Thought for food: the impact of ICT on agribusiness

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Introduction

In 2000, the European Commission as well as the Member States' representatives committed themselves in Lisbon to let the European Union become 'the most dynamic and competitive knowledge-based economy in the world' (High Level Group 2004). Competitiveness is considered to be a necessary condition for guaranteeing sustainable growth, more and better jobs as well as respect for the environment. So far, this so-called Lisbon strategy has failed. Economic growth in the US and Asia still outpaces growth in the EU. More in particular, US labour productivity growth outpaces European labour productivity growth ever since 1995. According to the High Level Group (2004) evaluating the Lisbon strategy, European performance is low due to insufficient investment in R&D, poor marketing performance and low productivity in both ICT production and application. The Lisbon targets may not be realized by 2010, however, they are no less necessary. European living standards depend on economic performance of the EU. In order to achieve the world's highest productivity levels, the European Union focuses on five areas including the knowledge economy. Given this background, this paper investigates the implications of the evolving knowledge and information economy for the food supply chain. Jean Kinsey (2001) identifies ICT - more in particular digital computing and the Internet - as one of the two major technologies driving changes in both consumer demand and supply chain organisation. ICT and biotechnology enable the transformation of the economy from an economy based on the production of physical goods to an economy based on the production and application of knowledge. Company assets are increasingly knowledge-based and intangible. Added value is created by making smarter use of natural and other resources. The impact of ICT is so large, because it enables new business practices, new skills and new industrial structures. It brings about fundamental changes in the way business is conducted and it is responsible for a range of new products and services as well as improvements in quality, variety, timeliness, convenience and sustainability.

The implications of ICT and the evolving knowledge and information economy are explored by a review and the integration of the literature from four disciplines: knowledge management, management information systems, operations research and logistics, and economics.

This paper is constructed as follows. Section 2 elaborates the main drivers behind the demand for new ICT applications: the demands of major stakeholders with respect to the food supply chain (sustainability, transparency, value added) as well as the demands following from economic and social processes such as competition and globalization (productivity, innovation). Section 3 presents the role of ICT in food supply chain networks and discusses major ICT applications. Section 4 matches demand (Section 2) and supply (Section 3). Section 5 discusses the diffusion of ICT applications at the industry level and the implications for industry structure, in particular industry concentration, transaction costs and transparency. Section 6 presents the implications for economy and society by studying productivity developments at the macroeconomic level and industrial relations. Section 7 summarizes the results.

Innovation on demand

International food industry and food supply chains are facing an ever increasing pressure to deliver safe, healthy and attractive food in a highly competitive environment. This imposes a strong pressure on innovation in short cycles, which in turn requires a continuous interaction between analytical science (creating new insight), applied research and development (creating new products and processes) and industrial applications. Moreover, claims made with respect to health effects, sustainability and ethical aspects of the production chain need to be transparent to society. Information technology plays an important role in increasing transparency, but also in virtualizing production.

Without being exhaustive one may distinguish the following drivers behind the pressure to apply ICT and other technologies (Van der Vorst *et al.,* 2005; Jacobs 2007):

- Changing market demands. In recent years, Western-European consumers have become more demanding on food attributes such as quality, integrity, safety, sustainability, diversity, and associated information services.
- Sustainability. Food supply chain networks (FSCN) face increasing demands with respect to the sustainability of production and distribution processes. Consumers, citizens, NGOs and public administrations continuously scrutinize the impact of food production and distribution on the natural resources and the environment.
- Economies of scale. Businesses are getting bigger and bigger in all stages of the supply chain network. Large retail companies dominate the market and put their own requirements regarding logistics, quality management and sustainability on a reducing number of larger suppliers. The demand for responsive and lean supply chains increases, putting high demands on logistics and information systems.
- Increase in international competition. Technological developments (ICT, processing and transport) make it possible to reach suppliers and customers all over the world. Companies in the food industry are acting more and more on a global scale. This is reflected by increasing cross-border flows of livestock and food products, and international cooperation and partnerships. Although this provides cheap products to our consumers, it raises questions regarding the quality, integrity, and safety of the food.
- Increasing logistics flows in dynamic networks. Chain actors may be involved in different food supply chain networks (FSCN), participate in a variety of business processes that change over time and in which dynamically changing vertical and horizontal partnerships are required. Companies act at the same time on global and regional markets resulting in a world-wide growth of goods flows and increased complexity and dynamics in logistics networks.

All these developments put ever changing requirements on the performance of the food system initiating a reorientation of companies on their roles, activities and strategies. The food industry is becoming an interconnected system with a large variety of complex relationships, reflected in the market place by the formation of (virtual) FSCN via alliances, horizontal and vertical cooperation, forward and backward integration in the supply chain and continuous innovation. FSCN encompass the development and implementation of enhanced quality, logistics and information systems. In order to satisfy the increasing demands of consumers, government, business partners, NGO's and to obtain the 'license to produce and deliver', companies continuously have to work on innovations in products, processes and forms of cooperation in the FSCN (van der Vorst *et al.,* 2005).

Applying ICT in food supply chain networks

Food supply chain networks (FSCN) consist of actors performing consecutive and mutually dependent business activities. The output of the business activities performed by the respective network actors are continuously exchanged between them. Flows within FSCN include products and services, information exchange and messages, and money and property flows. Most of the time, money and property flows are also represented in the form of information. Most business activities and exchanges involve such information activities as making, receiving and handling orders, including picking, labelling, billing, invoicing and dispatching. Many information processing activities have been automated in the last two-three decades using ICT.
In order to streamline the respective flows in FSCN, information sharing becomes a key factor in achieving supply chain co-ordination (Van der Vorst *et al.,* 2005). Information sharing requires the smooth integration of information in all relevant business processes throughout the supply chain leading to standardized communication. In order to integrate different types of information at various levels in FSCN, a range of information systems has been developed. Integration of information systems is required in order to guarantee the integrity of basic recordings and a correct and timely communication of information as well as to minimize the administrative burden. Information systems include production automation systems, Supervisory Control and Data Acquisition (SCADA) systems, Manufacturing Execution System (MES), Management Information Systems (MIS) and Decision Support Systems (DSS).
ICT plays a key role as enabling technology in organizing information sharing. This holds in particular for two emerging technologies: Service-Oriented Architecture (SOA) and Software as a Service (SaaS).

Service-Oriented Architecture
Service-Oriented Architecture (SOA) is a flexible, standardized software architecture supporting the connection of ICT applications and the sharing of data. A practical example is the use of a rental car company's reservation system while one is actually consulting an airline's reservation system. SOA allows different ICT applications to exchange data with one another as they participate in business processes. The aim is a loose coupling of services with operating systems, programming languages and other technologies which underlie applications (Newcomer and Lomow, 2005).

Software as a service
Software as a service (SaaS) is a model of software deployment where an application is hosted as a service provided to customers across the Internet. By eliminating the need to install and run the application on the customer's own computer, SaaS alleviates the customer's burden of software maintenance, ongoing operation, and support. Using SaaS also can reduce the up-front expense of software purchases, through less costly, on-demand pricing. From the software vendor's standpoint, SaaS has the attraction of providing stronger protection of its intellectual property and establishing an ongoing revenue stream. SaaS is successfully applied especially in the field of marketing and sales (e.g. webshops, e-market places, etc.). This emphasizes the fact that the service itself (buying, selling, procurement, etc.) is leading and software is just a tool (Wikipedia, 2008).
New developments in ICT have promising possibilities for the economy and society, because a couple of ten innovations have a radical impact on the computational power and transparency of the collective information system (Gartner 2008). The threshold for accessing the collective information system will decrease and its perceived intelligence will increase. In other words, the idea of the network as a 'massive collective brain' is coming into reach. It will contribute to the effectiveness

of supply chains because all required information is made available instantaneously. Moreover, this information is combined with knowledge, creating new insight and innovation. However, even though technological advance is moving forward almost autonomously, social and political issues may cause barriers or even unintended effects in the applications.
Even though knowledge sharing is typically a long term, collective interest at the organizational level, individual professionals and experts often fail to recognize the advantages of sharing their knowledge with others (Top and Broersma, 2008). Three conditions need to be satisfied before a general attitude towards knowledge sharing arises. First, social, psychological and political borders have to be removed (motivation, incentives, interests, trust, credits, commitment, time). This is a cultural change that is not easy to bring about. Secondly, processes, standards and agreements are needed to get the 'flow of knowledge' going. Agreements on knowledge collaboration between organizations have to be supported by detailed descriptions how knowledge transfer is actually implemented. Third, a technological infrastructure is required to make knowledge sharing easy, cheap and attractive. Wikipedia for example is apparently successful in alluring people to ventilate their knowledge. The use of ICT technologies has helped to support the shift towards more open, collaborative and network-centered innovation practices (Dogson *et al.,* 2006).

Managing ICT and FSCN transparency

Businesses and supply chains may match demand and supply by applying Business Process Management (BPM). BPM is a method of efficiently aligning an organization with the wants and needs of clients. It is a holistic management approach that promotes business effectiveness and efficiency while striving for innovation, flexibility and integration with technology. As organizations strive for attainment of their objectives, BPM attempts to continuously improve processes - the process to define, measure and improve your processes – a 'process optimization' process. A business process is a collection of related, structured activities that produce a service or product that meet the needs of a client. These processes are critical to any organization as they generate revenue and often represent a significant proportion of costs (Wikipedia, 2008a).
The connection between BPM and ICT is made by Business Process Modeling which can also be abbreviated by BPM but is in essential not the same as Business Process Management. BP Modeling is the activity of representing both current ('as is') and future ('to be') processes of an enterprise, so that current process may be analyzed and improved. BPM is typically performed by business analysts and managers who are seeking to improve process efficiency and quality (Wikipedia, 2008b). The process improvements identified by BPM may or may not require IT involvement, although that is a common driver for the need to model a business process, by creating a process master. Change management programs are typically involved to put the improved business processes into practice. With advances in technology from large platform vendors, the vision of BPM models becoming fully executable (and capable of simulations and round-trip engineering) is coming closer to reality every day. BP Modeling addresses the process aspects of an Enterprise Business Architecture, leading to an all encompassing Enterprise Architecture. The relationships of business processes in the context of the rest of the enterprise systems (e.g. data architecture, organizational structure, strategies, etc.) create greater capabilities when analyzing and planning enterprise changes.
Information management has major implications for supply chain transparency and the organisation of R&D and innovation processes.

Supply chain transparency

Information governs the relationship between suppliers on the one hand and customers and consumers on the other hand. Within supply chains, information governs the relationship between a chain of participants on a range of issues. With respect to information, one may make a difference between the past, the present and the future (after Hofstede *et al.,* 2004). Information on the past requires less strategic interaction and trust than information on the present, let alone the future.

- History transparency is about knowing the product and process history of food flowing through the FSCN. Its promise is to improve recall management and to prevent calamities. RFID technology is rapidly making detailed history transparency affordable in many agri-food sectors. Traceability is a special case of history transparency.
- Operational transparency is about knowing what is happening across the FSCN. It involves keeping partners informed on one's logistics and other operational parameters. Its promise is to improve the efficiency reduce waiting times and stocks, and improve effectiveness and responsiveness of FSCN.
- Strategy transparency is about deciding what may happen in the FSCN. It involves creative investigation of the FSCN's context to find opportunities and threats and to design adaptive responses. Joint innovation is a case in point.

Open innovations

Innovation processes are open if the development of new product and processes involves different categories of partners in FSCN, in particular customers or consumers (AWT 2006) Companies are demonstrating a greater openness to external knowledge and to new organisation models and principles in order to accelerate innovation. SOAs provide the technological infrastructure for realising open innovations. Open innovation is often contrasted with a closed innovation model, based on knowledge protection and the development of innovations within an R&D department. There are several reasons why this closed model is under pressure, including mobility of knowledge workers, the higher level of education among the working population, availability of venture capital, etc. These factors are making external cooperation and knowledge exchange simpler and, often, necessary. Open innovation is in fact a collective term for several trends that have been recognised by researchers for quite some time. These trends include the role of lead users and the organisation of R&D in network relationships. The literature on innovation contains numerous examples showing that multinationals in the Netherlands no longer innovate solely through their own R&D departments. Philips and DSM are well-known examples. However, the telephone survey and the analyses of secondary data sets show that small and medium-sized enterprises also frequently make use of open forms of innovation. In fact, SMEs have been using the open innovation method for many years. Because of their limited size, they lack the specific infrastructure needed for closed innovation and have to rely on contributions from and cooperation with other parties. Very few SMEs have their own R&D department.

Living Labs

Large-scale innovation requires experimentation with a large variety of technologies, and access to a wide range of potential service providers and users, from early on in the development phase. Local, regional, national and European policy makers are rushing to establish or support joint test and experimentation facilities as pivotal tools to drive broadband innovation. Living Labs are one of these broadband innovation methods. A Living Lab (LL) is an environment where the end-user takes part in the creation of new products and services (Garcia Guzman *et al.,* 2007; Mulder *et al.,* 2007 and Fahy *et al.,* 2007). They represent a user-centric innovation approach for sensing,

prototyping, validating and refining complex solutions in multiple and evolving real life contexts. LLs promote an alternative innovation paradigm, the end-user's role shifts from research object to a pro-active position where user communities are co-creators of product and service innovations.

ICT adoption and market structure

The spread of ICT applications does not only influence company and supply chain operations and performance, but also industry structure and performance. The impact of ICT on market structure and performance depends on the speed by which ICT applications spread through the economy and society. Diffusion of radical technologies takes time, often a lot of time, because the adoption of a technology is a social phenomenon involving the choices of many people, often in an interdependent manner. Before a new technology is adopted, people need time to find out that a new technology is available and they need to be convinced that the new technology is an improvement over existing technologies. And even then, the diffusion of technologies is typically slower than the diffusion of information. It is relatively easy to buy and install an ICT application. It is less self-evident that the ICT application is used effectively. In order to do so, one needs a thorough knowledge base. Part of the knowledge may come with the user manual; other parts come with experience and may very well remain tacit, *id est* embodied in an organization or even in an individual. The adoption of ICT applications requires well-educated employees with the incentives to act independently as well as interdependently.
Fortunately, both entrepreneurs and policy makers may influence the diffusion and success of ICT applications by the following variables:

- ICT is not a stand-alone technology. ICT contributes to firm performance, but only when it is complemented by other investments and activities such as changes in work organization (OECD 2003). ICT is a co-invention technology opening up a variety of innovation potentials such as restructuring organizations (delegation of responsibilities and reduction of hierarchy), re-engineering business processes (just-in-time management and e-commerce) and developing new products (Hempell *et al.,* 2004).
- Adoption of new technologies is regionally concentrated and depends on the proximity of early users. Geographical distance is a factor in spreading information on new technologies, their benefits as well as the knowledge required to apply them (Baptista, 2000).
- Adoption processes depend on network economies. Network economies refer to the fact that the value of a telephone, a fax or an e-mail account increases with the number of people and enterprises having a telephone, a fax or an e-mail account (Cabral 2000; Kinsey 2000). This also holds for e-commerce. Network economies are important in e-commerce, because they depend on the compatibility of ICT standards. Compatibility requires co-ordination by the firms involved (Kinsey 2000).
- Government policies may influence the speed with which technologies spread through the economy. With respect to ICT two government policies matter: the extent to which markets are liberalised and the extent to which governments are involved in a standard setting.

ICT has major implications for food industries as well as the food supply chain structures, because it influences market concentration, transaction costs and market transparency.

Market structures
Market structures change, because firms enter and exit industries and because firms gain or lose market share. ICT influences market structure by influencing firms performance and thus the

likelihood that firms enter or exit, grow or decline. Wal-Mart's rise in US general merchandising is a good example of the implications of ICT induced firm performance for market structure in food retailing. Recent studies on the relation between ICT and firm performance find that there is a positive correlation between the use of ICT and productivity (OECD, 2003). This holds in particular for firms investing in communication network technologies. US and Canadian evidence points out that enterprises using advanced technologies are more likely to expand their activities and are less likely to be forced to exit an industry (ibid.). The evidence for Canada shows that this leads to major shifts in market share over a decade. There are indications that ICT increases economies of scale in food wholesale and retail trade and leads to further market concentration at the retail and wholesale level. According to Kinsey and Ashman (2000), economies of scale in food retail are due to bargaining power vis-à-vis suppliers, more efficient use of transportation and ordering systems, and the ability to utilize information technology to manage inventory throughout the supply chain.

Transaction costs

ICT opens up new ways of doing transactions. This holds notably for e-commerce. Even though e-commerce is just getting of the ground, in particular in food retailing, it has the potential to broaden the scope of potential trade partners to the European market, if not to the 'global village'. E-commerce is still in its infancy due to the network effects just mentioned, but also due to a lack of trust. Indeed, trust is among the main reasons why electronic commerce develops slowly (OECD, 2003). There is a lack of trust with respect to the safety of personal information including financial data (OECD, 2003). There is also a lack of trust due to the absence of personal relationships (Hofstede *et al.,* 2008). The role of personal relationships in commercial relationships depends on cultural beliefs with respect to trust (ibid.).

Market transparency

From a consumers' perspective, markets are transparent if they have sufficient insight in the number of suppliers as well as the prices and qualities offered to reach a balanced choice (Stefanski *et al.,* 2002).[1] If markets are transparent, search costs - time and money spend in collecting and processing information - are low. Markets are transparent if information is accessible, understandable, reliable and comparable. In transparent markets, consumers buy the products they want in the price-quality relations they want. Electronic commerce creates the possibility for suppliers to target specific groups of customers and consumers. Consider e.g. small or tall people who probably had to resort to catalogs in the period before Internet in order to find clothing, shoes or furniture. Or alternatively, people with special dietary needs. Facilitated by electronic information, consumers also get access to information where they did not have access to up until now, e.g. with respect to such production conditions as environmental and animal welfare.

The knowledge economy

As already indicated in the introduction, European productivity as measured by GDP per hour has fallen relative to the US ever since 1995 (Figure 1). Differences in ICT-related productivity are a key explanatory variable in explaining this development. This holds in particular for the retail and wholesale trade. There is a substantial difference in the impact ICT has on factor productivity in the US and Australia on the one hand and the European Union, in particular Mediterranean countries, on the other hand (Pilat 2004; Van Ark *et al.,* 2008).

[1] For suppliers a similar analysis holds.

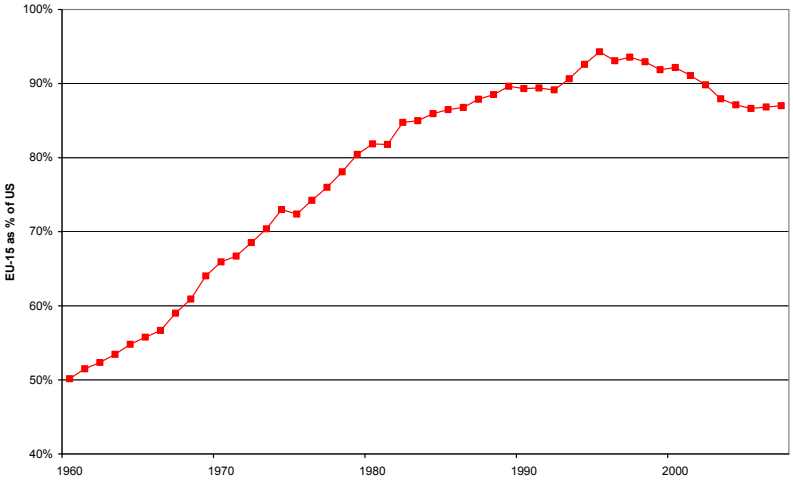

Figure 1. GDP per hour worked in EU 15, 1960-2007.

The fall in European labour productivity growth is primarily due to a fall in the availability of non-ICT capital and a lack of process and product innovations (multifactor productivity growth). The rise in the US growth rate is due to an increase in the availability of the amount and quality of both ICT and non-ICT capital and growth of both process and product innovations. Van Ark *et al.* (2008) show that the difference in productivity growth can be attributed to two sectors: distributive (wholesale and retail) trade and finance and business services. The contribution of agriculture, mining, manufacturing, construction, utilities, ICT production and personal services to national labour productivity growth is comparable between the EU and the US. There is wide gap for wholesale and retail trade and for finance and business services. For both sectors, the divergence is primarily due to process and product innovations and not so much to differences in the availability of human and physical capital. Apparently, the US is able to put through more process and product innovations in both sectors than the EU does.

Van Ark *et al.* (2008) posits several explanations for these differences. US retail makes more use of ICT capital (barcode scanners, communication devices, inventory tracking devices and transaction processing software). US retail may be more innovative in terms of new retail formats, service protocols, labour scheduling schemes and marketing campaigns. Finally, European regulation with respect to opening hours, land zoning and labour markets may have inhibited the rise of big-box formats such as Wal-Mart. The latter is considered to the driving force of productivity growth in the US (McKinsey, 2001).

Implications for the work floor

Above, we saw that investments in ICT generate high rates of return if they are accompanied by other investments, notably in skills and organizational change. ICT enhances firm performance if skills have been improved and organizational changes are introduced (OECD 2003). This result is emphasized in the literature on co-invention which argues that workers make investments in technologies more valuable by experimentation and invention. Without co-invention, the economic impact of ICT may actually be quite limited.

OECD (2003) discusses several longitudinal studies pointing out that investments in ICT are skill biased. For France, for instance, there is evidence that indicators of computerization and research on the one hand are positively correlated to productivity and wages on the other hand. There is also empirical evidence for France that organizational change leads to a fall of the share of unskilled workers. For the UK, there is also evidence that the demand for manual workers declines with computerization and that human capital, technology and organizational change are complementary. Similar results are presented for Germany, Australia and Canada.
The demand for skilled workers is not only related to computers as such, but also to organizational change. Investments in ICT complement organizational changes such as new strategies, new business processes and practices and new organisational structures. In the past, employees performed standardized tasks with the framework of standardized production processes. Today, workers have responsibilities in different domains. For this reason, they require multiple skills and the ability to co-ordinate their activities with other employees in a flexible way. Current work practices include team work, flatter management structures and employee involvement. Workers have a larger responsibility and autonomy. Because the organisation of work tends to be firm-specific, there are large differences in firm performance. OECD (2003) presents empirical evidence supporting this analysis.

Summary

This paper elaborates the importance of the ICT revolution for the food economy. The purpose of the paper is to come to a more thorough theoretical underpinning of analyses of the evolving food economy by exploring the contribution of ICT as one of the main drivers. The paper brings together a review of the literature from four disciplines: knowledge management, management information systems, operations research and logistics, and economics. The main conclusion we would like to draw is that FSCN develop into open networks sharing information. Open networks offer many opportunities for generating value added. FSCN slowly become a part of the knowledge economy. However, there are two bottlenecks in the knowledge economy. (1) Companies collect a lot of data most of which are not used at all. (2) Companies are not ready to process all data available. Managers, employees and the models they work with are not fully prepared for the knowledge economy as yet. ICT and the knowledge economy are about two issues: technologies and people. The most important challenge the food economy faces refer to getting the people ready for the new era.

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