw product, eg bitterness in large cucumbers when they are subjected to extreme growing conditions. Firms try to prevent this partly by requiring growers to have irrigation systems and partly by taste-sampling each delivery.

Apart from the above-mentioned examples, none of the interviewed firms mentioned taste as a quality parameter of raw products. This is probably because, apart from taste-sampling, there are no quick and easy methods for measuring the taste of the raw product. Berry production must therefore use proxy measures (acidity and dry matter content). The development of (quick) measurement methods for determining, for example, the taste characteristics of the raw product would make it easier and less costly for firms to pay growers according to these qualities. This would also increase growers' incentives to deliver raw products with the desired characteristics.

Evaluating the quality level of experience characteristics sometimes requires a small "test production", plus certain other tests. In the production of crisp-fried chopped onions, control of raw product quality is extended to the whole growing period (this is a part of the user rights which growers transfer to the firm), since the dry matter content is measured continuously from harvest to use. Growers are paid according to the dry matter content, but the firms bear the costs of inspection and testing of the raw product themselves. Growers thus have an incentive to develop cultivation methods which ensure the dry matter content of onions, while firms have an incentive to develop quicker methods of measuring the dry matter content.

As can be seen from the above, firms with contractual cultivation arrangements try to ensure a certain uniformity in the raw product and avoid a too-high rejection rate by means of differentiated payment, bonus schemes, and by keeping a right of complaint. It isn't always easy or cost-free to make growers economically responsible for variations in raw product quality, however. Firstly, not all quality characteristics of the raw product can be easily evaluated by the firm's quality control system. For example, it can be difficult to find wounds and bruises in potatoes and beetroots before they are peeled, which is why firms have introduced a manual screening process after peeling. This screening process ensures uniformity in the final product, which is an important search characteristic. Since 100% screening can only be carried out during the production process, whereby the firm may also cause some damage to the raw material making it more uncertain to define each party's influence of the quality, it is hard to make growers economically responsible for these variations. The firm therefore bears the loss of rejections.

Secondly, in some cases it can be difficult to tell whether blemishes in the final product are caused by shortcomings in the raw product or in production. Unless the firm can document that it is due to the raw product, it must bear the loss of scrapping itself. In chip production, for example, a certain level of biological knowledge is required in order to understand the connection between the quality of the final product (identical colour) and the quality of the

raw product (dry matter content and growing method). Without this knowledge, the buyer cannot guard against having to take delivery of raw products with varying quality characteristics at his own cost. Improved knowledge about cause and effect relations between crops, the way they are grown and handled, and the way they are treated in the firm is an important step towards safeguarding property rights.

Thirdly, it can be difficult for a firm to evaluate the level of an individual grower's quality. This can lead to "shirking". "Shirking" can be illustrated by the following example. A group of growers is paid on the basis of an average quality of crops delivered the previous year. The grower who delivered a below-average crop will thus receive the same as the grower who delivers a first class crop. In the following year, the payment is reduced a bit, because average quality fell. The grower who delivered the poorer quality product will still get much more for his crops than they're worth, but because his poor quality has pulled the average down, it affects the value of all the other growers' crops. This is particularly relevant where the quality characteristics first appear after the raw product has been used in production, eg potatoes and beetroots, where the quality can only be judged precisely after they have been fried or peeled. Both grower and firm have an incentive to limit the scope of shirking. This is typically done by separating different growers' deliveries throughout the production process, even as far as to the final product. By this, growers who make an extra effort to fulfil the specifications can be rewarded, and this also effectively stops problems caused by shirking. It is far from cost-free for the firm to protect itself against shirking on quality, however.

Lastly, it is especially difficult to make growers economically responsible for variations in credence characteristics, which cannot be measured directly in the raw product at all. Credence characteristics, eg the way the crop is grown, can only be ensured by the firm supervising the cultivation itself. One example of this is the production of potatoes for chips. Crop sprays against violet root rot affect the taste of the full-grown potatoes, and the firm is forced to dump whole consignments if the potatoes prove to be sprayed. It is difficult, if not impossible, for the firm to measure either the field or the crop for the amount of spray actually used, however. Firms therefore require growers to keep a record of when and how much they spray. The firm safeguards the value of the characteristic "not sprayed against violet root rot" by testing samples of the crop and by checking the spraying records. Since this control is subject to uncertainty, however, the firm has placed part of its user rights in the public domain. Growers could thus use resources to acquire part of the user rights by, for example, shirking with the records or spraying more than prescribed in order to increase yields³⁹. In this case, too, both the firm and the growers have an incentive to limit "shirking", since raw product prices were fixed according to expectations of a certain level of shirking. One of the ways in which the firm limits this type of shirking is to keep individual growers' deliveries separate throughout the production process, thereby keeping open the possibility for complaint or reducing bonus payments until the individual grower's quality has been checked. These measures protect the firm against some of the loss following the scrapping of a consign-

³⁹ This is a fictive example. All the firms claimed that they didn't have problems of this kind with their growers. Most of the firms had long-standing contracts with their growers, and since growers were interested in maintaining this contractual relationship, they didn't attempt to cheat.

ment⁴⁰. In most cases, however, the firm itself must bear the loss of energy and labour that has gone into the production. The quicker the firm can identify defective deliveries, the smaller this loss will be. Alternatively, by developing environmentally friendly cultivation methods whose costs and effect correspond to traditional methods, the parties can limit growers' incentives to use traditional methods. This would save the buyer from having to control growers in order to safeguard his rights (incentive alignment)⁴¹.

There are costs of protecting property rights in all contractually organized transactions, since there will always be costs associated with monitoring compliance with the conditions of the contract, and a number of examples of such costs have been given in this section. As the above has shown, buyers incur a lot of measuring and sorting costs in making sure that the specifications for the raw product's search characteristics are met, and partly also for the experience characteristics which can be measured on delivery. As regards the credence characteristics, which cannot be measured in the raw product itself, variations in quality are not easily avoided just by making growers economically responsible (giving them "residual claimant" status). The buyer protects the value of these rights by directly monitoring the cultivation and harvesting of the crops, which also involves costs. Both grower and buyer expect contracts between them to run over many seasons, however, and there are similarly stable business relations between order-producing firms and their buyers, which implies that there are far fewer incentives for opportunistic transactions (moral hazard, adverse selection, or shirking)⁴².

Ex post transaction costs

Ex post transaction costs are costs which result from poorly adjusted trade, costs of re-negotiating contracts, and costs of enforcing rights so that both parties remain in the transaction.

These ex post transaction costs, which in my opinion are primarily due to uncertainty surrounding the completing of the transactions, affect the parties' incentives to carry out technological development. Before going on to discuss ex post transaction costs in order and grower contracts, it will be useful to explain the reason for this uncertainty, because there are different views of what causes uncertainty.

⁴⁰ By building in the possibility for complaint in this way, growers are made responsible for that part of the quality variation which they directly control. This also increases their incentive to comply with the spraying programme.

⁴¹ In his analysis of "share contracts", Barzel (1989) has identified a similar way in which the parties can avoid the excessive use of characteristics which are not specified or controlled by the parties: "The excessive use of free attributes may be controlled by exploiting the fact that the consumption of a commodity will change when the prices or quantities of related commodities change. In the case of a soil nutrient, for instance, the difficulty in measuring its use over the rental area preclude its direct pricing and turns it into a free attribute. Its use, however, may be curbed by the appropriate manipulation of substitute or complementary attributes - for example, lowering the price of a substitute" (p 35).

⁴² The discounted income stream from continued trade is often greater than the profit from acting opportunistically in a single transaction. The parties can make it even more attractive to remain in the transaction through various safeguard mechanisms (see Williamson, 1985, chpts. 7 and 8).

Barzel (1985) primarily emphasizes the uncertainty due to the costs of obtaining precise product information. There will especially be a lot of uncertainty in transactions where the value created varies unpredictably. This applies, for example, in the production of many raw products, since their quality characteristics depend on a number of growing conditions, including the weather. In these transactions, it can be costly, if not impossible, to enforce the parties' rights through the courts, since they will have difficulty partly in proving breaches of contract and partly in determining how much is needed to compensate them⁴³.

Williamson (1985) attaches more importance to the uncertainty due to the limited rationality of the contract parties and the unpredictability of the future. This uncertainty creates problems in protracted caveat vendor transactions, because it can be necessary partly to continuously determine those property rights which become valuable as the contract conditions change and partly to continuously adjust the value of already determined property rights so that they remain attractive enough for the parties to go through with the contract - even if better, alternative uses of their assets should appear. In such cases, the courts are unsuitable for enforcing rights, because only the rights specified in the contract can be enforced by this means. Contract adjustments thus require special "governance structures" which protect the parties from each other's opportunistic exploitation of the situation.

Williamson also draws attention to the problem of how the parties safeguard and enforce their rights over the specific investments which transactions sometimes require. According to Williamson (1985), in a long-term relationship, the parties often accumulate a lot of knowledge and assets which are specially adapted to that specific trade relation. For example, it is often cheaper to renew a contract than it is to negotiate a completely new one, because the knowledge and information accumulated through the interplay between the parties makes it easier for both sides to carry out negotiations and transactions. Since this knowledge is worthless outside the transactions (asset specificity), both parties will be interested in continuing the relationship in other transactions. If this is the case, the aim of contracts will not only be to carry out a transaction, but just as much to ensure the continuation of the transaction⁴⁴. Since the value of such specific assets cannot be determined by a third party (there is no market price for these assets), it is impossible to enforce the rights over them through the courts.

Since the parties themselves have an interest in continuing the relationship, it is not so much protection against breach of contract as of continuously having to adjust the relationship to unforeseen events which becomes the main focus in drawing up the contract. One of the difficulties is that, because of asset specificity, both parties are able - through their negotiating position - to affect the value which the other party's investments can generate. If, in addition,

⁴³ As Barzel (1989) points out: "When the income stream is variable and not fully predictable, it is costly to determine whether the flow is what it should have been in any particular case. Consequently it is also costly to determine whether part of the income stream has been captured by the exchanging parties. The delineation of ownership is problematic, then, when the income stream from the exchanged property is subject to random fluctuations and when both parties can gain by affecting that income stream" (p 5).

⁴⁴ It is Williamson's contention that most long-term transactions result in the accumulation of asset specificity between the parties, so that in time they begin to focus more and more on ensuring the continuation of the transaction. Williamson calls this phenomenon "the fundamental transaction".

the parties in these transactions have difficulty in determining how much value their assets can generate, it gives them a lot more strategic freedom of action. In other words, the parties can more easily appropriate the quasi-rents created by the transaction when asset specificity makes one party vulnerable to possible “hold up” attempts by the other party. The problem is, therefore, for each party to stipulate conditions in the contract in such a way as to effectively protect the one party from the opportunistic behaviour of the other. Failing this, adjustments of the transaction relationship will often merely result in costly negotiations about how to divide the economic return on the investments.

In short, there are several kinds of uncertainty, each of which creates problems in adjusting the contract and enforcing the rights. These are: 1) Uncertainty due to the fact that the income stream generated by the parties’ assets varies unpredictably. This causes problems in protecting rights, partly because it is hard for the parties to know when a breach of contract occurs and partly because they don’t know precisely how much compensation they should have to make good their loss; 2) Uncertainty due to the unpredictability of the future, which makes adjusting long-term contracts problematical; and 3) Strategic uncertainty, due to the mutual dependence of the parties which results from their investments in specific assets. This uncertainty can (when the parties act opportunistically) lead to high negotiating costs of adjusting the contract to unforeseen occurrences.

4) Costs resulting from a poor adjustment of trade in order and grower contracts (“misalignment”)

The misalignment of trading relations is due to a lack of ability to adjust the contract to unforeseen changes. A change in raw product prices, and thus also the price of property rights laid down in the contract, is one example of an unpredictable change which creates uncertainty in grower contracts. If there is a drastic change in raw product prices from the time of contracting to the time of delivery, eg due to bumper or catastrophic harvests on a nationwide scale, then the parties will want to be able to adjust the prices agreed in the contract. Thus, contracts often include a clause stipulating that the buyer must take a certain quantity of the crop at a given price (depending on the quality level) and the rest at market price (which is fixed after the harvest and delivery). However, this requires that, before the contract is signed, both parties recognize that price adjustments might have to be made later.

For longer-term contracts, it will also often be impossible to determine property rights over all present and future valuable characteristics of the products or deliveries. If the property rights aren’t completely defined in the contract, the transaction could “drift out of alignment” (Williamson, 1985). Such situations can arise, for example, if the value of different characteristics of raw and input products increase over time while the conditions of payment in the contract remain fixed. For the seller, this means that, unless he can find alternative ways of adjusting to the new situation, he will be forced to place more value in the public domain. Contracts often give the contracting parties the possibility of adjusting to the new situation by using some of the characteristics of the exchange which are not specified in the contract (ie the contracts are often incomplete). For example, if the value of specific quality characteristics

of berries increases (eg because they are disease resistant) without the sellers who can deliver these characteristics being able to get a higher price, they can choose to compensate themselves by delivering at a later time (as long as this isn't specified in the contract). The seller thus adjusts to the new situation by reducing the resources he uses to guarantee a quick delivery⁴⁵. This enables him to transfer some of the costs to the buyer, who is perhaps forced to invest in a warehouse⁴⁶.

Problems with adjusting trade can also occur in grower contracts, because the introduction of new technology can bring the problem of protecting the parties' rights over joint assets to a head, which can result in the technology not being used. The introduction of such innovations as new varieties and new growing and harvesting methods can change the value of joint assets in unpredictable ways. The following example can illustrate the problems. If a new variety of pea is developed, with quality characteristics which better match firms' requirements, then the firm will specify this variety in the contract. If this new variety later turns out to exhaust the grower's soil more quickly than the previous varieties, then the grower ought to receive compensation for growing the new variety corresponding to the extra costs imposed on him. Since it is hard to fix the size of the compensation before the new variety has been developed and tried, it is almost impossible, a priori, to stipulate in the contract how much compensation the grower should receive for letting the buyer decide which varieties to grow. It can be difficult and costly enough to fix the size of the compensation even after the harvest, eg if the factors which affect the quality of the soil vary unpredictably. In such a case, it would be impossible to determine whether changes in the soil were due to its original condition, the way it was fertilized or otherwise tended, the weather, or the crops themselves.

These difficulties with determining the size of the compensation can affect the parties' ability to adjust the relationship to new technological opportunities, since growers' willingness to try new crop varieties and new growing and harvesting methods, etc., must be presumed to depend on whether or not they can get compensation for any opportunity costs of using the new varieties and methods instead of the old. It can also be difficult for the firm to determine a compensation which prevents growers' actions affecting the value of its rights. For example, it can be difficult to specify how all the growing and handling methods which can be employed by the grower are likely to affect the quality of the raw product. It will be especially problematical if new methods appear which both give growers a higher yield and reduce the value of the crop for the firms (especially if it is hard to measure the loss of quality directly). The better the knowledge about these conditions, the easier the contracting parties will be able to protect themselves against the uncompensated use of joint assets, and the easier it will be to adjust the relationship to the use of new technology. One possible solution in the fruit and vegetable industry would be for the parties to involve a third party, namely by enlisting the help of the Danish Institute of Plant and Soil Science or The Danish Agricultural Advisory

⁴⁵ This situation could also tempt the seller to break the contract before it expires ("contrived cancellation", Williamson, 1985). If there are difficulties in adjusting contracts to new situations which were unpredictable at the time of signing, it "... raises the possibility that assurance will take forms other than bonding" (Williamson, 1985, p 176).

⁴⁶ Moreover, if the attribute (disease-free berries) which the seller's assets (fruit bushes and the means of fighting disease) can produce varies unpredictably, his possibilities for maximizing the value of his rights under the given conditions will often be greater, since it is much more difficult for the buyer to judge whether the seller is being opportunistic about trying to acquire part of the value by, for example, shirking on quality or by selecting only the poorest berries for delivery.

Centre in the testing of new varieties. These institutions could analyse the factors which affect the yield and quality of a new crop. The parties could then agree to let the results form the basis for a renegotiation of the contract.

5) Negotiating costs incurred from adjusting trading conditions to external changes

The above examples of the poor adjustment of transactions can give rise to demands for a renegotiation of the contract. To a large extent, the costs will depend on how easy it is for the parties to specify and protect the value of their property rights under the new conditions. In turn, this depends on whether the income stream which the rights over particular assets can generate varies unpredictably, since it will then be more difficult for the parties to determine the economic implications of changes in the contract.

6) Costs of ensuring that both parties remain in the transaction

Control and monitoring are not enough in themselves to ensure that the contract is observed; both parties must also be able to *enforce* their rights. According to Williamson (1985), which “governance structures” are the most effective in ensuring the transactions depends on whether they are repeated transactions and whether the parties have invested (or accumulated) assets whose value depends on whether they are used in transactions or repeated transactions with the same parties⁴⁷.

If the parties were able to establish all property rights in advance, and were also able to discount the value of these rights under different market conditions, then they would also know the consequences of a breach of contract and thus easily be able to specify a compensation which protected the parties against the uncompensated use of joint assets. In the event of disagreement over compliance with the terms of the contract, the parties can enforce their rights through the courts. Under these circumstances, however, market competition (as a governance structure) would protect the parties against opportunism, because buyers’ costs of evaluating the product’s quality characteristics and comparing the quality characteristics of alternative sellers are low. Moreover, since no transaction-specific investments have been made, the parties can find new trading partners almost without cost⁴⁸.

Often, in transactions covering limited periods and involving standard products whose characteristics don’t vary unpredictably, it is only possible to draw up contracts which approximate the complete contracts described above. These conditions are more or less

⁴⁷ Williamson points out that, in selecting “governance structures”, firms ought to consider whether the cost advantages - of minor adjustments to the transactions through integration - are cancelled out by the loss of advantages of scale and scope. He also points out that there are costs involved in setting up specially adapted “governance structures”. Mostly, therefore, it is only in the case of repeated transactions that the parties benefit from such structures, even though the transaction is characterized by a high degree of specificity.

⁴⁸ In both order and grower contracts, market competition between alternative contract parties is an important disciplining mechanism.

fulfilled in the case of order contracts, even though the products traded in order contracts cannot quite be described as standard products offered in large volumes. Order contracts are not entirely complete either, since unpredictable occurrences can necessitate adjustment of, for example, price. If the parties in order contracts try to enforce their rights through the courts, they can also run into problems with fixing a compensation which fully covers the economic losses suffered by the parties due to breach of contract. The parties know most of the factors which affect the value of the rights specified, however, so in most cases, it is possible to stipulate when compensation is justified before the contract is signed. Moreover, the parties often specify a number of conditions in the contract which limit incentives to make uncompensated use of each other's assets through shirking on quality or breach of contract⁴⁹.

Grower contracts are often characterized by a greater degree of uncertainty for the sole reason that the contract often stretches over a longer period (one season at the minimum). If, at the same time, there is also a high degree of uncertainty in the market, it will be almost impossible to draw up complete contracts for such longer-term transactions in which all (also future) relevant property rights are fixed and valued. Since only those rights specified in the contract can be enforced through the courts⁵⁰, this can pose a problem for the parties if they also want to have the possibility of enforcing property rights specified during the contract period. Grower contracts can also be more difficult to enforce in the courts than order contracts because the parties often don't know beforehand how much value their assets can create. This also makes it harder for the parties to determine when the contract has been violated and how much compensation the parties should get.

Finally, these longer-term contracts are often characterized by a certain degree of asset specificity. This is because, on signing the contract, growers commit themselves to a specific use of their land and labour. The value of this specific use of their assets depends on the contract being completed, since, on account of time and place specificity (because some raw products can't tolerate long transport times before being processed, or because the raw product only has an optimal quality for a short period), it can be difficult to sell the products to other buyers. For the same reasons, a buyer can experience difficulties in obtaining raw products from alternative suppliers. Since the parties make (to a certain degree) specific investments in the transactions, they will often have a strong incentive to make sure that the transaction is carried out with the necessary adjustments. One solution to the problem of guaranteeing the parties the possibility of enforcing their rights during contract adjustments can be for them to deal through a third party ("bilateral governance", Williamson, 1985), or they can insert a clause in the contract stipulating how it can be changed ("trilateral governance"). This gives the parties the flexibility to adjust the contract to unforeseen occurrences during the contract period while at the same time taking account of the possibility of opportunism.

Under these "governance structures", the parties' incentives to act opportunistically is discouraged by building a self-disciplining mechanism (private ordering, Williamson, 1985) into the

⁴⁹ Order-producing firms, which, for example, demand some pre-payment in order to discourage buyers from choosing trading partners unfairly, use "private ordering" (Williamson, 1985) as a supplement to the courts.

⁵⁰ Moreover, the courts only guarantee economic compensation for breach of contract on condition that the parties have specified their rights to compensation for, for example, qualities which don't match the specifications, or their right to reject a delivery whose quality doesn't live up to that specified in the contract.

contract, which, on the one hand, protects the firm against growers shirking on quality or failing to deliver the quantities specified⁵¹, and, on the other hand, protects the growers against adverse selection on the part of the firm⁵². Some contracts thus stipulate that growers must deliver all they can produce to the firm. They receive a bonus for delivering a given quantity of raw products which live up to the contract specifications. The bonus lapses unless the full quality is delivered, however. This reduces growers' incentives to deliver a higher proportion of below-average products and to find alternative buyers. Growers can protect themselves against the firm finding other suppliers by demanding part-payment when the contract is signed. In addition, growers can also discipline the firm by obliging it to take all they can produce.

In the above examples, the investments which firms and growers make often have value in other uses, since the parties can find other transaction parties in the following season. In some cases, however, innovations in the form of new varieties or cultivation methods will constitute such specific investments that their value depends on the growers who made them being able to continue delivering to the same buyer. Which of the parties gets the highest return on such investments depends not only on their ability to specify their rights, but also on their ability to ensure that the return isn't appropriated by the other party first⁵³. In such cases, the parties' negotiating position is of great importance for their incentives to invest in these types of innovations. An effective adjustment of the trading relation and protection of rights can thus require buyers to invest in those innovations which they want growers to use. The rights over the innovation are then divided between the parties in a quasi-integration.

Summary

Order and grower contracts are used to organize transactions involving raw and input products where the firm has specific requirements concerning the product's characteristics. The seller is made economically responsible for variations in the quality characteristics, which can be measured directly in the product on arrival at the firm by means of differentiated payments, bonuses, or by the buyer retaining the right of complaint. In those cases where the quality characteristics of the raw product are difficult to measure and sort by on arrival at the firm, cultivation and handling methods are often specified in the contract. The buyer protects his rights in these cases by monitoring production.

⁵¹ The price for specific quality characteristics of the raw product agreed to in the contract reflects expectations of an average value and spread of quality within the specified quality grades. But by selecting a higher proportion of products with below-average quality, growers can get a higher price for the delivery than the actual mean value and spread of quality warrants.

⁵² The same principle is used in order contracts, since the order-producing firm also has an interest in protecting itself against buyers' unfair selection of trading partners.

⁵³ The firm can appropriate quasi-rent from the grower's investment corresponding to the return the grower could have obtained by offering the products to another buyer. If such a buyer doesn't exist, then the appropriable rent will depend on the investment's scrap value (Monteverde & Teece, 1982). Teece and Monteverde argue that quasi-integration (the firm buys the asset and rents it to the supplier) is more likely when the appropriable rents are high than when they are low - though with the reservation (which they mention themselves) that there are also costs connected with specifying and protecting rights over the products which the assets in a quasi-integration can produce. What they don't mention, however, is that there are also costs involved in protecting the value of this asset, because those who rent the asset - to use it to produce the products - are also those who are in the best position to maintain it, and therefore ensure its value as an investment.

As can be seen from the above, differentiated payment is chiefly used to make the seller economically responsible for variations in such easy-to-measure search characteristics as size, shape and colour. The size and shape of the raw product affects both the quality of the final product and the effective utilization of the raw product in production. Colour is another search characteristic which is frequently mentioned. Like size, colour can also be measured, and, since the introduction of optical sorting, it has become much simpler to sort the raw products by colour. Colour is important for the appearance of the final product, and is also often used as a proxy measure for the raw or final product's taste.

Even though taste is difficult to measure at present, it is often mentioned as a quality attribute of the final product. There is no general definition of good or bad taste in the industry, however. Each firm has its own criteria, which they try to fulfil by, for example, specifying production methods and raw product quality characteristics. The taste of the final product depends on the taste of the raw product, but to date nobody has developed a method for measuring the taste characteristics of the raw product. The shape and size of the raw product are often used as proxy measures of its taste and consistency. There doesn't have to be a precise relation between taste and, for example, the size and colour of the raw product, however. This ought to provide an incentive to develop other methods for measuring the taste of the raw products more precisely.

Which party has an incentive to invest in the various technological opportunities depends to a large extent on how the property rights are divided between the parties. In order contracts, the order-producing firm is made responsible for all variations in the quality characteristics specified in the contract, so it is presumably also these firms which have an incentive to develop production methods which ensure a certain uniform standard. The firm protects its rights by controlling the raw product quality, and should therefore have an incentive to develop quick and precise control methods.

In grower contracts, the parties share the property rights over the grower's land and labour. Growers are made economically responsible for variations in those search (and partly also experience) characteristics of the raw products which are due to their efforts, while the firm is made economically responsible for those variations in yield and quality which are due solely to the fact that growers follow the contractual specifications regarding cultivation, harvesting and handling.

In these contracts, firms protect their rights both by controlling the quality of the raw product and through direct monitoring of the growers. Indirect monitoring and control includes the compilation and control of fertilization and spraying manuals and offers to provide the seeds, seed potatoes and fertilizers, plus specify cultivation and harvesting methods. Apart from this, the large majority of firms separate different growers' raw products both in storage and throughout the entire production process (this is made possible by the widespread use of batch production). Finally, each single product is given a number, which enables it to be traced even after being sold to the final consumer. The separation of different growers' deliveries and the traceability of individual products throughout the production process gives firms an additional means of control and enables them to make growers responsible for variations in quality.

This division of rights implies that firms should primarily have an incentive to develop sorting and measuring methods for the control of the raw product's quality characteristics⁵⁴. Growers should have incentives to develop high-yielding varieties, together with more gentle and labour-saving harvesting methods. Very little research is being done into new fruit and vegetable varieties, however. Some work is being done on cabbages, carrots, cucumbers and leeks. In Scandinavia, only Balsgaard in Sweden are researching into new varieties of apple. The Aarslev research centre (a department of the Danish Institute of Plant and Soil Science) tests foreign apple varieties under Danish conditions. In addition, a varieties committee has been set up with representatives from research firms, the trade, consultants, and one grower representative (GASA, Odense, and FDB are often represented). Varieties committees have also been set up for blackcurrants and redcurrants (with most varieties coming from Scotland, England, Norway and Sweden).

As previously mentioned, growers in grower contracts are compensated for using varieties and cultivation and harvesting methods which are more costly. This might well give firms an incentive to develop new varieties and harvesting methods which reduce growers' costs of producing the desired qualities. This would not only reduce the firms' raw product costs, but also their costs of controlling the growers (who would have fewer incentives to deviate from the specifications in the contract). None of the firms interviewed carried out actual research into new varieties themselves - though one did make some effort toward incremental improvement, through the selection of seed potatoes from the year's crop. The development of new varieties is often extremely time-consuming and costly, and is mostly undertaken by international firms. The Danish Agricultural Advisory Centre and the Association of Danish Fruitgrowers also contribute with the testing of varieties.

Development costs are paid by the grower or firm when the new varieties are put into production. The development of harvesting methods is mostly carried out by harvesting machine manufacturers, and is aimed primarily at mechanized picking (as regards berries and fruit). One firm had developed a leek harvester itself, however, with facilities for cleaning the leeks in situ so that bacteria and waste from the harvest are not transported into the firm. The handling of onions is being improved through collaboration between growers, firms, and the Aarslev research centre, where studies are carried out on how the quality of the raw product depends on the time of harvest, geographical location of onion growers, and storage.

As can be seen from the above, the fruit and vegetable industry uses a lot of resources in preventing variations in raw products' quality characteristics.

The above analysis points to two areas where technological development can reduce transaction costs. Firstly, the development of better or cheaper methods of measuring experience characteristics in the products themselves. Failing this, efforts to reduce the costs of protecting the economic value of those property rights divided between grower and buyer. In this connection, it can often be of great importance for both growers and firms to know which conditions affect crop yields and quality during cultivation and production. Much of the knowledge concerning this can be found today at the Danish Institute of Plant and Soil Science.

⁵⁴ To be precise, firms were looking for such technological solutions as: quick methods for ascertaining products' taste, potatoes' frying characteristics, bruising and other blemishes in the raw products, raw products' microbiology, fertilizer and spray residuals.

11. The broad view: Technological solutions which reduce costs by producing final products of a given level and variation of quality characteristics

The transaction cost analysis of the relations between buyer and seller points to technological opportunities aimed both at reducing the costs of producing a product with a given level of search, experience and credence characteristics and avoiding variations in quality over time. The level of quality of the final product depends on the raw products and production methods used. Any fluctuation in quality from one delivery to the next is thus due partly to fluctuations in the quality of the raw product and partly to problems with controlling all the variables in the production process which affect product quality.

In principle, there appear to be four ways in which the firm can reduce the costs of producing a given quality with a given deviation.

1) Identical raw products

Firms can often reduce costs by having the raw product graded by size to match the processing technology used, thereby minimizing waste. For growers, however, grading can result in the rejection of products which don't live up to standard. Clearly, if new varieties with less variation in size can be developed through breeding, both the need for and the costs of grading will decline, and both grower and firm will avoid rejection of the raw product.

2) Differential payment for the raw product

Spot checks of the raw product is the most common way in which the firm guards against variations in quality. Besides this, a lot of firms in contractual cultivation also control cultivation and harvesting. (The development of cheap and better measures of quality characteristics will reduce firms' costs of control. Providing means of measure more quality characteristics will also reduce costs, because the grower can be made economically responsible for a higher proportion of quality variations.) At the same time, the grower will have an incentive to develop and improve both crop varieties and cultivation, harvesting and handling methods which make for uniformity in the desired qualities. In some cases, however, knowledge of the relation between the characteristics of the raw product and the quality of the final product is insufficient to guard the firm against fluctuations, eg discolouration of crisp-fried chopped onions, where the quality of the onion only becomes apparent during frying. Since the relation between discolouration and storage conditions is not known, the firm cannot limit the variation by specifying the conditions under which the onions are stored. Jam makers also have problems in ensuring the same consistency of the jam from one shipment to the next.

3) Better utilization of the raw product in production

Better utilization of the raw product is another way in which costs can be reduced. The introduction of new peeling methods which remove less of the raw product, enzymatic

treatment of berries before pressing, and the introduction of a hydrocutter which rotates the potatoes before cutting, are some of the methods which are used to increase the yield of the raw product. Other methods include improvements of production machines and the more effective organization of production.

4) Ensuring the smooth running of the production process

Variations in quality can also occur as a result of breakdowns in the production process. Computer monitoring, identification and monitoring of critical areas, and the testing of machine reliability are some of the ways in which the firm tries to reduce production failures.

12. Development of the final product's quality characteristics

The set of technological opportunities outlined up to now consist of incremental technological improvements which minimize the production and transaction costs of products with a given level of search, experience and credence characteristics. There is also a set of technological opportunities related to the actual development of products' search, experience and credence characteristics, however. The development of a product's quality often makes other demands on the raw products and production processes. This in itself leads to such technological problems as: how to produce a better raw product quality; how can the firm make sure that the raw product has the desired quality; and how to develop gentler production methods, etc.

Incentives for this kind of product development come from competition between firms and in part also from retailers' requirements. The set of technological opportunities related to the development of a product's quality characteristics must be expected to be influenced by the costs of transacting, however, and thus of existing standards for specifying and communicating quality characteristics.

The next section discusses the relation between standards which express the characteristics of products or deliveries and the development of the product's quality characteristics.

Standards and the development of a product's quality characteristics

Inspired by David (1987), the term "standards" is used here in the sense of a code which contains certain information about a product or products. This section discusses how the development of standards can affect firms' economic incentives to develop products' natural search and experience characteristics, as well as develop new credence characteristics.

In order to understand the possible influence which standards have on the development of a product's search, experience and credence characteristics, it is first necessary to examine their origin, the economic rationale behind their continued existence in the market, and the externalities associated with the spread of these standards throughout the industry. First of all, however, a brief explanation of terminology.

Standards can be classified into technical and behavioural standards, according to whether they refer to an object's characteristics or human behaviour (David, 1987). Technical standards often consist of well-known ordinal measurements, such as kg (lbs), mm (ins), specific gravity, etc., or threshold values which state a minimum or maximum value, while behavioural standards consist of codes for specific routines or skills. Examples of the latter are professional titles such as civil engineer, food technician, etc., while Integrated Production (IP) of fruit and vegetables or ISO standards are examples of the former behavioural standards. IP refers to the production of raw products with particular characteristics, while ISO standards are used in the production of goods (and services) with a given limited variation in selected quality characteristics⁵⁵. Those parts of production covered by the standard are identified by means of various codes, eg ISO 9001, ISO 9002, etc.⁵⁶ The standards are thus codes which contain information about a number of specifications, and which thus make it easier and less costly for the firm to communicate particular quality characteristics, because both parties in the transaction know what the standard covers.

From the point of view of general economic theory, therefore, standards are something which contributes to the reduction of information cost, and thus also transaction costs. As mentioned in chapter 6, information costs also include the costs of obtaining precise product information about variations in a product's or delivery's search, experience and credence characteristics. Therefore I suggest that standards which contain information about a product's or delivery's quality characteristics are classified according to whether the information they contain helps reduce the transaction costs of⁵⁷:

⁵⁵ Integrated Production and ISO standards consist of a number of specifications which are determined by means of both technical and behavioural standards.

⁵⁶ Several of the firms interviewed were in the process of becoming ISO certified. Many of them asserted that they chose ISO certification as a means of streamlining production and quality control. Actual certification was often only of secondary importance.

⁵⁷ My classification differs from that of David (1987) in that I have chosen the various underlying causes of information costs as my other criterion for the classification, while David has chosen to classify the standards on the basis of their ability to minimize transaction costs (which, however, are relatively unspecified) and create the basis for advantages of scale in disintegrated production systems. David's classification is as follows:

	Standards for technical design	Standards for behavioural performance
References	Weight, currency, units of measurement, dimensions of materials	Exam certificates, licences to practice, legal precedents
Threshold values	Safety levels, product quality	Laws, qualifications, certificates of skills
Interface agreement	Physical design of interface codes, signals	Trade norms, types of contracts

A number of the above standards for behavioural performance are described as institutions in parts of the new institutional literature (see, for example, North, 1990). Exam certificates and certificates of skills are more a form of market signal (Spence, 1973) which signal certain standards for behavioural performance.

The standards used here can also create the basis for economies of scale, since they function as a kind of coordinating mechanism between different parts of the transformation process. Some of the standards, eg standards for microbiology in vegetables, which ensure that they can be used in pre-cooked meals together with meat, and standard shapes of vegetables, which ensure a certain uniformity of size in mixed vegetables, make it easier to exploit advantages of scale in production.

- 1) Evaluating and ensuring a product's search, experience and credence characteristics;
- 2) Evaluating the distribution of a seller's search, experience and credence characteristics;
and
- 3) Comparing different sellers' offerings of search, experience and credence characteristics.

In the following, the term *quality standards* is used to describe standards which indicate the level of a product's search, experience and credence characteristics. Quality standards contribute primarily to reduce the information costs of communicating and obtaining knowledge about *the level of a product's quality characteristics*. Where possible, quality standards will be indicated by means of technical standards rather than behavioural standards, since the latter are often ambiguous (David, 1987). This is due to the fact that the specifications which they contain can often be interpreted differently by different firms. This ambiguity implies that the information value of the standard is reduced. If it is technically possible, peas will be classified into colour categories using special measure for colour intensity, rather than by specifying varieties, cultivation conditions, production methods, and other conditions which influence the colour. The ambiguity of behavioural standards can provide an incentive to develop more precise measurement methods, including methods to measure the characteristics directly in the product. It is not always possible to replace behavioural standards with technical standards, however.

Product standards is the term used to describe the conditions a product must fulfil before it can be classified into a particular category of products. One example is "real juice", which is a description that can only be used when the product contains pure fruit or vegetable juice. Another example is the set of criteria on which the recognition of a fruit or vegetable as a separate variety is based. From an information cost point of view, product standards have two functions. They 1) contribute to *reducing consumers' costs of comparing different sellers' offerings of desired quality characteristics* (consumers can just compare products with the same description), and 2) contribute to *reducing a buyer's costs of evaluating a seller's distribution of quality characteristics over time*. Sometimes it is relatively easy for buyers to decide whether a product belongs to one product category or another, eg it is easy to tell the difference between peas and other vegetables. It can be difficult for consumers to tell the difference between "real juice" and other juice, or between different kinds of carrots, however. In the former case, product standards are hardly likely to contribute much to a reduction in transaction costs.

Product standards should not be confused with registered titles of specific product classes within a product category, however, the main aim of which is to secure title owners an extra economic return (scarcity rent). One example of this is French wine, where the use of "titles" such as Bourgogne or Bordeaux is reserved for wine growers within a strictly defined geographical area. The possibility that such titles can have a transaction cost function cannot be ruled out, however, since the "title's value" depends on the producers who use it not cheating on quality.

The term *quality class* is used in the classification of raw or final products into groups of similar search, experience and credence characteristics. Within each product category,

individual products often vary in a lot of their search, experience and credence characteristics. In principle, each measurable characteristic could result in a separate quality class. In practice, however, there seems to be a hierarchy of relatively few defining characteristics for sorting products into groups which are common for all producers. In jam production, for example, the percentage of berries is the prime criterion for classifying jam into high and low quality. Berry quality is of secondary importance here. Like product standards, quality classes contribute to a *reduction in transaction costs, since they make it easier for buyers to compare different sellers' products.*

Finally, the term *production standard* is used here to describe the different kinds of quality control systems which guarantee uniform production. Production standards (eg ISO standards) contribute to a *reduction of the information costs of obtaining knowledge about the distribution of quality characteristics of an individual seller,* since they reduce the need to control whether the distribution of quality characteristics in the seller's products has changed over time.

All the above transaction-cost-reducing standards can be stated by means of technical or behavioural standards. Sometimes, behavioural standards which specify cultivation methods or production routines are used as an indirect description of the "value" of particular quality characteristics, while other times the value is determined by means of technical standards which set either an ordinal value (eg the size of a pea) or a threshold value (eg limits for product microbiology) for the quality attribute. This makes four ways in all of stating transaction cost standards. As illustrated in the model below, the way in which the standard is established will often depend on both the standard in question and the quality characteristics to be determined.

The following section discusses the importance of quality standards, product standards, and quality classes respectively for the guiding of product development. The role of production standards in product development is also briefly discussed. But we begin with a short history of the development of standards.

The development of standards

The spread of identical quality standards throughout an industry is often an initial prerequisite for establishing both product standards and quality classes, because these are typically defined by means of quality standards. Experience, and scientific and technical knowledge play an important role, especially in the development of the various quality standards which are based on technical standards, while various organizations seem to play an important role in the development and spread of quality standards based on behavioural standards.

Organizations also appear to play a big part in the spread of more complex product standards, production standards, and quality classes⁵⁸. For example, ISO standards are formulated by the

⁵⁸ The quality classes established by trade and other organizations are often based on current sorting methods in the industry. These methods, which are a result of the interplay between buyers and sellers, are wholly or partly independent of these organizations' influence. The spread of such "spontaneous" quality classes throughout the industry must initially be attributed to "system scale economies" in connection with the reduction of transaction costs.

Figure 3. Measures for quality characteristics

TRANSACTION-COST-MINIMIZING STANDARDS	TECHNICAL STANDARDS	BEHAVIOURAL STANDARDS
Measured in:	the product	the process
<p>ORDINAL (reference standards)</p> <p>Quality standards (reduce costs by evaluating and ensuring a product's quality characteristics)</p> <p>Production standards (reduce the costs of evaluating the distribution of quality characteristics of a single seller over time)</p>	<p>Search and experience characteristics, eg the size (in mm) of ingredients in a packet of mixed vegetables and the colour of juice in FNU.</p>	<p>Experience characteristics specified by means of a production concept; IP standards for the credibility characteristics "environmentally cultivated" specified by means of a set of routines; and technical standards for the use of, eg crop sprays.</p> <p>Eg, ISO standards, given by a number of specifications of routines which must be met</p>
<p>THRESHOLD VALUES (standards for the min level of characteristics which can be accepted)</p> <p>Quality standard</p> <p>Quality classes (reduce costs by comparing different sellers' products)</p> <p>Product standards (reduce costs by comparing different sellers' products)</p>	<p>Undesirable experience characteristics, eg max. allowed level of bacteria, pesticide residues, etc specified by means of particular measures.</p> <p>Credibility characteristics eg minimum perishability in days.</p> <p>The level of search and experience characteristics constitute the criteria for classifying peas and jam into different quality classes</p> <p>Real juice, specified by threshold values for the content of juice from fruits and berries.</p>	

International Standards Organization, while the concept of Integrated Production has been developed by researchers from the Aarslev research centre and the Royal Veterinary and Agricultural University in collaboration with The Department of Plant Production and The Danish Association of Fruitgrowers. Initially, IP was aimed solely at the market for fresh fruit and vegetables, but has since also been introduced for products grown for the food processing industry.

The establishment and diffusion of general quality classes for fresh fruit and vegetables is dominated by national and international organizations. Standards are drawn up by both the Danish food inspection agency and by EU and OECD agencies. International quality classes for fruit and vegetables have been in existence for more than 40 years. The first international standards were developed by UNECE (UN Economic Commission for Europe) and the OECD. Common EU norms have been established ever since the start of the Common Market in 1962. These norms are used in all stages of distribution, ie from production to sale (Frugt og Bær, 1/93). Within the EU, 34 of the most important fruits and vegetables are subject to EU quality standards. The EU requires that the country of origin, quality, and variation (within the given quality classes) of fruit and vegetables is clearly marked either on the packaging or on show cards. Fresh fruit and vegetables are classified into 4 quality classes, eg extra class 1 and class 2. Extra class 1 products are of an excellent and specially selected quality, while class 2 products are of good quality without any serious defects. Class 2 products often have one or two defects in the form of size, shape, colour, or spots (EIU 402).

For a number of intermediate products, eg berries for stewed fruit, jam, and squash and squash concentrates, which are purchased in bulk, there are no quality classes in the proper sense of the word. However, there is general agreement in these caveat vendor transactions as to which characteristics are specified and which quality standards are used in the specification. In the production of fruit juice, for example, bulk products are sold in three quality classes - single-strength juice, concentrated juice, and pulp or purée - depending on the customer's specifications. Within each category, concentrates are traded on the basis of the specifications of a number of selected quality characteristics, of which some of the most important are: the degree of concentration (measured by brix) and preservation (defined as frozen or bottled under sterile conditions). As regards fruit juice, the traditional specifications also include colour and clarity⁵⁹.

Common to the above standards is that, as previously mentioned, they can function as a means of specifying and communicating valued characteristics of the product or deliveries. However, the reduction in transaction costs which can be achieved by using standards as a basis for specifying characteristics and classifying products or deliveries depends on whether buyers can trust firms not to cheat.

Sellers can cheat on quality by disclosing wrong levels of quality characteristics, eg by specifying wrong sizes of ingredients in a vegetable mix. If buyers have the possibility of measuring the quality characteristics themselves, then cheating by sellers doesn't result in

⁵⁹ The level of the individual parameters is partly determined by the production plant of juice-bottling companies and partly by the quality standards (as regards taste, colour, and clarity) which individual firms set for their products.

mistrust of the standard as such. However, measurement uncertainty can be one of the sources of uncertainty about whether standards are being abused or not.

If a seller discloses wrong product standards, production standards, or quality classes, buyers might become generally suspicious about their information value. These problems of trust must be presumed to be greatest when the standard includes characteristics which the buyer has difficulty in controlling himself. One example of this is in the juice industry, where The International Juice Organization has developed a number of common European product standards. These standards distinguish between juice, nectar and fruit on the basis of specifications of the fruit juice and pulp content. The small profits involved in juice production, however, have tempted some producers to cheat by adding citric acid and other cheap ingredients to products which they still sell under the name of juice. This has led a number of firms in the Danish juice industry to jointly develop methods of measuring juice quality (especially its purity). The quality of the juice is to be further guaranteed through the development of a control programme based on sampling juice products in shops and unannounced visits to firms. The programme is financed by the firms themselves.

Another example of standards supported by voluntary control are ISO standards. Here, certification by a government-approved certification institute is a guarantee that a seller's products don't vary too much from the level of quality chosen as the basis for certification. This partly preserves trust in the standard and partly prevents some producers obtaining an unfair share of the value which the standard represents in a transaction cost context (free-riders).

The important point, however, is that when a standard is accepted and spread as a credible and well-known way of specifying and communicating a particular quality attribute, transaction costs are reduced. The following sections discuss the influence of quality standards, product standards and quality classes on economic incentives for product development. Production standards are only very briefly discussed, since they must be presumed to have only a limited effect on product development.

Quality standards and product development

The development of technical or behavioural standards which can function as a reference for quality characteristics play an important role in the type of product characteristics that can be specified, and thus ensured, in a transaction, while improvements and the further development of measurement techniques have an important effect on the costs of specifying the characteristics. Thus both the seller's ability to specify characteristics and the costs of doing so affect transaction costs, since they largely determine how much of the value the seller decides to place in the public domain, and thus in part also how many resources the buyer uses to obtain that value⁶⁰. The development of measures for search and experience characteristics⁶¹, for

⁶⁰ Buyers' preferences for the characteristics also play an important part in determining how many resources they use in acquiring the value, however.

⁶¹ Not all experience characteristics can be measured objectively, however. For example, good or bad taste can't be measured objectively, even though the individual taste components can.

example, means that the seller is better able to protect the value of his rights over characteristics of the product because it will be easier for him to grade the product into more homogeneous groups. Thus the development of quality standards for product characteristics also gives the seller more incentives to develop these characteristics.

If both buyer and seller use the same technical standards as units of reference, it also reduces the volume of asymmetrical information, since it creates the basis for a control of the deliveries. This also means that it is easier for the buyer to protect his rights in the transaction.

The economic benefit of using a particular quality standard depends in part on how widely it is used in the industry. If it is widely used, then buyers can more easily compare the prices and quality characteristics of different sellers, which is also an advantage for sellers of high-quality products. This can be illustrated by the production of jam, where the proportion of berries is an important quality attribute. If, for example, Danish and American producers declare the weight of the berries in different units of weight, it will be harder for consumers to compare quality vis-à-vis price than if they had used the same units. This makes it easier for sellers of lower-quality jam to get consumers to buy their products, even though their price is high compared with the quality.

Finally, quality standards and reliable measurement methods (with a small level of uncertainty) make it easier to enforce the rights specified in contract or product guarantees. This applies both to the quality standards set by technical standards and those determined by behavioural standards. In the latter case, the determination and diffusion of a standard makes it easier for the parties to evaluate a documentation of the routines laid down in that standard.

Since quality standards have such a great influence on information and transaction costs, it is reasonable to suppose that the development of new standards also has an influence on which product characteristics are developed, since the return on the investment depends on these costs. Since the development of the quality characteristics of the final product often depends on the development of the raw product's quality characteristics, quality standards and measurement methods for the latter's quality characteristics will also influence the costs of developing the quality characteristics of the final product. For example, it will be much more costly to improve the quality characteristics of the final product if this means a lot of new demands on the raw product which are not included in existing quality standards. The opposite is also true, since new quality standards for the raw product can make it easier to develop new characteristics in the final product. One example of this could be the spread of IP standards among growers. The formulation of standards and control routines in connection with IP is one of the ways in which growers can document the credence characteristic "environmentally friendly", since one of the aims of IP cultivation is to reduce the use of fertilizers and pesticides, eg by developing alternative control methods. Under IP, everything about the crop is recorded, from before planting to final consumption - even storage conditions are controlled, because IP crops must not be mixed with other crops. If IP evolves into a credible standard, it reduces firms' needs to monitor and control the growing conditions of the raw products. Finally, it should be mentioned that the most widely spread quality standards also influence the technological development of the measuring equipment.

Product standards and product development

Product standards have a lot of influence on the firm's development of new product lines, since the criteria on which the standards are based constitute the minimum threshold values for product categories which must be met before a product can be sold as a particular category of product.

From an economic and marketing point of view, product standards function mainly as a means of reducing buyers' costs of comparing different sellers' - or one seller's - distribution of quality characteristics over time. The lack of product standards thus influences competition within an industry, and can therefore result in a poorly functioning market for products with particular experience and credence characteristics.

An imaginary example from the market for squash can help illustrate this. Imagine that there are several kinds of squash on the market: one which contains 100% pure fruit juice, one where the fruit juice is mixed with citric acid, and one where the fruit taste is synthetically produced. All these different products are sold as squash. Buyers prefer a squash with the highest possible fruit content (which in this case is an experience characteristic). Without the existence of product standards which specify the proportion of fruit juice in squash, however, "squash" is not a registered title, and the total offering of squash will include both squash with 100% fruit juice, squash mixed with citric acid, and squash with a synthetic taste. Buyers would then not know in advance which kind of product they were buying. Gradually, however, they would develop a feeling for the likelihood of getting a squash with citric acid or synthetic taste. Since their demand depends on their expectations of quality, the price will gradually fall, and since at the same time the supply of real juice must be presumed to depend on the price, this will also fall. After a certain period of time, therefore, buyers will adjust their expectations of quality downwards, and so on. The end result of this chain reaction can be that all production of real juice ceases, even though there is a demand for it (Akelof, 1970). If it is so difficult for consumers to tell the difference between the various product categories, it can be necessary to introduce product standards to protect them. The absence of product standards can, in turn, affect producers' incentives to develop new product lines, because product standards can - as in the above example - form the basis for communicating and guaranteeing a product's experience or credence characteristics⁶².

In the above example, a declaration of contents of the various squashes, combined with a producer's brand as a signal of credibility, could also reduce the problem of asymmetrical information. It would still be very costly for buyers to compare different sellers' quality and distribution of many product characteristics, however. This is because the basis for comparison is much larger and much more varied than if there had been three different product categories. The more costly it is for buyers to compare different sellers' quality vis-à-vis price, the easier buyers are persuaded to pay a higher price than the product's quality characteristics warrants. The market might even be distorted in favour of those producers who mixed in citric acid. Without registered titles, therefore, it can be difficult for producers to

⁶² The example presupposes that none of the producers had well-established brands with which they could signal their "honesty" regarding the fruit juice content.

protect the value of the characteristic “real juice”, which explains why economic incentives to develop real juice products are relatively limited.

Product standards influence competition in the sense that they narrow the range of products which the buyer regards as a relevant basis for comparing the relationship between price and quality. In the above example, if a product standard for real juice emerged, then the various suppliers of juice would compete among themselves on search, experience, and credence characteristics, while juice producers as a group would compete with producers of various squash drinks. This is because the setting of standards for juice reduces buyers’ costs of comparing sellers’ products within a given product category, which at the same time increases price competition within this category, whereas competition between different product categories will, to a greater extent, develop into a struggle to persuade consumers to substitute one type of product for another.

Product standards can also influence the economic incentives to carry out product development, since appropriation possibilities in the form of patent rights can depend on whether product development takes account of the way in which a product’s defining standards are determined. An example of this can be found in the production of new plant varieties, since, by law, a new variety of garden plant can only be defined as a variety if it can be proved to have stable, consistent, and separate phenotypical characteristics. This means that, if the development of a plant’s functional characteristics (eg resistance to disease) doesn’t have a direct influence on the phenotypical characteristics which define the variety, it can’t be patented as a new variety. In this case, the standard which defines a variety limits incentives to improve the plant through breeding.

Quality classes and product development

In the fruit and vegetable industry, quality classes are established at two points in the transformation process, namely in the contract between grower and firm and between the firm and the buyers of its products. The industry’s established quality classes appear to play an important role in how the firms define product quality. In jam production, for example, the proportion of berries and the berries’ quality (their colour, and whether they are whole or not) are considered to be the most important criteria distinguishing high-quality from low-quality jam. The quality of crisp-fried chopped onions is evaluated on the basis of colour, oil content, whether there are any charred bits of onion or peel, plus the proportion of fatty acids⁶³.

Product standards can be necessary if the classification of products into quality classes is to reduce variations in quality characteristics, and thus also transaction costs. This is because, in the absence of product standards, it can be too easy to cheat on quality in a given quality class. One example of this - which, however, is from outside the fruit and vegetable industry - is the quality differentiation of English steak. Since there are no product standards for which cuts of meat can be called English steak, it is impossible to achieve any kind of credibility for

⁶³ This agrees with David’s (1987) arguments that technological standards have a big influence on the development and diffusion of new technological solutions and new types of products.

a classification of English steak into a first or second class on the basis of the quality characteristics (eg colour and tenderness) of the meat alone. An increased demand for English steak would merely result in them being taken from different cuts of meat, which in turn will increase the variations in all the quality characteristics not directly specified in the quality class.

For products which have well-defined product standards, the ability of quality classes to reduce transaction costs appreciably depends on the number of sellers who classify their products after the same criteria. The more sellers who use the same quality classes, the fewer resources buyers have to use to compare different sellers' offerings. And the fewer the resources buyers use, the bigger sellers' advantage in sorting into quality classes. Such "system scale economies"⁶⁴ (David, 1987) can help in spreading specific norms for classifying products with different levels of quality characteristics into quality classes. At the same time, however, system scale economies lead to a certain reluctance to change the criteria by which quality classes are defined. It is especially thanks to this "inertia" that well-established quality classes and associated quality standards for trade are able to nudge product development in particular directions, since there will be far fewer transaction costs involved in selling products which have been developed according to the specifications laid down in the most widely-used quality classes⁶⁵.

If, for example, size is the prime criterion for dividing peas into quality classes and colour the secondary, then sellers will have a greater incentive to develop pea size rather than colour (assuming that buyers attribute all quality characteristics the same value). A seller who has developed peas with, on average, a better colour, but whose size places them in the class of medium-sized peas, must sell them as medium-sized peas. Buyers will compare his peas with other peas in the quality class "medium-sized". Within this class, he will have a quality advantage (the colour) which should fetch him a higher price for his peas. The price he can get won't reflect the full value of the improved colour, however. This is due to the fact that it is more costly for buyers to evaluate the value of the peas' colour compared with that of competitors' peas. If, instead, he had developed a production method which guaranteed him a pea size which matched that of class 1 peas, then he would have realized a much larger part of the value of this effort, since buyers' costs are much lower for transactions involving this characteristic.

Alternatively, he could have chosen to protect the value of the "colour" of peas by grading after this characteristic. If a seller tries to grade his peas differently, so that colour, not size, is the main criterion, then buyers will use more resources in trying to find out whether the sel-

⁶⁴ "System scale economies" is the term David (1987) uses to describe the situation in which, for example, users of a particular type of car phone get more benefit from their phone the more subscribers they can use it to get in touch with - which in turn depends on other subscribers using the same type of phone. Similarly, if only a few sellers grade their peas by size, buyers get much less out of it, because they will still incur costs of comparing graded peas with non-graded peas. If all sellers graded peas using size as the main criterion, however, buyers' costs would be much less.

⁶⁵ This argument is supported by, among others, Barzel (1985): "...production itself is affected by the cost of transacting in at least two major ways. First, of two close substitutes, the one whose production cost is lower will not necessarily be the one produced, since the cost of transacting it may exceed that of transacting the other by an even larger amount, and the other will then be produced. For instance, it is possible that the varieties of fruits and vegetables offered in the market are not those least costly to produce relative to their valuation" (p 12).

ler's quality matches what they could get for the same price from other sellers. It thus seems reasonable to assume that the very hierarchical organization of quality classes can influence the *priority* sellers give to the development of different quality characteristics of the final product.

The development of quality classes

Since quality classes appear to influence the priority producers give to product development efforts, it could be interesting to examine the possibilities for changes in the hierarchy. The question is, which characteristics are the development of quality classes based on, and which factors could conceivably change them. On the face of it, it would seem reasonable to assume that those product characteristics which vary a lot in quality level from product to product, and which at the same time are valued most by the majority of buyers, will underlie the hierarchical organization in classes. This is supported by the presumption that maximizing buyers will use a lot of resources in comparing sellers' products for the quality characteristics they value the most. Reducing the variation of precisely these characteristics in a seller's product range "saves" most resources in the transaction.

Precisely which characteristics will be in demand is often historically determined, however. When buyers come across a new product in the frozen food counter, for example, they are not likely to be able to make snap judgements on its price and quality compared with competing products. An important factor of demand is the development of buyers' concept of the product. Take peas, for example. The first time buyers come across frozen peas, they will try to evaluate them by placing them in the category "green vegetables". This doesn't give much indication of buyers' preferences for different qualities of peas, however. After buying them a few times, some buyers might develop the idea that colour is crucial to the taste. Other consumers make the same discovery. Gradually, buyers discover that peas of different size require different boiling times to get an optimal taste, or they develop a special liking for small peas in some meals and large peas in others. In time, variations in pea colour and size become parameters after which they sort packets of peas or choose between different sellers' products. Only after a longer learning period will they develop an actual concept of the product which will enable them fairly quickly (and at less cost) to evaluate the product's quality (Clark, 1985). It is possible, therefore, that demand, and with it the value of different quality characteristics, changes over time as consumers gradually develop their concept of the product.

Variability and demand aren't the only factors of importance for the economic benefit of sorting, however; sellers' costs of grading the peas after specific criteria are also important. Such costs depend in part on the development of quality standards and measurement methods for the characteristics.

These arguments lead to the hypothesis that the quality characteristics which form the basis for the hierarchical organization of quality classes are primarily:

- 1) the valued search (and possibly experience) characteristics which are easy and cheap for sellers to sort by, and

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- 2) which at the same time are difficult for buyers to evaluate, because they vary widely from one unit to the next.

The sources of change in quality classes should thus be found partly in changes in buyers' preferences and partly in the development of better and cheaper measurement and sorting methods⁶⁶. It is reasonable to assume, however, that there is some difference in the way in which quality classes are changed for raw products and final products respectively, because firms' demand for particular quality characteristics in raw or input products is to a large extent also determined by production considerations. The diffusion of a new production technology can thus also be a source of change in a standard's specifications.

Quality classes and standards' specifications seem to be quite stable, however. New product characteristics, eg credence characteristics, are often just added to the hierarchies. There are good arguments for such stability, since it would be costly for buyers to have to get to know new quality classes. The more often the criteria for class 1 peas are changed, the more resources buyers have to use, both in evaluating the individual seller's products and in comparing different sellers' products. Furthermore, it will take time for a new standard for sorting to spread to all firms. It will thus also take time for the same "system scale economic" benefits to emerge under the new standard as under the old standard.

While it may be difficult to change the order of priority of quality characteristics in quality classes without incurring new transaction costs, the characteristics themselves are not totally unchangeable. Stricter criteria for first or second class quality can be introduced without this incurring significantly greater transaction costs. Such stricter criteria for sorting within fixed quality classes (standard variation) must be presumed to stem from competition, which forces firms to differentiate on quality by making tougher demands on the minimum level and maximum variation of quality. In time, these tougher firm-specific demands on the raw product can spread to other firms, and thereby end up as a change in the standard.

Production standards and product development

First and foremost, production standards make it easy for buyers to evaluate the relation between price and the distribution of quality of a single producer over time, because they guarantee a certain level of and variation in quality. In the same way, the growing use of ISO certification could make it easier for buyers to compare different sellers' abilities to meet the quality criteria of the standard rather than just having to rely on historical production data, eg past performance.

Conceivably, firms' desires to live up to specific production standards, eg ISO standards, could have a certain influence on product development, since the development of a product's quality characteristics can sometimes lead to an increased variation in delivery quality. If the standard for variation in a delivery is overstepped, it again increases buyers' costs of

⁶⁶ There is often a connection between incentives to develop measurement techniques and changes in buyers' preferences.

evaluating the seller's level of quality, which might force the seller to accept a lower price for his products than he could otherwise have received if he had been able to control the variation.

Summary

Quality standards, product standards, and quality classes can all serve a general cost-minimizing purpose, since they can be regarded as codes which make it easier for the economic agents to specify those product characteristics they want.

The influence of quality standards on product development is mainly due to their function as a means of specifying valuable product characteristics. Such standards make it easier for sellers to protect the value of characteristics developed in product development projects. For example, in the case of measures, or proxy measures, for search and experience characteristics, a standard makes it possible to sort products into more homogeneous categories, thus limiting the need for buyers to look quite so hard for the desired search characteristics. As far as experience characteristics are concerned, the development of precise proxy measures ensures that the seller doesn't place too much of his value in the public domain by setting too low a price. In addition, it is often easier for the buyer to protect his rights in the transaction by controlling the measurement of the characteristics.

Since there is a certain degree of "system scale economies" in all transaction-cost-reducing standards, the diffusion of these standards throughout the industry will make it easier for buyers to compare the prices and distributions of different sellers.

The influence of product standards and quality classes on product development is first and foremost due to their ability to reduce buyers' costs of comparing different sellers' quality. This reduces sellers' incentives to cheat on quality, and makes it easier for honest sellers to realize an economic benefit from development efforts aimed at increasing the level of their products' search, experience, and credence characteristics. Quality classes, which consist of hierarchies of criteria for classifying products into groups, also influence the priority the firm gives to further development of particular product characteristics, and thus also which technological problems the firm regards as central.

Lastly, the function of production standards as a means of reducing buyers' costs of evaluating sellers' products over time can also influence the priority individual producers give to various product development opportunities, eg by giving a lower priority to product development which increases the probability of bigger variations in the seller's products.

The various transaction-cost-minimizing standards can thus mean that the main focus of product development⁶⁷ is on the technological problems involved in reducing costs by measuring

⁶⁷ Transaction-cost-minimizing standards can perhaps have a more direct importance for firms' innovative behaviour than for that of public research institutions, because the former only go ahead with development projects if there is a chance of a return on the investment, and this depends on the costs of protecting their rights in either caveat emptor or caveat vendor transactions.

“selected” quality characteristics in the final product. These technological problems will in part be influenced by the way in which the quality standard is defined. Another aim of product development is to raise the level and standard of those search, experience, and credence characteristics which define a product category or quality class. Finally, attention is also directed towards reducing the costs of producing identical products in order to meet ISO standards.

13. Technological opportunities in the development of the search, experience, and credence characteristics of final products in the fruit and vegetable industry

The set of technological opportunities related to the development of products’ quality characteristics seems to take two forms. First, there are a number of technological problems involved in optimizing the production processes firms use to keep important search or experience characteristics in the products. This applies, for example, in the production of squash, jam, and frozen peas. Second, there are a number of technical problems involved in developing measures and measurement methods for specifying several of the products’ search, experience, and credence characteristics. The commercial success of the latter will often depend on the setting up of institutions which can both guarantee the credibility of specified characteristics and reduce the transaction costs due to the difficulties buyers have in comparing different sellers’ products. The clearest example of the development of such standards with accompanying control organs is Integrated Production, which ensures that raw products are grown according to environmentally friendly methods.

The following section looks at a number of examples of how firms try to develop a product’s search, experience, and credence characteristics respectively.

Technological opportunities of raising the level of a product’s search and experience characteristics

Search characteristics

Improving the search characteristics of the final product by making stricter demands on the size of the ingredients and homogeneity of the final product often involves making stricter demands on the search characteristics of the raw product, resulting in a higher proportion is rejected on delivery or during production⁶⁸. Infrared and laser graders, which allow a much finer grading of both raw products and intermediate products, have already been introduced by several firms. Finer grading can lead to an increase in raw product waste, which in turn can give firms an incentive either to develop new varieties which meet the new requirements or develop methods to separate unsuitable raw products prior to production.

⁶⁸ It is impossible to tell whether the introduction of, for example, optical screening in pea production will just lead to an increase in quality differentiation between producers, or whether it will lead to the development of more quality classes for frozen peas.

The development of product colour can partly result in the development of new varieties and partly in the development of new production methods which retain more of the natural colours. Keeping more of the natural colour in the final product creates technical problems in the production of, for example, jam, squash, and cucumber salad, because the raw products lose a lot of their colour during the heating process. A colorant is added to cucumbers before pasteurization. As regards jam, the sugar content plays an important part in preserving the colour, which is why artificially sweetened products often have a duller colour. No solution to this problem other than artificial colorants has yet been found. In general, most firms want to avoid artificial colorants as much as possible, so the development of gentler production methods which retain more of the natural colour could be an alternative solution, and it would also help to raise the level of quality of the final product. As mentioned previously, both colour intensity and clarity are two important search characteristics in juice and squash production. The development of these search characteristics in the final products depends, among other things, on the development of better filtration methods, which is also one of the things the industry is working on.

Experience characteristics

Firms try to “improve” taste, which is an important experience characteristic of both raw and final products, primarily by developing production methods which reduce the loss of aroma from the harvesting to the preservation of the products. The taste (and nutritional content) of such perishables as cucumbers, pumpkins, spinach, kale, peas and strawberries depends to a large extent of the processing time from harvesting to preservation. It therefore requires careful planning of the harvest and a lot of processing and refrigeration capacity to preserve the taste of the raw products. Any capacity problems which arise can, in some cases, be met by using varieties which ripen at different times. Generally speaking, improved harvest planning and a better organization of production are important elements of the initiatives which processing firms have taken to improve taste. In the case of berries and fruit, evaporation of the aroma as early as the time of harvest is an important factor, leading to a deterioration in the taste and aroma of the raw product. Rapid refrigeration or storage in a controlled atmosphere helps limit this evaporation, but the berries can lose even more aroma when they are defrosted again. This loss is limited by keeping the berries covered. In leek production, other ways have been tried, namely by developing a new leek harvester which shortens the process time by allowing part of the processing to be done in the fields. Similar solutions are being tried for other vegetables. Reducing the process time not only ensures a better taste, but also reduces the danger of loss of quality of the raw product and increased variations in the final products. Firms pointed out, however, that new harvesting and processing machines have to be highly reliable, because production hold-ups can result in a sharp deterioration in raw product quality.

In the production of such processed final products as squash, stewed fruit, jam, and blanched vegetables, firms are putting a lot of effort into preserving the natural taste of the raw product during processing in order to improve the taste characteristics of the final product. The process of defrosting and heating the raw product is an important cause of loss of aroma (and vitamins). In the production of jam, stewed fruit, and squash, firms are thus trying to develop

more gentle methods which will reduce this loss. In the case of peas and carrots, the loss of aroma is limited by rapid refrigeration after blanching. Boiling, autoclaving, and pasteurization in the packet limits some of the loss of aroma for certain other products.

In some of the final products, eg jam, stewed fruit, and crisp-fried chopped onions, efforts are also being put into “improving” the nutritional content without changing any of the traditional taste characteristics of the products. The nutritional content is defined here as a product’s content of sugar, fat, and “artificial” additives (E numbers). The elimination of preservatives presents a lot of problems, especially in the production of jam and stewed fruit. The problems arise because manufacturers want to keep the sugar content as low as possible, which means that the jam doesn’t keep as well after it has been opened. The desire to reduce the sugar content has in some cases resulted in the development of a line of light products. The main problem here is to find artificial sweeteners which taste like natural sugar. Another problem is to make sure that the colour of, for example, jam isn’t changed when sugar is replaced by artificial sweeteners. Yet another problem is the effect sugar has on gelling in jam. When sugar is replaced by other sweeteners, the pectins must also be replaced by other gelling agents. In other products, eg chips, crisp-fried chopped onions, etc., a reduction of the fat content is desirable. This has succeeded in the case of chips by developing a new type which can be cooked in the oven. Firms are still working on how to reduce the fat content of crisp-fried chopped onions without it affecting the taste.

Credence characteristics

Several of the interviewed firms stated that a lot of consumers are starting to attach more importance to products’ nutritional content and the environment. Concern for the environment and consumer demands for more unadulterated products can turn growing conditions, and especially the use of crop sprays, into important credence characteristics which firms can develop and use in their marketing strategies.

Several of the interviewed firms tried to strengthen the credibility of their products vis-à-vis growing conditions through the development of, among other things, sorting and control systems which ensured that variations in these characteristics over time simply didn’t occur. Guaranteeing such credence characteristics as “environmentally friendly” or “ecological” can easily result in increased production costs, however, because growers get a smaller crop and processing firms face higher costs, partly because they have to keep ecological and non-ecological products separate and partly because there is often a higher percentage of waste due to “damaged” raw products. Increased production costs often result in higher prices, which makes these credence characteristics hard to sell.

The development of resistant varieties, natural and biological pest control, and the development of techniques for separating out “damaged” raw products before production should cut both growers’ and firms’ production costs. In addition, the development of methods of tracing crop sprays can reduce firms’ control costs considerably. However, it is often far more costly to develop alternative solutions to, for example, pest control, than to

improve existing solutions. This is because a lot is already known about how to improve crop sprays, whereas knowledge of biological and other forms of pest control is limited. Moreover, growers often have to be taught how to use such alternative methods. But here, too, it can be much easier to teach growers about known methods than new methods. Nevertheless, efforts are being made to develop alternative solutions to chemical control to make it easier for growers to comply with the requirements of environmentally correct cultivation. For example, the Danish Institute of Plant and Soil Science, in collaboration with Frigodan, has tested natural warning systems. In addition, a lot of work is being done on breeding disease-resistant crops, as well as developing biological means of control.

Products' nutritional content is another important credence characteristic which could form the basis for new quality characteristics. A product's nutritional content is a credence characteristic in the sense that the consumer can't directly observe it, and would have difficulty experiencing it even after consuming the product. Vegetables are naturally healthy and full of vitamins. Some of these vitamins are lost between the time of harvest to packaging and freezing, however. Quick processing, including rapid refrigeration after blanching, are two ways of limiting this vitamin loss. In vegetables which are sliced or chopped (eg lettuce), 90% of the loss occurs during the cutting process. As yet, none of the firms have been able to find of way of reducing this loss. However, limiting the vitamin loss is not considered a particularly important competition parameter, because the loss is no greater in the industry than it is in the home, when consumers chop lettuce in their own kitchens. Finally, some firms mentioned the microbiology of raw and final products as a potentially important future credence characteristic. This mainly applied to producers of ingredients for baby food and ready-cooked meals, however.

Summary

It can be seen from the above that firms mainly strive to improve their production methods for the purpose of raising the level of search and experience characteristics, plus to develop measurement and control systems. None of the firms mentioned the development of raw products with a better colour or taste as a way of improving the quality of their products. There can be several reasons for this. Partly, it is because plant breeding is extremely time-consuming, partly because there are limits to the characteristics which can be bred. Part of the explanation could also be that the firms have difficulty in communicating their wishes for new crops to the right research institutes. Lastly, firms possibly feel that they can get more out of improving existing products than from developing new crops.

The firms who make final products seem to concentrate their efforts in tow areas, namely preserving the natural search and experience characteristics of the raw product and developing new product lines based on improved nutritional characteristics (eg light products). There was also some interest in developing new credence characteristics which could form the basis for a differentiation of the firm's existing products or for completely new product lines.

14. Conclusion

The set of technological opportunities in the fruit and vegetable industry consists of such technological problems and solutions as improvements to and development of crops, harvesting methods, storage of the raw product, and production methods.

For some firms, the effect of the innovations which emerge from this set of opportunities can be seen in the form of improvements in productivity, and thus also in price competitiveness. For other firms, it can be seen in the improvements in their products' quality characteristics and in the number of new products or new product characteristics, and thus in their possibilities for differentiation benefits. Finally, a number of innovations are primarily aimed at reducing quality variations in the firms' deliveries. The competitive importance of these innovations can only be understood from an exchange point of view, since they primarily contribute to reducing the transaction costs incurred as a result of the difficulties of obtaining precise information about the products. Transaction costs can also have an indirect effect on the development of products' quality characteristics, however, since there are a number of externalities in the fruit and vegetable industry, in the form of transaction-cost-reducing standards, which influence individual firms' incentives to develop these characteristics.

As mentioned above, changes in competitive conditions in the fruit and vegetable industry allow for the possibility of two technological paths, of which the one can be understood from a production point of view and the other from an exchange point of view. The above analysis indicates that an "exchange" perspective can help throw light on technological development, something which would normally come from the production side. However, on the basis of the present information, it is not possible to be more precise about the direction of technological development, since the material doesn't contain any data on the historical development of the techniques currently used in the industry. The interviews do show, however, that the physical and biological characteristics of the raw product play a big part in both the scale of transaction costs and the solutions that are developed.

In those cases where firms must choose between using resources on productivity-improving technological developments and transaction-cost-minimizing technological developments, the choice will probably depend on how the firms evaluate the technological and marketing opportunities of each path.

Appendix

Method

The report is based on a number of interviews of firms and institutions, several of which involved interviews with more than one respondent.

The following firms and institutions were interviewed:

Institutions, etc.:

The Danish Agricultural Advisory Centre
The Royal Danish Veterinary and Agricultural University
Danish Association of Fruitgrowers

Firms:

KV Saft
Den Gamle Fabrik
Vendelbo
Rynkeby
Ørbæk Most
Frigodan
Flensted
Beauvais
Sønderjyds Kål
Løgfabrikken
Samsø Konservesfabrik

The interviews were open-structured and included the following areas:

- A description of the firm's product range, markets, customers and suppliers.
- The firm's competitive strategy, including how it differed from that of its competitors.
- A description of the firm's product and process technology.
- Technological problems and bottlenecks in relation to product and process development.
- The firm's product and process development abilities, including the educational background of its employees and experience from previous development projects.

The technological opportunities for product and process development described in this report emerged from a joint collaboration between the Biotechnological Institute and the firms involved.

The interviews have been collated in order to examine how firms have tried to solve such technological problems as:

- 1) Reducing production costs
- 2) Producing new product variants
- 3) Producing products with a similar level of search, experience, or credence characteristics
- 4) Raising the level of products' search, experience, and credence characteristics.

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Titel: *Udvikling og afprøvning af instrumenter til analyse af trends i forbrugernes og detaillisternes værdi-opfattelse på eksportmarkederne*

DIFTA m.fl.

Titel: *Markedsstyret kvalitetsudvikling af danske åleprodukter med henblik på det tyske marked*

Frigodan m.fl.

Titel: *Strategiske dybfrostærter*

Intergoods Bakery Ltd.

Titel: *Udvikling af systemer, rutiner og værktøj til effektivisering af produktudviklingen og lanceringen på de internationale markeder for Intergoods Bakery Ltd.*

MD Foods A.m.b.a. m.fl.

Titel: *Kunde- og miljøtilpasset emballage- og distributionsteknik nationalt og internationalt*

SANT + Bendix m.fl.

Titel: *Styrkelse af produktudviklingsfunktionen i mellemstore fødevarer virksomheder*

Slagteriernes Fællesindkøbsforening A.m.b.a. m.fl.

Titel: *Udvikling af magnetisk fjernlæsbar mærker og tilhørende terminaludstyr til identifikation af kvæg bl.a. med henblik på forbedrede muligheder for kvalitet-, proces-, og avlskontrol og -udvikling*

Slagteriernes Forskningsinstitut

Titel: *Forbrugerundersøgelse af svinekød*

Tulip International A/S

Titel: *Kvalitetscertificering som nøglesuccesfaktor ved markedsføringen af danske fødevarer internationalt*

Tulip International A/S

Titel: *Udnyttelse af kulturelle forskelle i den internationale markedsføring*

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Furthermore there are a number of project papers, which are not available to the public.

The Mapp programme consists of the following 15 projects

1. Strategic Planning and Innovation Capability in the Danish Food Sector
Morten Kvistgaard & Kirsten Plichta, Copenhagen Business School
2. Innovation Capability as a Key Success Factor
Klaus G. Grunert & Hanne Harmsen, The Aarhus School of Business
3. Quality Certification as a Key Success Factor in International Marketing of Food Products
Niels Jørgensen, Business University of South Jutland
4. Definition of the Sales Potential for a New Food Product to be Launched on Home or Foreign Markets
Anne Martensen & Kenneth Kæregaard, Copenhagen Business School
5. Primary Producers and Product Innovation in the Food Industry
Villy Sjøgaard, University Centre of South Jutland
6. Controlling Processes of Production to Guarantee Process Characteristics Demanded by Consumers of Food Products: Paradigms and Danish Experiences
Esben Sloth-Andersen, Aalborg University Centre
7. The Role of the Distribution System in Product Innovation
Hanne Hartvig Larsen, Copenhagen Business School
8. Prototyping in the Danish Food Industry
Preben Sander Kristensen, Aalborg University Centre
9. Product Quality and Consumer Preferences: Assessing the Optimum Design of Food Products
Kai Kristensen, Hans Jørn Juhl, Anne Bech & Erling Engelund, The Aarhus School of Business; Carsten Stig Poulsen, Aalborg University Centre
10. Product Innovation and Packaging in the Food Industry - Environmental Consequences and Consumer Reactions
John Thøgersen & Tino Bech-Larsen, The Aarhus School of Business
11. The Consumer as Agent in Relation to Research and Development in Food Technology
Erling Jelsøe, Birgit Land & Jesper Lassen, Roskilde University Centre
12. Households' Choice of Foodstuffs with Different Kinds of Preparation
Jens Bonke, University of Copenhagen
13. The Cultural Dimensions of Food Consumption and the Implications for Strategy Formation and Implementation in Small and Medium-sized Danish Companies
Dominique Bouchet, Josette Andersen, Søren Askegaard, Tage Koed Madsen & Per Østergaard, Odense University
14. Market Surveillance Systems for the Food Sector
Klaus G. Grunert & Karen Brunsø, The Aarhus School of Business
15. Identification of Key Success Factors
Klaus G. Grunert & Elin Sørensen, The Aarhus School of Business