Applications of blockchain technology in pig meat market concepts

MSc-thesis

Student name:	**Stefan ten Pierik**
Student number:	950903652010
E-mail address:	stefan.tenpierik@wur.nl
Phone number:	+31640471445

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First supervisor:	dr. Jos Bijman
Second supervisor:	prof. dr. Jacques Trienekens

Wageningen University
Department of Management Studies
Hollandseweg 1
6706 KN Wageningen

ABSTRACT

The aim of this qualitative study was to find out how blockchain technology could be used to increase the success of Dutch pig meat market concepts (PMMC's). This was done by using scientific literature, professional literature and interviews with PMMC supply chain partners and blockchain experts.

PMMC's are collaborations between farmers and other chain partners, which use a differentiation strategy to create high valuable meat products for consumers and to increase profit. Fraud or unmarked errors, like selling conventional meat as PMMC meat, may be financial rewarding. However, this has a negative effect on trust among supply chain partners and the credibility of the PMMC towards consumers. Therefore, a good and credible assurance of the PMMC is important. Blockchain technology (BT) can help to assure PMMC product and production process information. In blockchains, users together maintain a decentral stored and continuous synchronized database. Existing data within a blockchain can because of this setup not be changed. Therefore, the blockchain provides trust for supply chain partners in each other.

This research found that BT can help to increase success of PMMC's by assuring information and increasing transparency and traceability, but is not the Holy Grail to all problems within PMMC's. Centralisation of data in one single database might be an even more important first step that leads to increased insights in products and production processes through the supply chain. However, BT has a high potential to disrupt information sharing between chain partners in the pig supply chain, by e.g. the development of new financing models.

Keywords: blockchain, pig supply chain, agri-food, pig meat market concepts, transparency, traceability, meat supply chain

MANAGEMENT SUMMARY

Fraud within pig meat market concepts (PMMC's) could be rewarding for individual chain partners, but is bad for the consumer credibility of the whole PMMC. This can decrease profit and market share. New information technologies, like blockchain technology (BT), might help to decrease possibilities and consequences of fraud in PMMC's. In a BT supported information system, chain partners together maintain a database. Every partner has its own identical copy of the database, which is continuously synchronized with the copies of the other chain partners. Data can only be added to the system, every attempt to delete or change existing information in the blockchain will automatically be rejected. This system makes a BT supported database practically tamper-proof. There is a difference between open blockchain systems, in which everyone can participate, and closed blockchain systems, in which participants are invited. Open blockchain systems have the highest level of security, but have a lower level of privacy and require more processing capacity than closed blockchain systems.

The main research question of this study was: "how can blockchain technology help to increase the success of pig meat market concepts?" This question was answered using a qualitative approach. Three types of sources were used, namely scientific literature, professional literature and in-depth interviews with PMMC chain partners and blockchain experts. Interviews were recorded, transcribed and coded using a top-down and a bottom-up approach.

Success of PMMC's can be defined and measured into two variables: creating added value for consumers and creating profit for PMMC chain partners. Several factors can contribute to the success of a PMMC, like being efficient in the process of pig farming, having a constant product quality, being relevant for consumers, valorisation of all parts of the pig under the concept (square valorisation), a good tracing of origin, having a limited price distance to conventional produced products and being able to communicate product guarantees to consumers. Furthermore, it was found that setting up a PMMC is a time and effort costly process. Besides, the time in which producers can profit from their additional taken measures is limited.

It turned out that BT can help to increase the success of Dutch PMMC's by increasing supply chain transparency in order to provide more information to chain partners and consumers. The added value for consumers is that they will be better informed about the origin of the products they have bought. This strengthens consumer trust and PMMC credibility, which can lead to more sales and more profit for chain partners. The increased transparency can lead to a higher square valorisation by e.g. better valorisation of minced meat products. This results in a higher supply chain efficiency and a lower cost price of products. Applying BT in PMMC's might create space for new finance models, e.g. by applying smart contracts. Smart contracts can help to pay out premiums to parties that create added value within the supply chain which is not directly delivering profit to themselves, like farmers who are using RFID ear tags instead of conventional ear tags.

Consumers can profit from application of BT in PMMC's by a better assurance of product origin and less possibilities for fraud with products. Furthermore, they will be able to get more information about the production process of the products they buy. However, consumers presumably take fraud prevention for granted and thus might not be willing to pay a premium for products of a PMMC with BT applied because of fraud prevention.

DNA and RFID technologies can contribute to a successful application of BT in PMMC's. By DNA technology, pigs can be traced from birth to plate. RFID technology can be used to track pigs from birth to slaughter and track batches of products from slaughter to supermarket. However, both technologies currently still are relative costly for usage on individual animals, and thus there should be a clear case for doing so. Furthermore, RFID ear tags can get lost during the process of pig farming. For all three technologies (DNA, RFID, BT) it applies that they are not panaceas which solve all problems within PMMC's. Finding clear business models for applying BT in PMMC's might be difficult, but might be found in the area of guaranteeing origin of products and decreasing impact of fraud and scandals. Respondents currently do not see applications of open blockchain systems in PMMC's, because of the lower level of privacy that is involved. However, they see possibilities for applying closed blockchain systems in PMMC's.

Sharing information between chain partners increases efficiency and decreases unnecessary production costs. Applying BT is not the most important factor that increases information sharing, creating a central information platform is an even more important first step. Setting up such a central database increases transparency, efficiency and possible lead to new insights which can improve current supply chain processes. However, in order to keep a (BT supported) central database compact, data sharing should be limited to high relevant data only. The definition of high relevant data might however differ between chain partners. So, good agreements between chain partners should be made on which information is shared in a (BT supported) central information system, and to which level of detail.

Gathering data at individual animal level might be an ideal situation for PMMC's, because it can lead to more specific insights in products and production processes. However, currently technical difficulties and relatively high costs are involved which causes that most data collection is still done on animal group level. Possibly, developments in DNA and RFID technology can contribute to increase possibilities for individual data collection.

Some technical and privacy issues are involved in setting up BT systems in PMMC's. Firstly, setting up a BT system is a process that costs a lot of time and effort. Besides, as already stated, finding a business model for the system might be difficult. Furthermore, chain partners should discuss a lot of different topics with each other and make clear agreements on those topics. For example, a clear error protocol need to be developed. Besides, technical development and maintenance of a BT supported information system will probably be done by a third party with expertise on software development. Chain partners should make clear agreements on how this party is paid. Furthermore, the increased level of information sharing in a BT system may lead to privacy concerns of chain partners. Chain partners should clearly discuss ownership of shared data, which level of information detail is demanded and who gets access to shared data.

Future research could be done on the application of BT in other animal production chains like the production chains of eggs, beef, veal and chicken meat and organic products. Furthermore BT might be applicable in manure accounting and feed production processes.

It is argued that the conclusions of this research are justified, and that they are transferable to other livestock sectors like beef production chains, egg production chains and chicken meat production chains. Furthermore, it is argued that the research is transferable to international applications of BT in livestock farming.

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LIST OF ABBREVIATIONS

BT:	Blockchain Technology
CODP:	Customer Order Decoupling Point
DNA:	Deoxyribonucleic acid, *building block of life, unique for every life individual*
RFID:	Radio-frequency Identification
PMMC:	Pig Meat Market Concept
SC:	Smart Contract
SCM:	Supply Chain Management

1. INTRODUCTION

1.1. BACKGROUND AND SIGNIFICANCE

Profit in Dutch pig sector is under constant pressure (Agrimatie, 2016). Pig meat is produced for an anonymous bulk market, in which price is the only way of product differentiation (Bos, Grin, Spoelstra, & Groot Koerkamp, 2010). Because of this system of price differentiation, the pig sector is strongly cost-price driven. Another factor that pressures prices is the circular surplus (and shortage) of supply and demand of pigs caused by farm termination and scaling of other farms. Therefore, prices in the pig sector follow a price cycle. This principle is very old and is known as the pig cycle (Coase & Fowler, 1935).

An additional factor that explains the low profit of Dutch pig farmers is the skewed power balance between farmers and retail organizations. This is causes by the funnel shape of the pig supply chain. There were 4137 pig farms in the Netherlands in 2018 (Centraal Bureau voor de Statistiek, 2018). Ninety percent of the pig slaughtering in the Netherlands takes place at one of the four biggest slaughterhouses in the Netherlands (Hoste, 2016). Furthermore, there are only five major retail buying organizations (Rol & van Diermen, 2018). This numerical difference in market parties in different chain layers causes a skewed power balance in the pig supply chain, which creates a strong power position for parties with an oligopoly position.

Another reason for the low margins on pig meat is that most consumers choose the cheapest products in the supermarket (van Vliet & van den Brink, 2011). This forces farmers to produce as cost-effective as possible, but also causes a low margin on revenues.

Some farmers do not want to participate in the rat race of lowest-cost price production anymore (Hilkens, Dijkman, Backus, & Klep, 2014). Therefore they change their strategy from a cost leadership strategy to a differentiation strategy. Those strategies were further described by Michael Porter in 1980 (Porter, 1980). Moving to a differentiation strategy is often done in collaboration with other farmers and supply chain partners (ING Economisch Bureau, 2011). This collaboration results in a pig meat market concept (PMMC). In such a concept, additional perceived value (extrinsic quality) for customers is created by usage of extra-legal measures in the production process (Ge, Brewster, Spek, Smeenk, & Top, 2017). For example, most farmers put for instance as many pigs at a square meter as allowed by law in order to produce as cost-efficient as possible. When taking extra-legal measures, less pigs are kept at a square meter. This may improve animal welfare, but also increase costs and is therefore only done when it delivers a higher selling price. Other value propositions of PMMC's include e.g. lower environmental footprint, local production or increased meat taste (van Vliet & van den Brink, 2011). Some examples of Dutch PMMC's are Livar (focusses on regional, small scale production with more animal welfare), Good Farming (more animal welfare in conventional production stables) and Frievar (increased meat taste, supply chain collaboration) (van Vliet & van den Brink, 2011). Some farmers have in fact a business-to-business PMMC, like producers of breeding gilts.

Because of the higher cost and selling prices of pigs and pig meat in a PMMC, fraud can be rewarding. An example of fraud in a Dutch PMMC is the selling of conventional pig meat as organic pig meat by a Dutch slaughterhouse in 2012 (Huisman & Van Ruth, 2014). In order to prevent fraud in PMMC's in the future and increase transparency and traceability in the pig supply chain and credibility of the pig supply chain, the blockchain technology (BT) can be useful (Tian, 2016).

The blockchain is an information technology that is nowadays best known of its application in the Bitcoin cryptocurrency (Tapscott & Tapscott, 2016). The ABN AMRO bank describe the blockchain as a technology that let data on property transparent, safely and reliable be saved, transferred and chronological retrieved (Hofstede, 2017). The Rabobank mention three possible benefits of the blockchain: new business opportunities, increased supply chain transparency and lower transaction costs (Smit, 2017). In blockchains, a distributed database is used to keep data in a system that is prevented from manipulation and falsification (Swan, 2015). Distributed means that data is not centrally stored, but at all computers within the network. Data within the network is synchronized, so that at every computer the exact same version of the database exists. Every transaction has to be verified by other computers in the blockchain. After approval of the transaction, it is added to the blockchain. As a result, there is no central owner of the storage facility who might be able to change information in his favour (Hackius & Petersen, 2017). When anyone would like to manipulate data, he has to manipulate that data at all computers within the blockchain network. Since most often the non-manipulating parties have more computing power than the manipulating party, it is very hard to manipulate data that is stored within the blockchain. Therefore, blockchains are very useful to store data that should be prevented from manipulating.

1.1.1. CONCLUSION OF BACKGROUND AND SIGNIFICANCE

In the current supply chain there can be a lack of trust among chain partners. Besides, fraud can be committed which decreases the credibility of the pig sector (van Vliet & van den Brink, 2011). The blockchain technology may solve those problems (Smit, 2017).

1.2. DUTCH PIG MEAT MARKET CONCEPTS

In this paragraph, PMMC's will be further introduced and be placed in the context of the whole pig sector. First, a general introduction about figures and numbers can be found in 1.2.1 and 1.2.2. In 1.2.3, motives for producing in a PMMC are given. Thereafter, different value propositions are given, and the term square valorisation is introduced. Finally, the importance of tracking and tracing through the supply chain is given.

1.2.1. GENERAL INTRODUCTION TO THE DUTCH PIG SECTOR

In 2018, the total Dutch pig sector included 12.416.161 pigs at 4.137 farms (Centraal Bureau voor de Statistiek, 2018). There are only five major retail organizations, which causes a skewed power balance. Furthermore, there is a high level of competition between the Dutch pig sector and pig sectors from other European countries (Hoste, 2011). Individual farmers have not much negotiating power, because of the skewed power balance in the pig supply chain. Compared to feed producers, slaughterhouses and retailers, the financial margin of pig farmers is low (van Grinsven, van Eerdt, & Westhoek, 2014). Because of the low profit made, innovation is difficult for farmers. In figure 1.1, the Dutch pig supply chain is visualized.

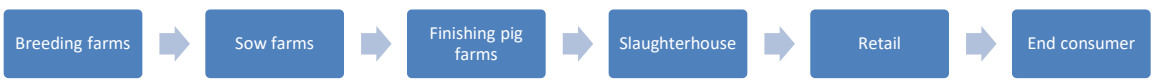

Figure 1.1: Depiction of Dutch Pig Supply Chain

1.2.2. RELATIVE SIZE OF DUTCH PMMC's

In 2011, it was estimated that 1.800.000 pigs at 450 farms were kept in Dutch PMMC's (van Vliet & van den Brink, 2011). At that moment, there were in total 12.429.138 pigs in the Netherlands at 6.525 farms (Centraal Bureau voor de Statistiek, 2018). In 2014, the number of Dutch pigs

kept in PMMC's grew to 3.000.000 pigs at 700 farms (Hilkens et al., 2014). In 2017, it is estimated that the total Dutch pig sector included 12.400.699 pigs at 4.301 farms (Centraal Bureau voor de Statistiek, 2018). It is estimated that 45% of the total number of Dutch pigs produced (so almost 5.6 million pigs) are produced in a PMMC (van Bergen, 2018). All those data taken together, it can be seen that the total number of pigs in the Netherlands is constant, the total number of pig farms decreases and the number of PMMC-farms increases.

1.2.3. VALUE PROPOSITIONS IN PMMC'S

Besides scale advantages in purchasing and sale that PMMC's create, is one of their main characteristics the creation of a (perceived) value proposition for end consumers. All those value propositions involve extra-legal measures in the production process and handle in fact the creation of additional extrinsic quality (Van Stokkom & Kamps, 2014). In chapter 3.5, quality cues will be further elaborated on.

1.2.4. ALLIANCE FORMATION

In order to successfully bring products of pigs in PMMC's to the customer, creating a strategic alliance with a slaughterhouse and retail organization is of great importance (van Vliet & van den Brink, 2011). In such an alliance, relationships are focussed on long term and costs and benefits are shared.

1.2.5. STRATEGIES AND MOTIVES

Farmers who start producing in a PMMC move from a cost-leadership strategy to a differentiation strategy or differentiation focus strategy (Hilkens et al., 2014). Concepts like Good Farming Star from VION or Beter Leven from the Dierenbescherming use a normal differentiation strategy, since they serve a mid-range meat segment via supermarket (Dierenbescherming, 2017; VION, 2017). Livar however is an example of a company with a differentiation focus strategy, because they only serve the high-end segment of the PMMC market via traditional butchers and exclusive restaurants (Livar, 2017).

Among farmers that produce in a PMMC, there are different reasons to participate in a PMMC. Additional revenue is mentioned, as is the wish to produce more animal friendly (Van Der Schans, 2004). For super markets, motives to more to more differentiated products are improvement of animal welfare and to provide more possibilities to choose between different products for critical consumers (van Galen et al., 2011). Furthermore, pressure from NGO's like Wakker Dier let them change their procurement policy (Rotgers, 2011).

Pig farms that start to collaborate in a PMMC often change their whole farm to the way of producing that is prescribed by the PMMC (Van Der Schans, 2004). For other chain partners, the PMMC is often just a product besides conventional products that they sell. Therefore, pig farmers are much more dependent on success of the PMMC compared to e.g. a slaughterhouse or a retail organization (Van Der Schans, 2004). Continuous sales are thus necessary for the proliferation of a PMMC (Sukkel & Van der Waal, 2007).

1.2.6. SQUARE VALORIZATION

In selling PMMC pigs and meat, the principle of square valorisation is of great importance (van Vliet & van den Brink, 2011). High value parts of pigs from PMMC's can relative easily be sold for a higher selling price compared to the same parts of pigs from a conventional system, because of the value proposition of the PMMC. However, for less valuable parts that are sold in an anonymous market, this value proposition does not add value to the product. Therefore, it is sold

for the price of conventional meat, but has the higher cost price of meat from the PMMC. The more parts of the pig that can be valorised in the PMMC, the higher the profit on the total pig that is made despite the higher production costs. A good supply chain tracking system can increase the square valorisation rate of the PMMC products, because origin of minced meat products like e.g. sausages can be traced and product streams of PMMC meat and non-PMMC meat can be better separated. Tracing of PMMC products thus could be an essential step in assuring origin of meat in order to increase the square valorisation rate of PMMC meat.

1.2.7. TRACING INDIVIDUAL PIGS: RFID AND DNA MARKERS IN PIG SUPPLY CHAIN

An important issue in pig meat in PMMC's is assurance of origin (Wognum & van Erp, 2013). Assurance of the pig supply chain, thus improving traceability in the pig supply chain, improves credibility of extrinsic quality traits (Northen, 2000). Besides, it prevents fraud (e.g. relabelling of non-PMMC meat to PMMC meat) (Huisman & Van Ruth, 2014). DNA-tracing and RFID technique are the two ways of product tracing through the pig supply chain (Wognum & van Erp, 2013). Both technologies are however quite costly to use for following individual pigs (Dalton BV, 2017; Van Haeringen Laboratorium, 2017). Furthermore, for both technologies some issues should be fixed before they can help to verify origin of meat for 100%, as can read in section 5.9 (Wognum & van Erp, 2013)

1.3. BLOCKCHAIN TECHNOLOGY

The blockchain is a central database which is decentralized stored (Swan, 2015). Transactions that take place will be packed with other transactions in a block. So called miners check whether the transactions are correct according to the rules of the system. An example of such an check is that money cannot be spend twice (Drescher, 2017). Furthermore, a hash code for the block is calculated (see 4.2). After agreement of all miners, the block is added to the blockchain.

BT was first used as the technology behind cryptocurrencies as bitcoin, which was established in 2009. Other uses of BT are even newer, which can be illustrated by the fact that the English Wikipedia page of BT only was created at the 19th of May, 2015 (Wikipedia.org, 2017). Applications of BT are still in their early stage of development (Pilkington, 2015). However, many authors state that BT has a high potential to disrupt current supply chains, like e.g. (Smit, 2017). Implementing BT in the financial world could possibly save 15 to 20 billion dollars, because e.g. transaction costs drop and less employees are necessary (Shrier, Sharma, & Pentland, 2016).

Because of the newness of BT, not much scientific literature is present yet. This is especially within the agriculture and food sector, since only a limited amount of studies match the search queries "Blockchain AND agriculture" (five studies from 2017, 25 studies from 2018) and "Blockchain AND food" (three studies from 2016, seven studies from 2017, 37 studies from 2018) at Scopus.

1.4. PROBLEM DESCRIPTION

Fraud in PMMC's is bad for the credibility of the PMMC. Furthermore, chain partners can lose revenues when conventional products are unfairly upgraded to PMMC products (fraud). This decreases trust of chain partners in other chain partners. Trust is hard to get and easy to lose, thus assurance of trust for chain partners and consumers is of great importance for vital PMMC's.

According to Tian and Smit, blockchain technology (BT) is a high potential technology that can help to solve problems on credibility and fraud within Agri-Food supply chains by increasing transparency and traceability (Smit, 2017; Tian, 2016). This can be done by creating a supply chain broad information system in which individual animal products can be traced from *farm to fork*. The advantage of a SC information system supported with BT compared to a non BT-supported SC information system is the distributed ledger technology, which guarantees the integrity of the information in the system (Smit, 2017). However, since BT is very new and applications are still in their infancy, not much is yet known about the application of BT in Agri-Food information systems. This research will try to fill the knowledge gap on how fraud and credibility problems in PMMC's can be solved by implementing BT in SC information systems in those PMMC's.

1.5. PURPOSE

The purpose of this research is:

PURPOSE

To gain insight in how blockchain technology can be used to increase the success of PMMC's.

1.6. PROBLEM STATEMENT

MAIN RESEARCH QUESTION

How can Blockchain Technology (BT) help to increase the success of Dutch Pig Meat Market Concepts (PMMC's)?

In order to answer this main research question, six sub research questions have been formulated. Those can be divided in two groups and are formulated as follows:

PMMC's

1. How can success of PMMC's be defined and measured?
2. What is important information to share between partners in PMMC's?
3. What are the critical factors that determine the success of Dutch PMMC's?
4. What are challenges for current and future Dutch PMMC's from information management point of view?

Blockchain Technology in PMMC's

5. What are applications of blockchain technology in PMMC's?
6. What are challenges in applying blockchain technology in Dutch PMMC's?

All the results that are gathered in those six sub questions together will answer the main research question. A further elaboration on research methods will be given in the research methods chapter. In figure 1.2, the relationship between the main research question and the different sub research questions is visualized.

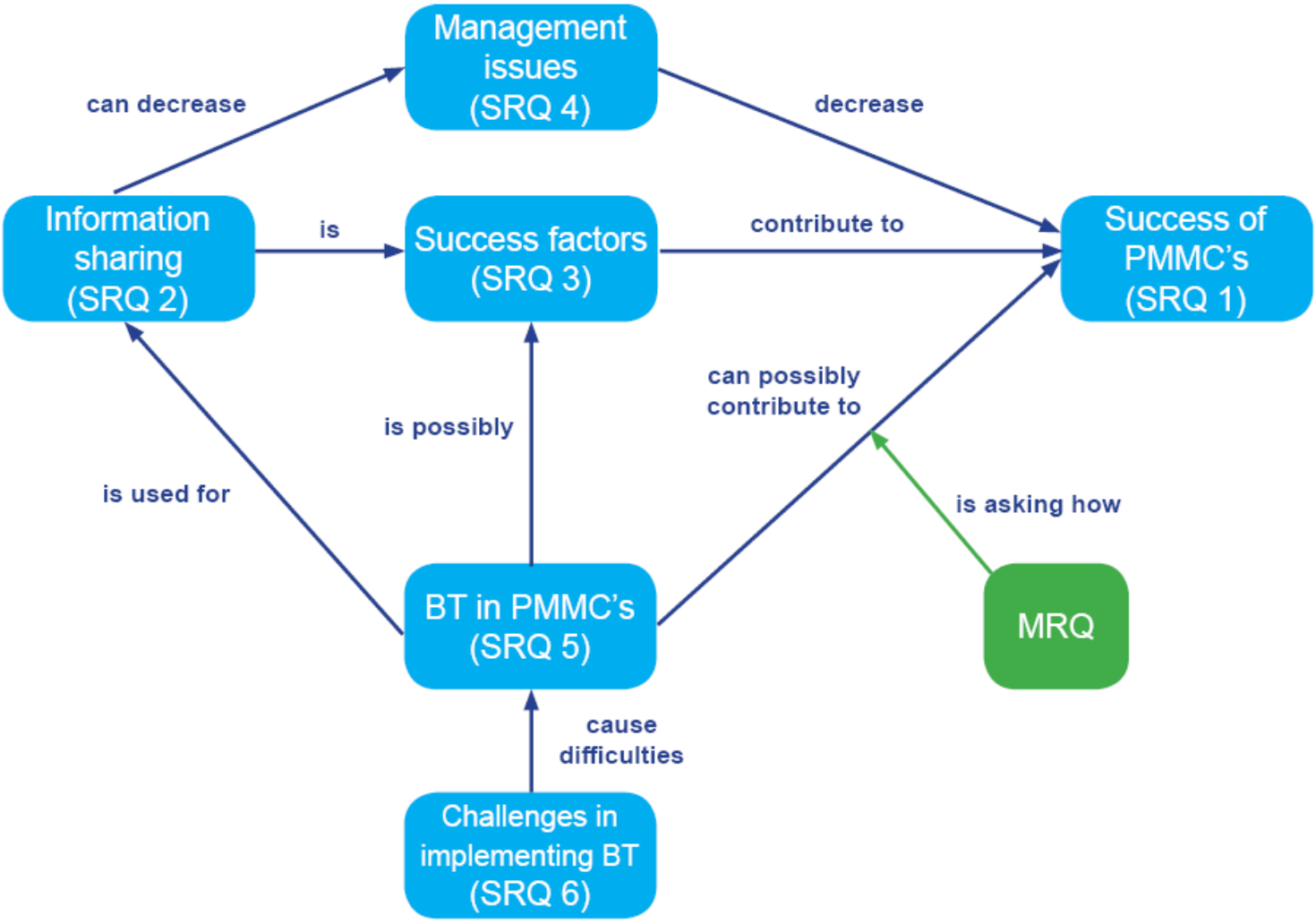

Figure 1.2: Visualisation of relationships between sub research questions and the main research question. Source: own elaboration.

2. RESEARCH DESIGN AND METHODS

2.1. STUDY DESIGN

Since the blockchain technology is relatively new, not much literature about application of this technology in Agri-Food is available at the moment. Therefore, this research is exploratory of nature. For exploratory research, qualitative studies are appropriate to use (Boeije, 't Hart, & Hox, 2009). Forman *et al.* described qualitative research as a discovery process (Forman, Creswell, Damschroder, Kowalski, & Krein, 2008). In table 2.1, the sub research questions (SRQ's) are given together with the research and analysis methods. The centre of gravity of this research lays in SRQ 5 and 6. Those topics on which the least information is available in literature.

Table 2.1 List of sub research questions with required data, research methods and analysis methods.

#	Sub Research Question (SRQ)	Required data	Research Method	Analysis Method
1a	How can success of PMMC's be defined and measured?	**Definitions of success of PMMC's**	Reading scientific and professional literature	Literature review
1b			*Conducting chain partner interviews*	*Transcription, coding and analysing interviews*
2a	What is important information to share between partners in PMMC's?	**Types of information shared between chain partners**	Reading scientific and professional literature	Literature review
2b			*Conducting chain partner interviews*	*Transcription, coding and analysing interviews*
3a	What are the critical factors that determine the success of Dutch PMMC's?	**Critical success factors of PMMC's**	Reading scientific and professional literature	Literature review
3b			*Conducting chain partner interviews*	*Transcription, coding and analysing interviews*
4a	What are challenges for Dutch PMMC's from information management point of view?	**Management challenges in PMMC's**	Reading scientific and professional literature	Literature review
4b			*Conducting chain partner interviews*	*Transcription, coding and analysing interviews*
5a	What are applications of blockchain technology in Dutch PMMC's?	**Applications of BT in PMMC's**	Reading scientific and professional literature	Literature review
5b			*Conducting expert interviews*	*Transcription, coding and analysing interviews*
6a	What are challenges in applying blockchain technology in Dutch PMMC's?	**Management challenges in setting up BT systems PMMC's**	Reading scientific and professional literature	Literature review
6b			*Conducting expert interviews*	*Transcription, coding and analysing interviews*

The SRQ's consist out of a literature part and an interview part. The results of the literature parts of each SRQ deliver the theoretical background that was used to put up the interview protocol for the second part of that SRQ. The interviews aim at finding new insights that are not yet present in scientific or professional literature.

2.2. LITERATURE REVIEW

To gain insight in success factors of PMMC's, scientific literature and documents or professional literature were reviewed. Professional literature include websites of chain partners, websites of concepts, magazines and news articles.

The literature review of SRQ 5a and 6a were done systematically. In table 4.2, the used keywords for scientific article selection are given. The first step of article selection was checking whether

the article is in Dutch or English. Secondly, the title and the abstracts of the found articles were read to check whether the article really could be useful. When this was the case, the full article was read. Possible interesting articles to which is referred by the research were found through snowballing.

Table 2.2: Keywords and numbers of hits, as of 26 April 2018.

Keyword	Number of hits	Combined with	Number of hits
Applications AND Blockchain	280	Food	11
Applications AND Blockchain	240	Agriculture	2
Blockchain AND Agriculture	4		
Blockchain AND Food	8		

2.3. INTERVIEWS

The results of the literature parts of the SRQ's were used to make an interview protocol and an initial code book. The (in-depth) interviews were done using a semi-structured interview approach. This approach was chosen to set a main structure to the interview but give the interviewee the chance to elaborate on concepts that are important but unknown to the researcher.

For the interviews, purposive sampling was used. This means that the respondents were not randomly selected, but especially selected because the researcher consider them as the best available useful sources (Forman et al., 2008). Purposive sampling is the main way of sampling that is used in qualitative research. By purposive sampling, some respondents were selected which also had interesting former working experience in a complete different role within the supply chain. Namely, one of the respondents was involved in trading, one in a meat processing company and a third in the financial world. This made it possible to cover a broad part of the supply chain, while the amount of respondents was limited because of availability and time issues.

In table 2.3, selected interviewees and companies are given. Because of the diverse backgrounds of the interviewees, a special question list was prepared for almost every interviewee (except for the blockchain experts). In appendix 1, the questionnaires that were used are given.

Table 2.3: Interviewed respondents and their employers

Type of company	Interviewee	Code	Date
Blockchain consultancy company	Blockchain specialist	E1	03-10-2018
Breeding company	Information specialist	G1	05-10-2018
PMMC chain director	Chain director	C1	08-10-2018
Feed company	Concept manager	F1	05-11-2018
Research institute	Blockchain specialist	E2	05-11-2018

The functions of the interviewees at their employers is mentioned in the respondents list, which can give readers clues why those respondents have certain knowledge or a certain opinion. Quotes from the interviews were used to illustrate the opinions of respondents, which improves clarity of the findings. However, the names of the respondents and companies could not be provided in this research, because of privacy considerations.

2.4. ANALYSIS OF INTERVIEWS

The concepts that were found during the literature review were used to set up a top-down code book (see Appendix II.a). This code book was used during the set-up of the interview protocols, in order to be sure to cover all topics found in literature.

After permission of the interviewee, the interview was recorded in order to be able to transcribe and analyse it well. The audio files were transcribed in Dutch, since all the interviews took place in Dutch. The transcripts were coded deductively, or using a top-down approach. That means, the codes are based on the results of the literature review. The codes used when analysing the interviews using a top-down approach can be found in appendix II.a. Besides, also inductive coding was used. Inductive coding means that new codes can be added in a bottom up approach because the researcher thinks that those concepts are important to take into account (Forman & Damschroder, 2007). In appendix II.b, the codes used in analysing the interviews in a bottom up approach can be found. The results from the interviews were used to answer SRQ 1b, 2b, 3b, 4b, 5b and 6b. In figure 2.1, this procedure is visualized.

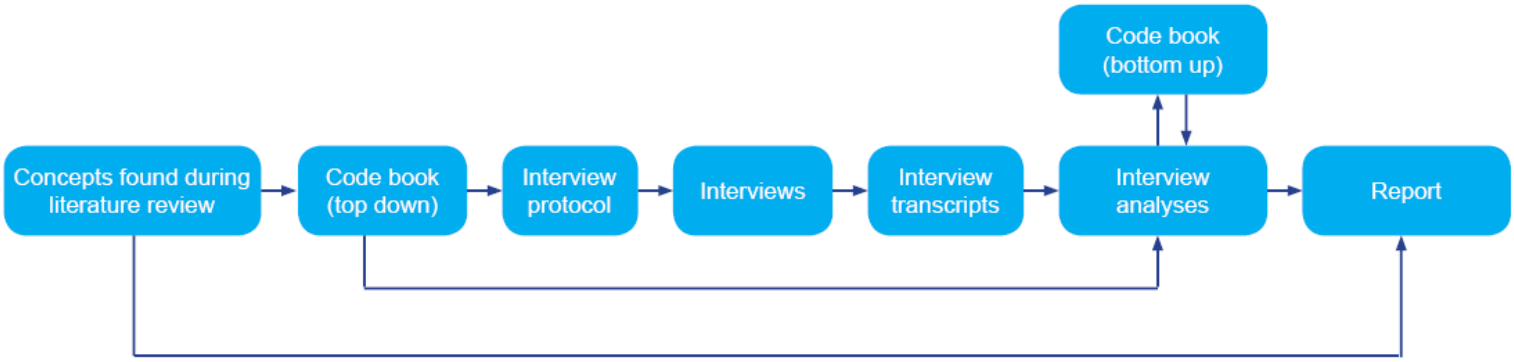

Figure 2.1: Used procedure in setting up and analysing interviews. Source: own elaboration.

3. THEORETICAL FRAMEWORK

In this section, literature about relevant concepts for this research will be presented. In paragraph 3.6, a conceptual model is set up.

3.1. AGENCY THEORY

The agency theory explains the relationship between principals and agents. An example of such an relationship is employer-employee, or insurer-insured person (Douma & Schreuder, 2008). The agency theory describes two problems in this relationship: conflicting interests and asymmetric information. The concept of asymmetric information was introduced by George Akerlof in 1970 (Akerlof, 1970). A further elaboration on asymmetric information will be given in paragraph 3.2.

An example of the agency theory: the agent has to fulfil the task that was imposed by the principal. The principle may estimate a certain task to last for four hours. The agent has to conduct the task and has additional information about the duration of the task, which is in this example three hours. When the agent is paid per hour, it is thus not in his favour to work very hard and finish the work in three hours instead of four. The principal however does not know that he pays too much salary, because he has not information about the duration of the task. In this example, both conflicting interests (maximal salary is in favour of the employee, minimal salary expenses is in favour of the employer) and asymmetric information (duration of the task is not known by the employer) play an important role.

The principal can designate a monitor to check the agent on work efficiency (Douma & Schreuder, 2008). However, two problems emerge. Firstly, paying salary for a monitor increases costs. Secondly, the monitor also may shirk (neglect) his task. So, a monitor should monitor the monitor. Since monitoring the monitor can be done endless, the end responsibility of monitoring should be given to the person who his reward is the profit minus all other costs (Douma & Schreuder, 2008). After all, if this person shirks his task he would have less income which is unfavourable for him.

Another solution for the endless monitor cycle problem is creating competition between different agents. When there is competition between different agents, an agent is more likely to increase the speed and quality of his work (Douma & Schreuder, 2008). Otherwise, he may lose the task to the other agent. Within supply chains, a lot of principal-agent relationships are serial interlinked (Lazzarini, Chaddad, & Cook, 2001).

3.2. ASYMMETRIC INFORMATION

3.2.1. THE PROBLEM

As said in paragraph 3.1, the principle of asymmetric information was described first by George Akerlof in the paper “The Market for Lemons” (Akerlof, 1970). The key of the paper is that uncertainty on the quality of products in a market can have big consequences on which products are sold in that market. There is no effort for a seller to sell an product with an above-average quality, because selling price is the average market price (Akerlof, 1970). The reason for this is that information on production quality is lacking, or not perceived as credible by consumers.

However, there is effort for the seller to sell a product with a below-average quality against market price. Since customers cannot distinguish good and bad quality products, they will buy less products. Therefore, market price drop. For sellers of good products, it is not attractive anymore to sell their products in the market. Thus, they withdraw their products from the market. Thus, information asymmetry makes prices drop and market volume shrink (Akerlof, 1970). The outflow of good quality products and product sellers caused by this effect is called adverse selection.

In such a situation of information asymmetry, customers have to put additional effort in obtaining enough information on product quality. This results in additional transaction costs (see paragraph 2.3). Furthermore, there is a relationship between theory on asymmetric information and the agency theory. When a customer could not get good insight in product quality, it is for a seller not necessary to sell good products to customers.

3.2.2. POSSIBLE SOLUTIONS

There are different ways, or institutions, to decrease the effects of information asymmetry on quality (Akerlof, 1970). Firstly, guarantees can be provided. Sellers will not give much guarantee on bad products, and buyers will prefer products with much guarantee on it. Secondly, companies can build a certain (good) reputation with their products (Akerlof, 1970). This reputation can be expressed to customers by setting up a brand. In this way, the reputation of the product is communicated via the brand (Akerlof, 1970). For example, people may prefer MC Donald's restaurants above local fast-food restaurants, because they have a reputation of providing a fixed level of quality in every restaurant. Important then is that the brand is credible so that customers trust a brand in delivering constant quality. Because the MC Donald's brand is perceived as credible by consumers, it functions as an institution for consumers.

Thirdly, a system of licensing may be used to accredit sellers of good quality products and thus provide trust for customers (Akerlof, 1970). The role of licenser can be taken by either governments or private organizations. However, having the monitoring role in a certain role gives organizations a lot of power (Akerlof, 1970). Furthermore, monitoring will cost money, which should be paid by monitored parties, parties who profit from this monitoring or the government.

The function of spreading information through the supply chain in order to decrease information asymmetry could be conducted by a central information system, supported by blockchain technology (Shrier et al., 2016). The information system can be compared with a database programme like Microsoft Access, the blockchain technology as a module that sets additional rules for data handling and changing in the database. Because of the better information quality and flow through the supply chain, fraud decreases and credibility and trust increase. Furthermore, monitoring costs will decrease when this function is fulfilled by the blockchain. However, data follows the *garbage in, garbage out* principle. So, when incorrect data is entered into the blockchain, the data never gets better than what is entered into the system. However, because more information sources can be better compared with a central data system, it gets easier to find mistakes or cases of fraud. More about this can be found in chapter 4.2.3.

3.3. TRANSACTION COST THEORY

Transaction costs (TC's) are costs that are made to come up to a transaction. TC's should be counted up to the normal production costs in order to get a complete overview about the costs of a product of a service (Douma & Schreuder, 2008). TC's within companies are normally lower than TC's between companies.

A lot different in between strength of relationship of parties conducting a transactions exist (Williamson, 1979). The freest one is a pure market transaction, in which parties are hardly known to each other. This kind of relationship has the highest TC's. The relationship with the lowest TC is the hierarchical relationship, in which the transaction is conducted within the same company (Williamson, 1979).

According to MacNeil, the purpose of contracts is to facilitate exchange (MacNeil, 1973). This is necessary since transactions cause friction between firms (Hobbs, 1996). Thus, the contract has the function to decrease risks (Williamson, 1979). Costs of transactions can be separated into three kinds of costs, namely costs to gather information, costs on negotiation and costs on monitoring. The costs on gathering information are e.g. the hourly wage for the time in which different suppliers are compared with each other. Negotiation costs include e.g. the actual negotiating, the setup of a contract and possibly the hiring of a third party like a notary or auctioneer to function as an intermediate in the transaction (Hobbs, 1996). Thirdly, monitoring costs involve costs that are made when e.g. it is checked that the other party comes to the agreements from the contract. Furthermore, quality control of obtained products involves costs. The legal enforcement of a contract that was broken is another cost item that can be placed under monitoring costs (Hobbs, 1996)

At the basis of the transaction cost theory, four other concepts are present (Hobbs, 1996). Firstly, bounded rationality is mentioned. This means that in complex situations a human is not psychical capable of taking into account all different possibilities (Douma & Schreuder, 2008). An example is a chess match, in which all pieces are visible, but evaluation of all possible options is hardly possible.

Secondly, in every transaction there is a risk that parties have opportunism, i.e. they exploit a certain situation in their advantage (Hobbs, 1996). An example is a situation with an unequal power ratio because of a big difference in number of suppliers and buyers. For instance, since there are not so many retailers in the Netherlands compared to a lot different pig farmers, it is easily for the retailers to exploit this power difference by not coming to previous made agreements or add additional requirements to product or production methods.

Thirdly, asset specificity is an important concept within transaction cost theory (Hobbs, 1996). The production of specialized products is an important source of value creation in supply chains (Subramani, 2004). An example: Firm A produces a specialized product for firm B. However, B acts opportunistically and reduce buying price, because it knows that the products of firm A could not be sold to other firms than firm B (Hobbs, 1996). Hobbs calls this opportunistic behaviour of B opportunistic recontracting.

Fourthly, information asymmetry is important in transaction cost theory (Hobbs, 1996). This theory of George Akerlof was already handled in paragraph 3.2, but now it will be applied on opportunistic behaviour and transaction cost theory. Two kinds of opportunism may rise from information asymmetry, namely *ex ante* and *ex post* opportunism. The first kind of opportunism is involved in the adverse selection that was developed by Akerlof and already handled in paragraph 3.2 (Akerlof, 1970). The other kind of opportunism, *ex post* opportunism, is called moral hazard. An example is that insured persons are not very careful in preventing damage, because they know that damage is reimbursed by the insurance company (Hobbs, 1996). A possible way to decrease this effect is the use of an own risk rate, which is paid by the insured person before the insurance company starts paying.

3.4. SUPPLY CHAIN MANAGEMENT

Benton and McHenry defined supply chain management (SCM) as the management of a network of interconnected businesses involved in the provision of product and service packages required by the end customers in a supply chain (Benton & McHenry L.F., 2010).

In SCM, all storage and movements of materials, inventories, finished goods from their point of origin to their point of consumption are included (Fawcett et al., 2013). SCM tries to make the cost of storage and movement of products and services through the supply chain as low as possible. Examples in

which ways this can be derived are efficient allocation of production facilities and an appropriate purchasing strategy, to that there will not be costly surpluses or shortages of products. Furthermore, increasing the efficiency of logistics is important in SCM. The difference between TC theory and SCM theory is that the first focusses on lowering (potential) costs in individual transactions, while as the second theory focusses on lowering costs in the whole supply chain (Williamson, 2008).

Information systems contribute in realising efficient supply chains (Subramani, 2004). For example, the bullwhip effect decreases when information is well spread (Bray & Mendelson, 2012) The bullwhip effect causes a disproportionate increase or decrease in demand of upstream supply chain partners, caused by a lack of information on small changes of demand down in the supply chain (Fawcett et al., 2013). Thus, a lower bullwhip effect stabilizes production (Bray & Mendelson, 2012). Furthermore, a good information system can decrease TC's and therefore provide competitive advantage that works inter-organizational (Subramani, 2004).

3.5. QUALITY MANAGEMENT

The most common definition of quality that is used nowadays is described by Juran: "Quality is fitness for use" (Juran, 2003)(p15). Attributes of the product that do not contribute to the functionality of the product may be important for customers to fulfil their needs (Kianpour, Jusoh, & Asghari, 2014).

In Agri-Food, functional and non-functional are better known as respectively intrinsic quality traits and extrinsic quality traits (Van Stokkom & Kamps, 2014). Examples of intrinsic quality traits are e.g. colour, leanness and marbling of the meat, while as country of origin, price, quality/brand assurance labels and place of purchase are extrinsic quality cues according to consumer research of Henson, Northen and others (Henson, Northen, Schiefer, & Helbig, 1997). Because extrinsic quality traits are not measurable in the end product (meat), it is important to assure them by a good information system in the pork supply chain (Balendonck, Bruins, Hogewerf, & Ipema, 2003). Without a clear and credible information system, information asymmetry emerges between the seller and buyer (Akerlof, 1970). This has a negative effect on product images, product prices and market size.

Processes within the supply chain can have a big effect on intrinsic quality cues of meat (Northen, 2000). For example, a too high temperature during transportation of meat can reduce shelf life of the meat. Assuring supply chain variables that influence intrinsic quality cues in a management system, for example a management system supported by BT, may increase overall product quality and credibility. Quality assurance schemes can help in communicate information about extrinsic quality cues to consumers and thereby providing trust (Spriggs, Hobbs, & Fearne, 2000). However, the quality management system then should be credible and inspections that make sure rules are respected should be trusted by the consumers.

By implementing quality management systems, a lot of technical data on products and processes within Agri-Food supply chains can be gathered. However, this information is often not usable by consumers because it is quite technical (Northen, 2000). Therefore, a lot of the data on quality that is collected in the supply chain is mainly meant for downstream chain partners in order to determine the quality of the received products. A good quality assurance systems is useful for supply chain partners, since it decreases transaction costs (Trienekens & Zuurbier, 2008).

Furthermore, Northen states that effective communication between supply chain partners can reduce costs on quality assurance (Northen, 2000). This may provide possibilities for implementing BT, since in a central database variables on production processes can be stored and quality can be better

monitored. This possibly also encourages chain partners to improve quality of products they deliver, because they are no longer anonymous producers of anonymous products.

3.6. PRELIMINARY CONCEPTUAL FRAMEWORK

The preliminary conceptual framework derived from the literature study is graphical visualized in figure 3.1. The pluses and minuses between factors determine whether there is a positive or a negative correlation expected between them.

The reason that conflicting interests and information asymmetry are together in one box is that the combination of those both factors result in fraud, transaction costs and a decreased level of customer perception of quality. Without conflicting interests, there is no reason for fraud. Without information asymmetry, there are no transaction costs. And consumers might probably perceive quality of products of a PMMC higher when chain partners agreeing with each other instead of having conflicts with each other.

The preliminary conceptual framework severed as input for the literature research, which at its turn was the input for the top-down code book that was used to set up the interview protocols. In appendix III, more information about the operationalisation of the conceptual model can be found.

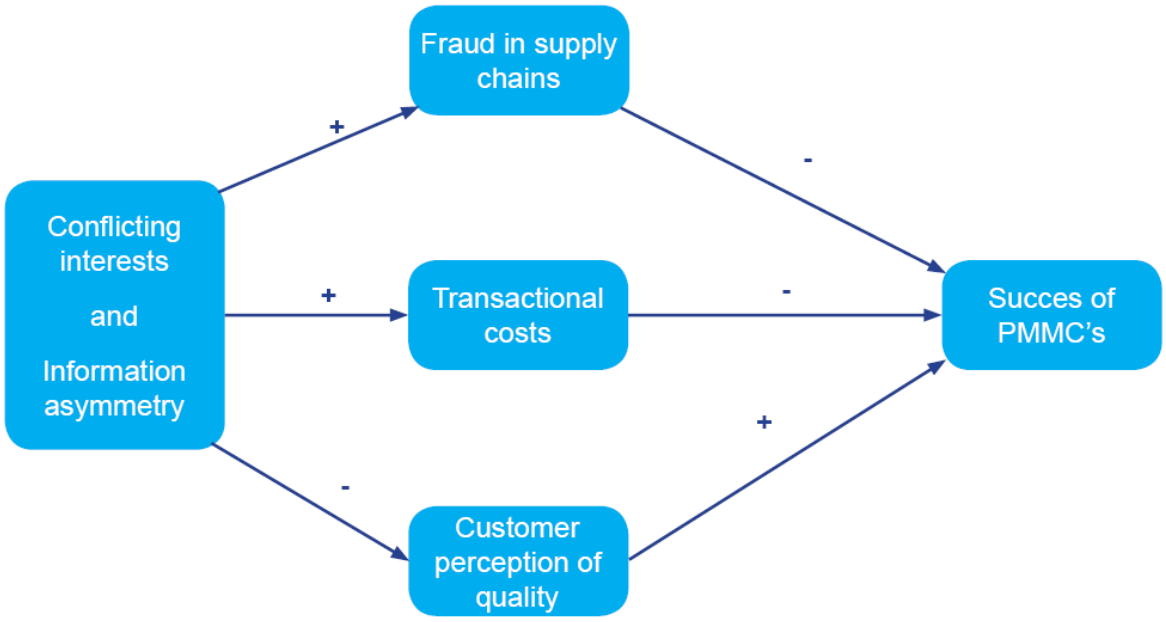

Figure 3.1: Preliminary Conceptual Framework. Source: own elaboration.

4. BLOCKCHAIN TECHNOLOGY

4.1. INTRODUCTION

In chapter 4, general information about the possible applications of blockchain technology is given. This information is quite technical and not directly related to blockchains in Agri-Food systems. Therefore, it is treated in a separate chapter before chapter 5, which contains the results of this research.

4.2. TECHNOLOGY BEHIND THE BLOCKCHAIN: HASH CODES

From the input data, a hash code is calculated (Swan, 2015). This hash code is a unique derivative of the data with a fixed number of characters. Because of asymmetric cryptography, it is almost impossible to calculate the original data from a hash code (Drescher, 2017). Even the smallest change in the input data, like a change of a capital letter to a lower-case letter, will result in a complete different hash code. This is important, since it makes the data which is represented by the hash code unchangeable without changing the hash code. Besides, it is important that it should not be possible to predict the hash code from the original data (Drescher, 2017)

The block that is added to the blockchain contains at least the hash of the block, the hash of the previous block and a timestamp in order to determine the order of the blocks (Drescher, 2017). Since in blockchains all blocks refer to the hash of the previous block, a change of a hash somewhere in the chain will result in a discontinuous chain. This is not allowed by the protocol of the blockchain, so the adapted block is rejected. This principle is the basis for the infeasibility of unauthorized changes to data in the blockchain. Note “infeasibility” instead of “impossibility” since theoretical it is possible to change a blockchain when a party has more than fifty percent of the computing power within the blockchain (Tian, 2016).

4.3. FRAUD PREVENTION AND TRUST ASSURANCE

Since data in the blockchain is not changeable and data is only added when it meet the rules of the blockchain, fraud becomes hardly possible (Hackius & Petersen, 2017). In conventional systems, third parties like governments, the cadastre, banks, notaries or other private organizations have the role of approving transactions. Those parties check that every party comes to his agreements. Thus, they provide the trust within the agreement. In a system with a blockchain, the blockchain serves as a third party that approves transactions and therefore provides trust in business partners. So, the governments, cadastre, banks, notaries and other private organizations are not necessary anymore to confirm and monitor transactions and become superfluous (Drescher, 2017). This decreases costs of transactions. Besides, because less trust in the other party is needed, trade with less known or unknown parties is made safely possible (Drescher, 2017).

However, the principle of garbage-in garbage-out is also in systems with a blockchain important to consider (Ge et al., 2017). When incorrect data is put into the information system, the output data is also not credible. For example, it may be possible to enter 13 piglets in the information system instead of the 15 piglets that were born when this would be favourable for the farmer. However, transparency improves in blockchain systems and cross-linkages of data are easier to conduct (Ge et al., 2017). Since data input, output and sharing of data becomes more transparent and quality of information gets better, it becomes easier to find cases of fraud.

4.4. SMART CONTRACTS

Smart contracts (SC) are another high potential application of BT (Smit, 2017). Swan (2015) mention smart contracts as a 2.0 application of blockchains, between cryptocurrencies (1.0) and beyond-

financial applications, like e.g. copyright assurance or applications in PMMC's (3.0). In order to execute a SC, all relevant variables should be digitally available (Swan, 2015). As a side effect, this storage of data in the blockchain makes the (independent) variables, and thus the (dependent) contract, tamper-proof (Mattila, 2016).

Smart contracts work fully automatically. When all requirements for a certain transaction from a SC are fulfilled, the asset changes automatically from owner. Compared to normal contracts, there is no trust in the other party needed about them fulfilling their commitments from the contract. After all, this trust is assured by the BT behind the SC and the contract is conducted autonomous (Swan, 2015).

4.5. DISADVANTAGES OF THE BLOCKCHAIN

Besides all aforementioned advantages on preventing fraud and assuring credibility in supply chains, there are also some disadvantages. Firstly, since the monitoring role is taken by the blockchain, it is not necessary for third parties anymore to fulfil this role and many jobs will be lost (Drescher, 2017). Secondly, since data in the blockchain is open available for the public (in open blockchains) or other partners (in closed blockchains), the level of privacy decreases. This is mainly a problem for companies who have trade advantages because of information asymmetry between them and their suppliers and customers (Akerlof, 1970). Implementation of blockchain technology can result in complete different hierarchies and power relationships than nowadays the case is (Swan, 2015). This development is not per definition wrong, but it can have far going social consequences. Lastly, open blockchains are often considered as not environmental sustainable, since a high amount of energy is used by the mining computers (Swan, 2015).

5. RESULTS

5.1. INTRODUCTION

In this chapter, the results of the literature study (SRQ 1a to SRQ 6a) and the results of the empirical research (SRQ 1b to SRQ 6b) are presented. The outcomes of the literature study served as input for the empirical part of the research: they were used to create the different lists with interview questions.

The interviews were transcribed and analysed using the code book that was made out of the results of the literature study (top-down). Furthermore, when unknown concepts emerged out of the empirical research, they were added (bottom-up). Combining top-down and bottom-up coding makes it possible to analyse interviews in-depth (Saldaña, 2014). In doing so, insights were acquired which were used to answer the research questions.

In this chapter, for every discussed topic the relevant literature is given first. Thereafter, the opinions of the respondents are given. Thereafter, similarities and differences between the literature and practice are discussed.

An overview of the interviews that were held is presented in table 5.1. This table is equal to table 2.3 in paragraph 2.3, where more information about the sampling and interview procedure can be found.

Table 5.1: Overview of interviews and respondents

Type of company	Interviewee	Code	Date
Blockchain consultancy company	Blockchain specialist	E1	03-10-2018
Breeding company	Information specialist	G1	05-10-2018
PMMC chain director	Chain director	C1	08-10-2018
Feed company	Concept manager	F1	05-11-2018
Research institute	Blockchain specialist	E2	05-11-2018

5.1.1. CONTRIBUTION OF RESPONDENTS TO PMMC's

Respondents G1, C1 and F1 were asked: "In which way do you contribute to PMMC's?". They mentioned several ways in which they are able to contribute to PMMC's. The breeding company can select boars which inherit specific traits that are interesting for a PMMC, by creating e.g. a custom breeding index. Those boars are always part of the general population; it is not economically interesting to create a special pig breed for a certain PMMC. Furthermore, the breeding company could play a role in tracing of PMMC pigs through the supply chain by giving support on individual animal registration and DNA tracing of pigs and meat (e.g. facilitation of sample analysis process, creating pedigrees).

Farm supplying companies are interested in how they could support PMMC's. For example, one of the respondents was especially hired to manage all affairs with PMMC that are present within the company. The respondent advises other chain partners like farmers, and contribute in PMMC-pilots on behalf of the company to gain knowledge about the do's and don'ts in PMMC's. One of the respondents described that the responsibility of a company is different when they are producing in a PMMC, compared to their responsibility in a non-consolidated supply chain. Namely, working together on a successful result is namely even more important in a PMMC than in a non-consolidated supply chain according to the respondent.

When the respondents F1 and G1 were asked for their revenue model on PMMC's, it turned out to be that PMMC revenue models of their companies do not differ that much from revenue models on

conventional farms. Thus, the farmer pays the feed company for the feed and the genetic company for the semen. However, sometimes a price premium is involved, when e.g. boars are especially reserved for usage by the PMMC. Additional services, like facilitating a DNA-tracing program, can be billed to the PMMC via the chain concept manager. At their turn, chain concept managing companies (like the company of respondent C1) can give out licenses, so every user of the meat pays a premium for that usage to the chain concept manager.

5.1.2. READING GUIDE

In paragraph 5.2, the results on what success of PMMC's is (SRQ 1) are presented. Thereafter, success factors (SRQ 3) and challenges (SRQ 4) of PMMC's are discussed in section 5.3 to 5.6. Section 5.7 deals with transparency issues of supply chain. Section 5.8 handles what information is important to share between chain partners (SRQ 2). In paragraph 5.9, DNA and RFID techniques are discussed, which can support blockchain supported information systems. In paragraph 5.10-5.13, applications of BT in PMMC's and issues on those applications are discussed (SRQ 5 and 6).

5.2. DEFINITION OF SUCCES

5.2.1. LITERATURE

In the sub research questions, the term success is several times used. Furthermore, it is the goal to find out how success of Dutch PMMC's can be increased by help of using BT. Therefore, it is important to have clear what success is. However, giving one general definition of success is difficult (Goldenberg & Kline, 1999). In many definitions, economic performance is included. Also survival of the business and winning of the big game are mentioned (Collins-Dodd, Gordon, & Smart, 2003). Nash and Stevenson distinguished four different dimensions of success: achievement, happiness, legacy and significance (Nash & Stevenson, 2004). So, success is multidimensional. HBS Business defines a successful business as: *An organization that makes current customers happy and gets new customers while earning a profit (Hersch, n.d.) (p3).*

5.2.2. INTERVIEWS

Respondents were asked: "When is a PMMC successful according to you?" There were some different views on when a PMMC is successful. One of the respondents describes success of the PMMC he is involved in as a stream of about 5000 pigs per week, which are completely valuable under the label of the PMMC. This opinion corresponds to the opinion of several other respondents, which described that creating valuable products should be a more important goal than solely generating profit. As one of the respondents described:

[A PMMC is successful...] *...when people buy the products and it is relevant for a consumer. If consumers do not see the added value and thus do not spend money on it, a PMMC is not successful. It should be relevant. – (F1)*

5.2.3. DISCUSSION

There is a striking difference between the view of literature and the view of respondents on a definition of success. In literature, economic performance is one of the most important things mentioned. At a second place, consumer satisfaction is mentioned. Respondents mention the creation of valuable products for consumers as the most important definition of success. Making profit is for them only the second most important factor in calling a PMMC successful.

5.3. SUCCESS FACTORS OF PMMC'S

In order to answer the main research question, success has to be operationalized into success factors that are definable and measurable. Success factors are thus variables which influence success (Collins-

Dodd et al., 2003). A complete list with factors that are correlated to a greater or lesser extent with success of PMMC's would however be almost infinite long. It thus is important to focus only on the most important success factors.

Since this research deals about information issues in supply chains, the focus of this chapter is at success factors that handle this topic. Some other success factors will however be mentioned too, since are the key success factors of PMMC's according to several authors. The overview about success factors and challenges of PMMC's will be given in the discussion sections of paragraph 5.3 – 5.6.

5.3.1. LITERATURE

PMMC's are created to get an exception position within the pig meat segment, in order to decrease competition and increase profit (van Vliet & van den Brink, 2011).

Starting a new PMMC or early adopting a PMMC can be an advantage compared to stepping in later, since at the beginning important decisions on e.g. chain strategies are made (Van Der Schans, 2004). Creating a successful PMMC requires the input of a lot of energy, financial investments and research by the involved parties (Stichting Vlees.nl, n.d.; van Galen et al., 2011). Because of those investments, it is essential that a PMMC gains enough market volume at which the cost price of products is relatively low and the PMMC is economically viable (van Galen et al., 2011; van Vliet & van den Brink, 2011). This can only be done when the PMMC is producing on base of a clear market demand.

Important is that the products of the PMMC should nowadays be differentiated from conventional products, but also in the future (Sukkel & Van der Waal, 2007). Since retailers (supermarkets, but also butchers) are selling the products towards consumers, it is important to involve them in an early stage in PMMC development (van Vliet & van den Brink, 2011). For retailers, collaboration in a PMMC might be interesting because of the increased societal pressure on animal friendly production (van Galen et al., 2011).

Farmers should carefully think about their wish to produce in a PMMC because not only additional costs are involved, but also additional craftsmanship which is not always easy to acquire (Verbong, 2006). Trust in the market for the PMMC products is important (Sukkel & Van der Waal, 2007).

Different authors describe that a PMMC should be mainly market-driven, and have enough market volume (Sukkel & Van der Waal, 2007). Thus, a good consumer research should be done (van Galen et al., 2011). In those niche markets, creating a total market concept with every aspect of the product and production process taken into account is important (Wognum & van Erp, 2013). In order to do this, chain partners should work closely together (Murk & Grievink, 2013). When products are produced that have an added value for consumers, the PMMC might able to set a premium on their products (Verbong, 2006).

Creative marketing can help in getting a successful PMMC (van Vliet & van den Brink, 2011). Some ways in which this could be done is by creating a good slogan, smartphone app, making the farmer visible and put attention on societal sustainable production.

Traders, slaughterhouses and supermarkets play a key role in increasing insight in the market, sale of switching products, agreements on sales guarantees, acquisition of new producers and communication to the existing producers (Sukkel & Van der Waal, 2007). Banks also play an important role in starting up PMMC production locations, by giving financial support for switching farmers and providing capital for investments at existing farms.

When the PMMC has enough sales to increase the production and expansion of existing production facilities is not possible, new entrepreneurs should be found to enter the PMMC (Sukkel & Van der Waal, 2007). It is important to give one of the chain partners the primary responsibility for attracting new chain partners to the PMMC. Possibly, a chain director can fulfil this role. In order to make it easier for new entrants to start producing in the PMMC, an information platform with knowledge on production process may be useful (Verbong, 2006).

GUARANTEES FOR FARMERS

Often, the only party in the supply chain that fully moves from a conventional production system towards a PMMC system is the farmer (Van Der Schans, 2004). This involves great risks for the farmer, since the farmer stays behind with expensive production facilities in case of failure of the PMMC. Therefore, it is important to guarantee a certain amount of sales (Sukkel & Van der Waal, 2007). The guarantee on sale of products with a price premium can be set for a certain pre-agreed period, for example two years (van Galen et al., 2011). Costs should be carried by chain partners together.

INCREMENTAL INNOVATION

Important is that the innovation towards a PMMC is done in small steps (van Galen et al., 2011). This gives consumers and producers the possibility to get used to the products and way of production. Furthermore, consumers show more interest to buy the PMMC products when there is only a limited price distance between PMMC products and conventional products (van Galen et al., 2011). Van Galen *et al.* mention 20 to 25% as a good maximum price distance. Thus, the additional costs that can be made for PMMC products are limited.

Increasing the amount of sales of the PMMC should be done gradually, on basis of a clear demand from the market. Verbong (2006) states that a market-driven organisation leads to better efficiency of the organisation and a lower amount of costs. Maintaining a market-driven concept also implies that the PMMC is dynamic, thus is able to adapt the products and production processes to a changing demand from the market (van Galen et al., 2011). This requires flexible attitudes of entrepreneurs, since they need to agree with the fact that they have to do investments to meet up with the stricter rules that are set for products and production methods of the PMMC.

NETWORK OF SUPPLY CHAIN PARTNERS

Many different authors mention a good network of supply chain partners in order to set up a successful PMMC, e.g. (Verbong, 2006). Hereby, it might be useful to look how other sectors in Agri-Food have organized this (van Vliet & van den Brink, 2011). All actors in the supply chain, from farmer to supermarket should be included in order to valuate products and make this valuation lasting for a longer time (van Galen et al., 2011). Some authors mention chain collaboration as essential in order to come to an added product value (Wognum & van Erp, 2013), or better selling prices for farmers (van Vliet & van den Brink, 2011). In many supply chain wide collaboration initiatives (like PMMC's), one party is designated as chain director (Van Der Schans, 2004). A chain director can implement initiatives that are affecting and influencing the whole supply chain, like DNA-tracing in PMMC's (Wognum & van Erp, 2013). Furthermore, they might be able to limit the amount of production so that it matches the amount of sales. For that amount of production, sales guarantees can be given to producers (Sukkel & Van der Waal, 2007). When the production is too low to fulfil the demand, the chain director can look for new PMMC producers. However, the chain director only has an initiative taking role, i.e. all other chain partners also should work together in order to create lasting valorisation of PMMC products (Wognum & van Erp, 2013). Besides, the chain director should

not have too much power because this would decrease the dynamic collaboration between different chain partners (van Galen et al., 2011).

QUALITY ASSURANCE

An important success factor for PMMC's is the assurance of quality (Verbong, 2006). Guarantees about origin and quality of meat (extrinsic quality traits) are of great importance in communication towards consumers (Wognum & van Erp, 2013). Preferably, product quality should be expressed by a quality mark (van Vliet & van den Brink, 2011). However, because nowadays there are already a lot of different active quality systems in the pig meat segment, it is difficult to stand out on the competition. A creative marketing could help with this (van Vliet & van den Brink, 2011).

5.3.2. INTERVIEWS

Like described in the literature study, many success factors for PMMC's are obvious. For example, chain partners need to trust each other and sometimes put their own interest on a back burner because of a different interest of the whole PMMC. As one of the respondents describe:

Operating in a chain (...) requires other things of a company then just selling products and: "just see what you do with it". In a chain, you have a somewhat different responsibility. – (F1)

Respondent C1 describes that the products of a PMMC should have a high quality and should be tasteful. Health and a minimum amount of stress for the piglets can contribute to these factors. Respondent E1 stated explicitly:

Tracing of origin is the key to a successful concept. – (E1)

EFFICIENT PROCESS OF PIG FARMING

According to respondent C1, an important requirement in setting up a PMMC is that the basic production process of pig farming is controlled well. Having an efficient farming process increases production and saves money. Thus, a sow is inseminated, about 115 days later the piglets are born, about 147 days after the insemination (in conventional systems) the sow is inseminated again and ten months after the insemination, the piglets go to the slaughterhouse. The process duration of sow farming could not further be shortened because then legal and natural borders are crossed. When one wants to further increase the production per sow, he thus should look to other factors to improve than decreasing the cycle duration.

Furthermore, respondent C1 describes that besides being efficient in the process of pig farming, a PMMC should have an efficient overall process. So, the amount of produced piglets should match the amount of meat that can be sold under the flag of the concept. Besides that, the pigs, carcasses and meat should be at exact the right place, at exact the right moment.

Information sharing generally leads to a more efficient production process. Respondent F1 mentions that an efficient production process, by e.g. an increased level of collaboration between supply chain partners, lead to a lower cost price of products. However, respondent E1 states that improving the information flow in a supply chain costs a lot of effort and money. Producing in a PMMC creates the need for collaboration between supply chain partners. Respondent E1 describes this as

"In a non-consolidated supply chain, application of blockchain could be a good way to share information between supply chain partners." – (E1)

Limiting the amount of involved chain partners is another way to keep overview over the distribution of the products. One of the respondents describe that working with one central, bigger meat distributor provides more overview about the distribution than collaborating with several smaller parties does. At such a central distributor, a cross dock logistic system can be implemented more easily. This means that all the products are coming in (as carcasses) and are without a long storage time cut into consumer-ready pieces of meat and repacked into smaller packages that go directly to the retailer or end customer. This results in a clearer distribution process, which increases possibilities for traceability.

CRITICAL MINIMUM SIZE AND COST PRICE

Generally, processes at a large scale could be conducted more efficient and (additional) costs could be lower per kilogram of product produced. Respondent C1 mentions as example that costs of an air washer per kilogram of meat are lower at a big farm compared to a small farm. However, this also have its downsides, because many citizens do not like mega stables. Therefore, farms should not grow bigger than the maximum size that is accepted by the environment. The respondent mentions that balanced farming is important, with attention for the interests of pigs, farmers, consumers, and the environment and other stakeholders so that welfare, the environment, efficiency and cost price get an equal amount of attention.

However, he describes that a PMMC should have a certain critical minimum size in order to prevent unnecessary production costs. For instance, transport costs per pig are much higher when a truck is filled half than when a truck is fully loaded with pigs. Those transport costs should be paid, but do not have any effect on the final product. So, a certain minimum size is necessary to decrease production costs to an acceptable level.

In one of the interviews it came out that producing in a PMMC does not automatically mean that the cost price of products is higher. By close collaboration between supply chain partners, the cost price of products could drop. Possibly, the cost price of PMMC products (with additional measures in the production process) even is lower compared to the cost price of conventional products because of the collaboration between chain partners.

CONTINIOUS PRODUCT QUALITY

Respondent C1 described that it is of big importance that products produced by the PMMC are of continuous quality. Even the smallest changes in the product process may have a large influence on the quality of the final product. It may sometimes be hard to find out what exact cause have changed a change in the quality of a product. One of the respondents illustrated the influence of a small production process change on the quality of the final product with an example:

> *Once a slaughter called me that the meat was much wetter, and he asked what had changed in the production process. Nothing, the respondent thought, until he noticed that the employee of the slaughterhouse who receives the finished pigs was on a vacation. The man who replaced him treated the pigs quite rough, which gave the pigs a higher stress level. This worked out in the meat quality negatively: the meat became much wetter. – (C1)*

5.3.3. DISCUSSION

In table 5.2, the most important success factors from section 5.3 are given. Several success factors from literature were not identified as success factors during the analysis of the interviews. Those topics were discussed during the interviews, but not identified as a success factor by respondents. For example, having an introduction program for new entrants and involving retailers were discussed

during the interviews but not explicitly identified by chain partners as essential factors that contributes to success.

Table 5.2: Success factors for PMMC's from section 5.3.

Concept	Literature	Respondents
Invest time, money, research and energy in setting up the PMMC	yes	
Having trust in the PMMC and PMMC partners	yes	
Being guaranteed of sales of products for several years	yes	
Having a chain director	yes	
Having an introduction program for new chain entrants	yes	
Having a creative marketing	yes	
Close collaboration of a network of chain partners	yes	
Involve retailers (butchers, restaurants, supermarkets) in the PMMC	yes	
Quality assurance of products	yes	
Little (cost) price distance to conventional products	yes	C1
Ongoing product innovation, adapted to market demands	yes	C1
Critical minimum market size	yes	C1, F1
Produce on base of a clear market demand (create added value for consumers)	yes	F1, C1
Continuous product quality	yes	C1, E1
Efficient process of pig farming		C1, F1

Respondent C1 mentioned that an efficient process of pig farming is important, and that there is a certain limit on this efficiency. However, efficiency of finishing pig farming was not discussed in the interview. This process can be made more efficient by a higher growth of the pigs, which shorten the duration of finishing a batch of pigs. However, also at finishing pigs there are legal and natural borders applicable which set the maximum efficiency to a maximum level.

Respondents stated that creating a constant supply of pigs is important for a PMMC to prevent shortages or oversupplies. However, production of (and by) life animals cause always uncertainties in the production process. This problem is especially involved in the first four months of the pig production process. For example, when many sows are returning or staying empty after insemination, there can be a shortage of finished pigs ten months later. In reverse, when in a week group a lot of sows get 18 piglets and some foster sows can be made, an oversupply of finished pigs could develop after ten months. Because of the difficultness of predicting the exact number of finished pigs from a group of e.g. ten inseminated sows, it is very hard to predict the number of finished pigs at a certain moments before the piglets are a few days old.

5.4. OUTLINE OF THE SUPPLY CHAIN

In this section, issues on the outline of PMMC supply chains that were found are discussed. In literature, only a limited amount of information was found on this topic. However, during the interviews some more information was found.

5.4.1. LITERATURE

Nowadays, added value in the pig supply chain is often not created by the farmer himself, but in the further supply chain (van Vliet & van den Brink, 2011). Supermarkets can dictate a low price for producers of bulk products. Chain partners thus could try to increase the selling price of their products by creating an exception position in the pig meat segment (van Vliet & van den Brink, 2011). In this way, competition with other products is done on added value instead of price.

Image and economic damage because of e.g. animal health issues is a risk that is always present (van Vliet & van den Brink, 2011). For example, the outbreak of Classical Swine Fever in 1997-1998 costed about 450 million euros (Verbong, 2006). A lot of economic damage and image damage could have been saved when every party had respected the transport bans (Verbong, 2006). Currently, vaccination against Classical Swine Fever is possible, but it is important that the meat of vaccinated animals and non-vaccinated animals needs to be separated very strictly, because foreign countries do not like infected or vaccinated meat (Bergevoet et al., 2007). A central chain information system might help to better track healthy, vaccinated and infected animals in crisis time, which can contribute to less economic damage and image damage.

5.4.2. INTERVIEWS

SEPARATION OF PRODUCT STREAMS

According to respondents C1 and F1, it is important that every chain partner has a good separating of the different product streams within their company. One of the respondents described an example in which PMMC meat was, aware or unaware, mixed with conventional meat by some chain partners. This might have a negative influence on the product image. If this mixing means an increase in volume of the PMMC product stream, a party wrongly earns extra money. This issue was revealed by using DNA technique, to trace back the sold meat to the boars used by the farmers of the PMMC.

One of the respondents described a system which minimalizes the chance of mixing of meat of different origins at a company. In this system, the most luxury meat is handled at the beginning of the day, followed by the second most luxury kind of meat, etc. When meat is mixed by mistake in this system, it will get a lower value instead of a higher value. This should be a high driver for the people at the company to work meticulously, because otherwise their company will lose a lot of money.

INTERMEDIARY PRODUCTS

One respondent points out that the majority of the pig meat produced in the Netherlands is produced for selling in Germany, Belgium, the UK and France. He mentioned a self-sufficiency rate of the Dutch pig meat production of 230 percent. So, only a low percentage of the Dutch pigs is sold in a Dutch supermarket, while as the rest is sold in foreign countries. Those products are most often sold as half fabricate (piglets of about 23 kilograms or finishing pig of about 120 kilograms).

The respondent mentions that because the consumer package is not included in such a half fabricate, it is not possible to use this as a way of communicating between the producer and the (foreign) consumer. Akerlof already described that without background information about a product, the only way of competition possible is on price (Akerlof, 1970). Thus, when competition on quality is wanted, more background thus needs to be provided. This is according to respondent E1 however hard to do in a half fabricates market. Respondent C1 suggests that communication on a consumer package e.g. be done by putting a barcode or QR code on it, so that consumers can check out more information on a website. A good information system may contribute to this.

According to respondent E1, a way to get more competition on base of quality in foreign markets is to create a PMMC in collaboration with supermarkets in surrounding countries, like REWE, Aldi, Lidl or Carrefour. So, German, Belgian and French consumers should be asked for their demands and in collaboration with the local supermarkets a PMMC should be created. With the additional product information that could be provided on consumer packages of PMMC meat, it becomes easier to compete on basis of quality instead of competition on basis of price.

Respondent C1 described that it is difficult to involve (Dutch) retailers in PMMC's. However, he thinks that retailers might be interested in a kind of "light version" of a PMMC, so that they are buying products from the PMMC organization, pick some treats from the PMMC that are interesting to them, and sell the products without the brand name of the PMMC as a higher standard pig. He thinks that assurance of the production process with use of blockchain techniques might then be a treat of the PMMC that they want to use.

SELLER OF THE PRODUCTS

One of the respondents states that the party who finally sell the product of the supply chain, to either the retailer or the consumer, has to play a key role in asking retailers and consumers for their demands. Other respondents state that it is important to notice that consumers are also a part of the supply chain, and that the supply chain is not stopping after the meat processer have sold the meat to the retailer.

The first respondent gave an explanation on his opinion: in a supermarket or a restaurant the products of a PMMC have to compete for space with other products. If they are not selling enough, the supermarket will choose to use the space for other products than the products of the PMMC. This respondent thus sees the meat processor, who brings the meat product to the distribution centre of the retailer, as the seller of the supply chain. All chain partners before the meat processor are according to his view facilitators, i.e. they need to help a creating a good quality product so that the seller can sell it. The seller sets up the requirements to which the products and production processes need to fit to. Those requirements have as a goal to increase the product value or decrease the production costs.

CUT IN SUPPLY CHAIN AT SLAUGHTERHOUSE

According to respondent C1, farmers do currently in general not have much knowledge about cutting meat and selling meat to consumers. In reverse, people who work in the meat sector do not know much anymore about farming. He states that the slaughter house could be seen as a "Berlin Wall" between the part of the supply chain that produces pigs and the part of the supply chain that produces meat and meat products.

Another respondent argues that this could be caused by the big challenge in tracking and tracing that takes place at the slaughterhouse: the product (a pig) transforms to a complete other product (meat), with other units of measurements, other variables and requirements on treating and storage and a complete different size and volume per product. Comparable pieces of meat of different pigs are collected together, so now the meat of one pig is separated over different product groups. Respondent G1 describes the transformation of the pig at the slaughterhouse as following:

At the moment that you have changed a pig into a steak, it becomes very difficult to keep tracing that. – (G1)

In that view, the slaughterhouse could be seen as the Customer Order Decoupling Point (CODP). Before the slaughterhouse, partners are busy with growing pigs and look mostly from the supply side of view. After the slaughterhouse, partners look from the demand side of view. According to respondent C1, getting expertise at the other side of the "Berlin Wall" by attending courses or hiring experienced people thus might be useful to get knowledge of the other side of the supply chain. He sees as his mission to break through the "Berlin Wall" between farmers and consumers:

Why is it [selling high value meat to consumers] always failing, the pig goes from €0 to €150 in eleven months, and then in two weeks from €150 to €500. – (C1)

5.4.3. DISCUSSION

In table 5.3, the most important success factors from section 5.4 are given.

Table 5.3: Success factors for PMMC's from section 5.4.

Concept	Literature	Respondents
Creating a differentiated product to earn a premium price	yes	
Track animals and products through the supply chain and separate them from other product streams (because of preserving generated added value or disease control)	yes	C1, F1
Creating a PMMC with supermarkets from surrounding countries to increase the value of intermediary products		E1
Get access to space on the consumer package to tell the story of the PMMC		E1
Have a differentiated product that is able to compete with other products in the supermarkets' shelf		E1
Being able to trace products of pigs after moment of slaughter		G1, C1
Get consumer knowledge and think from the demand side of view		C1

Especially from the interviews, some new insights were gathered about the outline of the supply chain. Interviewees agree with literature that it is important to be able to separate several product streams within companies. In literature, the most important reason to do this preventing image damage and economic damage in case of animal diseases. Interviewees mention guaranteeing origin of PMMC meat at retailers as an important reason for strictly separating product streams within companies.

One respondent thinks that a PMMC which works in collaboration with supermarkets in surrounding countries can be successful. By producing products for a certain foreign consumer segment, the PMMC can communicate quality cues on the consumer package (by e.g. a QR code or reference to a website), which is not possible when only live pigs or whole carcasses are exported to foreign countries.

Another respondent mention that PMMC's might be able to work together with supermarkets in order to create a kind of higher standard product. This statement does agree with literature, which describes that when an exception position within the product segment is created, the meat can compete with other products on base of quality instead of cost price.

Because the shelf of the supermarket is the place where the PMMC products have to compete with other products, one of the respondents sees the party who deliver the products there as the seller of the supply chain. That party has to do customer research and translate that information into production requirements which increase product value or decrease cost price for facilitators, parties before him in the supply chain.

One respondent states that the pig supply chain is separated into two pieces, i.e. a part before the slaughterhouse and a part after the slaughterhouse. There are some important differences between those two parts of the supply chain: the first part is having a more supply minded view on production, the second part a more demand minded view. Secondly, an important difference is that the type of product (life pigs versus pig meat) those two supply chain parts are handling is totally different. Getting knowledge at the other side of the "Berlin Wall" is quite hard according to the respondent.

5.5. SQUARE VALORISATION

In order to have an acceptable cost price as a PMMC, it is according to literature and interviews important to have a high square valorisation. Some parts of a pig are not easy to sell under a price premium. This can be solved by producing more minced meat products like sausages, which however has some traceability issues.

5.5.1. LITERATURE

Many different authors subscribe the importance of a high square valorisation (van Vliet & van den Brink, 2011). Square valorisation means the percentage of the meat of a pig that is sold under the quality mark of the PMMC. Often it is not possible to sell the whole pig under the quality mark of the PMMC, since consumers are not interested in paying a high price for low value parts of a pig. PMMC-chains which are able to generate a high square valorisation by e.g. new product development have an advantage compared to PMMC-chains with a low square valorisation because of the increased revenue per pig that is created (van Vliet & van den Brink, 2011). This can result in a higher amount of profit.

In 2011, only 25 kilos of the 90 kilo slaughtered weight of a one-star Beter Leven pig was sold as one-star Beter Leven meat (van Vliet & van den Brink, 2011). The square valorisation thus should be further improved in order to sell a bigger part of the meat available as PMMC meat.

A problem however is that raw material flows for meat products in supermarkets are very diverse and not very transparent (van Vliet & van den Brink, 2011). Currently, some products that can be bought in the supermarket can be traced to an enormous amount of pigs. In the TIVO-project, a slice of liver cheese was traced back to 6117 animals from 84 different farms (Wognum & van Erp, 2013). Thus, tracing back products in the pig supply chain is not always easy.

5.5.2. INTERVIEWS

Many respondents see the need for a high square valorisation, but did not have a clear answer on how their company directly could contribute to increasing the square valorisation of pigs in a certain PMMC. Most often this was caused because their companies are active in different parts of the supply chain than in meat handling, in which the puzzle of the square valorisation needs to be made. A remark that was made by one of the respondents is that chain partners can contribute to make sure that there are enough piglets in the supply chain, so there is a decent amount of meat in the process of the slaughterhouse. According to respondent F1, this gives a good starting point for the slaughterhouse can more easily make the puzzle of square valorisation.

Respondent G1 describes that from breeding side of view, it is hard to contribute to square valorisation of specific PMMC's. A breeding company can develop a special breeding value for a PMMC, in which the weighting of factors is different from the weighting of factors that is used in the general used breeding value. However, breeding lines are developed for general use and there are no specific breeding lines for PMMC's. The long term development of the pig breed used in the PMMC thus depends on the long term goal of the whole breeding line. And thus, improvement of specific parts of a pig (like e.g. the shape of a ham) is thus only possible when this fits in the long term goal prepared by the breeding company.

According to a respondent, it is important to realise that additional costs made in the PMMC only can be paid back by products that are sold under the flag of the PMMC, i.e. serve an additional source of revenues. If costs are made and there is uncertainty about whether they are earned back, those costs better could not be made. According to respondent C1, a good square valorisation can help to

decrease additional costs per kilogram of product produced. When only e.g. 25% of the pig could be sold under the flag of the PMMC, this meat also should earn the additional costs made on the other 75% of the meat which is sold as conventional meat. So, it thus is important to have the square valorisation as high as possible in order have a viable PMMC.

According to respondent C1, selling every week certain parts of the pig like the meat around the shoulder blades is no problem. However, other parts are harder to sell. He illustrates this with the example of Livar, which sells some parts for only a slightly higher price than conventional products. Other parts of a Livar pig have a price that is much higher than the price of conventional meat. Furthermore, respondent C1 mention that some parts of a pig like paws and heads are useless for them at the moment. Therefore, their PMMC gets the carcasses back from the slaughterhouse without those parts.

According to respondent C1, a possible way to increase the square valorisation is to make more products like sausages and meat products for on bread from bad selling parts of a pig. However, then traceability becomes an issue. One of the respondents described a tumbler at a meat processing company in which 5000 kilograms could be handled at once, so meat of many pigs. Because sausages are composed from such a lot of different pieces of meat, tracing is difficult. Respondent C1 mentions that without a good tracing, meat from different origins could be mixed unaware, which has a bad influence on the credibility of the PMMC. Improving traceability may thus help valorisation of products of the PMMC.

Respondent F1 mentioned that seasonal differences in demand for certain products of the pig are important to take into account. For instance, parts of a pig that are used for meat products on bread are also used for making smoked sausages. Smoked sausages have a longer shelf time than most meat products for on bread. Since there is a peak in demand for smoked sausages in autumn and winter, a good production planning through the year can prevent shortages of certain parts of the pig at certain moments in the year. This has a good influence on square valorisation, because no additional piglets have to produced especially for once part of their meat, while as there is an oversupply of other body parts.

According to respondent C1, another factor that may have an effect on the square valorisation within a PMMC is whether there are boars or barrows finished. Since boars are not favourable by butchers and restaurants because of possible odd odours in their meat, finishing boars will make the puzzle of square valorisation more difficult.

5.5.3. DISCUSSION

In table 5.4, the most important success factors from section 5.5 are given.

Table 5.4: Success factors for PMMC's from section 5.5.

Concept	Literature	Respondents
Having a high square valorisation	yes	C1, F1, E1, G1
Being able to trace minced meat back to PMMC pigs	yes	C1,F1
Having a certain size of production to make the process of square valorisation more easy		F1
Produce and sell more minced meat products like sausages from less popular parts of the pig to increase square valorisation		C1
Take into account seasonal differences in sales to increase square valorisation		F1
Finishing barrows instead of boars to increase square valorisation		C1

A remark that was made by one of the respondents was that the square valorisation always should be 100%, in the sense of selling every week every part of the pigs. If this is not achievable, the concept will not be viable on the long term. However, his definition of square valorisation is slightly different from the definition which is used this research, namely:

Square valorisation is defined as the percentage of the carcass weight that can be sold for a higher selling price then the price of a comparable piece of conventional meat. – (own elaboration)

Literature states just like respondents that the square valorisation of a PMMC should be as high as possible. Many respondents did not see a lot possibilities to contribute to this, because they having another role in the supply chain than farmer or slaughterhouse.

Finishing as much as possible barrows instead of boars has a positive effect on square valorisation, because barrow meat can be sold to restaurants and butchers, while as they are not interested in buying boar meat. However, finishing boars is in favour from the animal welfare and public opinion sides of view because then the animals are not castrated.

A good traceability of products through the supply chain can contribute to a high square valorisation. In order to increase transparency of the supply chain, meat products like sausages might be made with less mixing of meat. When product streams of conventional meat and PMMC meat are separated strictly, sausages can be produced from PMMC meat only. And when sausages are produced from low value meat that formerly could not be sold as PMMC meat, the square valorisation increases. Thus, by increasing transparency of product streams in the supply chain, the square valorisation of PMMC meat might be increased.

5.6. MANAGEMENT ISSUES IN PMMC's

5.6.1. LITERATURE

One trait of agriculture that is different compared to other economic sectors is that there are farms that are ending their activities, but no newcomers who start a farm out of the blue (Verbong, 2006). This is caused by the high costs that it takes to start up a farm (Sukkel & Van der Waal, 2007). Furthermore, it implies that farmers who start producing for a PMMC are also "side-entrants" who are switching their production methods from a conventional system to a PMMC system.

Another issue is the increasing aging of current farmers, which is not limited to conventional farmers (Sukkel & Van der Waal, 2007). Not all farmers have a successor in their family, while as others without a farm would like to start a farm. Transfer of a farm to someone without a farm is however often difficult, because of financial aspects. Setting up good contracts in order to fix this problem may save PMMC farms from termination. This would contribute to the proliferation of PMMC farms in the Netherlands (Sukkel & Van der Waal, 2007).

Another problem is the temporary income decrease during switching from a conventional system to an organic system or other PMMC system (Sukkel & Van der Waal, 2007). Costs are already increasing, but the products cannot yet be sold as fully PMMC products. A decrease of those entry levels could increase the number of farmers that want to switch their farm to a PMMC farm.

LOW PRODUCT PRICES

Because pig meat is a bulk product, retail prices are relatively low. Pig meat has an image of cheapness (Verbong, 2006). The supply of meat is often higher than the demand (van Vliet & van den

Brink, 2011). At the international market, there is a lot of competition between different producers of pigs and pig meat products (Stichting Vlees.nl, n.d.). Together with high production costs, this results in low profit margins for farmers, traders and slaughterhouses (van Vliet & van den Brink, 2011).

Supermarkets often attract consumers with selling products like beer and Coca Cola for relative cheap prices (van Vliet & van den Brink, 2011). When consumers buy those products, they often also buy products on which the supermarket has a bigger margin, like meat. The low buying price of meat decreases innovations at suppliers of supermarkets (van Vliet & van den Brink, 2011).

5.6.2. INTERVIEWS

Many points that are mentioned under the success factors for PMMC's also might be challenges when they are not conducted to the right level. For instance, it is necessary to have trust in supply chain partners and sometimes interests of the whole supply chain should be more important than interests of one party. One of the respondents mention that pig farmers are quite individual of nature, which makes it difficult to group them together.

Because of the continuously changing pig sector, all chain actors (within and outside PMMC's) should be able to innovate if they want to stay active in pig business. Respondent C1 describes that also chain partners in a PMMC are continuous innovating on e.g. norms, protocols, animal health, hygiene, meat quality, etc. Respondent G1 mentions that the added value of a concept is corrosive, i.e. consumers perceive additional measurements after a few years for standard. If those measurements are then made compulsory for the whole pig sector, the added value is gone but the additional costs are still there. So, there is only a limited time for concepts to profit from their additional measurements.

Respondents mention that creating a PMMC is a long term process which costs a lot of effort. Besides, a lot of agreements needs to be made between PMMC partners. Not honouring those agreements can result in a lower level of trust between supply chain partners and may result in lower revenues for the whole supply chain. However, chain partners together can set additional production rules that are compulsory to follow up in order to stay a PMMC partner. Respondent E1 mentions that collaborating in a blockchain project might e.g. be a required part of the presence in a PMMC.

According to respondent E1, farmers are often price takers in supply chains. Namely, other parties decide what their products costs, and there is only possibility for them to earn money when all other chain parties are earning money too. Combined with the fact that the products of pig farmers only are ready after a production process of ten months, this means that farmers have a weak position in the supply chain.

One respondent describes that some chain partners may need to switch to another business model when they enter in a PMMC. In the PMMC of respondent C1, the veterinary practice is included as a chain partner with such a new business model. However, the goal of that PMMC is to use as little antibiotics and vaccines as necessary. This is thus at odds with the revenue model of the veterinary practice. To overcome this difference of interest, the veterinary practice got a new role within the PMMC: they got role of quality manager of the supply chain. This quality manager can check the claims that are made on the PMMC meat, like more living space, provision of roughages, etc. The checking of the claims on the PMMC meat by a quality manager can be an important step in strengthening of the trust of consumers in the PMMC.

POWER WITHIN PMMC'S

Many respondents think that the question "who has the power within the supply chain" is difficult to answer. The word "power", especially "power abuse" can raise strong negative associations. One of the respondents describe this "power abuse" as the use of information of small supply chain partners by big supply chain partners, to get an advantage, without converting this advantage to the party that delivered the information. If the provider of the information also gets a part of the advantage, there is not a case of "abuse" anymore.

According to respondent F1, it is difficult to say whether all chain partners should have the same level of power, or that there should be a difference between power levels of supply chain partners. Should a farmer with 300 sows have the same amount of power as a farmer with 800 sows? The interests of the farmer with 800 sows are in terms of money much bigger than the interests of the farmer with 300 sows, but other factors also might weight through.

A fact is that in the pig sector in general, there are compared to the number of farmers not many slaughterhouses and retailers. Because of their oligopoly position, those parties have relatively a lot of power within the supply chain. However, there is no central control of the supply chain without PMMC's. In PMMC's, a chain director company can fulfil this role. The other chain partners can then for example be involved in the management of the concept by the role of a member of the management team, in which they are involved in all decisions.

When a central information system is set up in a PMMC, with or without blockchain technology, this can have influence on the existing power relations within the PMMC. According to respondent E2, the power relations at the start of the system are important for this, because partners who have more power can demand more. On the other hand, small chain partners who work closely together with a bigger chain party can built on an equal relationship with that bigger chain party when they work closely together. One of the respondents stated that big chain partners who work on blockchain projects probably even might strengthen their power position, instead of losing this position.

CREATING ADDED VALUE FOR CONSUMERS

In the pig sector, it is quite hard to produce a distinctive product that is really different from other products produced by the sector. Respondent state that look at the supply chain from a demand side of view instead of viewing from a supply side of view is important in order to come to a distinctive product. However, often consumer knowledge is lacking. Respondent C1 stated that when that knowledge is not available, supply chain partners should acquire it themselves or attract new chain partners who have knowledge on meat demands of consumers. Respondent E1 mentioned that in order to increase product value, a PMMC should start with asking consumers what they are willing to pay for.

According to respondent G1, consumers have a double role in the supply chain. From their role of citizens, they like PMMC's because of the higher perceived living standards for pigs compared to those in conventional systems. However, from their role as a consumer many people choose the cheapest products in the supermarket. This problem is more psychological of nature, and quite hard to handle. It gives however problems when cost price increasing factors (like e.g. application of BT in PMMC's) are taken.

5.6.3. DISCUSSION

In table 5.5, the most important management issues from section 5.6 are given.

Table 5.5: Management issues in PMMC's from section 5.6.

Concept	Literature	Respondents
Decrease of number of farms because of lack of successors	yes	
Starting up a new farm is almost impossible because of high entrance costs	yes	
Transferring a farm to an owner outside the family is difficult because of financial issues	yes	
Temporary income decrease for switchers from conventional to PMMC production	yes	
Low product prices	yes	
Pig farmers are difficult to group together		F1
Added value of a PMMC is corrosive		G1, C1
Starting a PMMC is a long process which costs a lot of effort		C1
Farmers have a weak position within the supply chain		E1
Chain partners might not be willing to apply to all rules the PMMC prescribes		C1, E1
Chain partners might need to which to another role in a PMMC than in conventional systems		C1
Power relations might change compared to the relations in conventional systems		E2
Consumer knowledge is not always present up in the supply chain		C1
Consumers like PMMC's, but are often not willing to pay a premium price for their products		G1

Literature mentioned some complete other management issues in PMMC's than the ones that were mentioned by respondents. However, this might also be caused by the fact that there is no hard line between success factors and management challenges in PMMC's: when a success factor is not conducted to the right level, it automatically becomes a management challenge. Therefore, the tables of the success factor paragraphs are related to table 5.5. Furthermore, the concepts mentioned by respondents are somewhat more applied to PMMC's than the concepts found from literature. In the overall discussion and conclusion of chapter 6, those tables will be discussed together.

5.7. TRANSPARENCY OF THE SUPPLY CHAIN

Consumers only buy products in which they have a certain amount of trust. Being transparent about production processes can increase the level of trust of consumers in products of e.g. a PMMC. In this paragraph, pros and cons of an increased level of transparency in PMMC's are discussed.

5.7.1. LITERATURE

A good image is of great importance for PMMC's (van Galen et al., 2011). An example is Livar, which uses the image of monastery pigs (Verbong, 2006). Because keeping customer trust is crucial in PMMC's, assurance of origin of pig meat is an important issue in PMMC's (Wognum & van Erp, 2013). Assurance of the pig supply chain, thus improving traceability in the pig supply chain, improves credibility of extrinsic quality traits (Northen, 2000). In this way, the traceability prevents fraud (e.g. relabelling of non-PMMC meat to PMMC) (Huisman & Van Ruth, 2014). Strict enforcement of the rules in a PMMC is also necessary in order to preserve the image of chain partners (van Galen et al., 2011). Furthermore, quality of pigs can be increased when more accurate data from the slaughterhouse is fed back to upstream supply chain partners like farmers (Wognum & van Erp, 2013).

In current years, more and more attention on animal welfare and environmental impact of farming in general and especially pig farming is given by the Dutch society (van Vliet & van den Brink, 2011). When transparency of the pig supply chain is low, information on those topics does not reach consumers. Improving traceability has a positive effect on supply chain credibility for consumers

(Tian, 2016). Furthermore, a higher supply chain transparency has a positive influence on trust between supply chain partners (van Vliet & van den Brink, 2011).

When meat is traceable through the whole supply chain, it becomes possible to provide guarantees on origin of meat to consumers and chain partners (Wognum & van Erp, 2013). Important factors to take into account are clear communication, collaboration of all involved chain partners and costs. Currently, full tracing through the supply chain is possible, but costs are however often higher than the benefits of such a system (Wognum & van Erp, 2013).

5.7.2. INTERVIEWS

Generally, provide transparency is a good way to help the strengthen trust of consumers in a PMMC. A quote of one of the respondents:

Do what you say and say what you do. Be open about that, and then you get more trust. – (F1)

It is however difficult to translate technical data of the PMMC into usable and interesting information for consumers. One of the respondents describe that consumers might be interested in PMMC's, but often not in the technical background of the PMMC. As an example, he mentions the possibility to check the farm origin of an egg by checking the code that was printed on it. Many consumers know that there is the possibility to do this, only a very few do it. However, in case of a food scandal more consumers are interested in the origin of their egg or, in the case of PMMC's, meat. The respondent states that it is important to be able to react quickly then in checking what went wrong.

An example in which the feeling with the product is more important than technical data in selling products was mentioned by respondent F1. This example involves selling free-range eggs to consumers. The consumers often do not know all the technical background values of those eggs, but are interested in free-range eggs because "free range" appeals to them. So, a good marketing might be more important than technical background information in customer decision making.

A respondent describes that the fact that consumers have *the possibility* to check out the origin of their piece of meat is important. This attitude of openness shows self-confidence of the producer in the integrity of the production process. After all, producers would not be transparent about their production process when they are not sure about the integrity of those processes. With a higher level of transparency, many consumers would presumably still not check the background of their meat. However the possibility to check the origin of the product will comfort them though.

With more transparency about production processes, groups and people who are against livestock farming also get more information. They possibly might use this information against the livestock sector. One of the respondents describes this problem as following: there always will be a small minority which keeps on bashing the livestock sector until everyone is vegetarian. However, because of the increased level of transparency it is possible to keep the confidence of a major part of the consumers.

5.7.3. DISCUSSION

Respondents and literature agree that an increased level of transparency in the pig supply chain can increase the trust of consumers in that supply chain. When the level of transparency is increased, information on extrinsic quality traits can more easily reach consumers.

Respondents argue that many consumers might not be interested in technical background information about the products they have bought. A good marketing might be more important to sell

products. However, giving the possibility to consumers to retrieve more background information on products shows self-confidence of producers in the production process. Malicious parties can use the additional information to bash the livestock sector, but respondents think that the majority of the consumers will get more trust in the pig sector by an increased level of information sharing.

5.8. INFORMATION SYSTEMS

Being more transparent about production processes through the supply chain involves an increased level of information sharing. In this paragraph, different outlines of information systems are discussed, as are important types of information to share between chain partners.

5.8.1. LITERATURE

Information collection and processing can help to create added value for pig meat supply chains (Wognum & van Erp, 2013). A central information system, which could be accessed by e.g. a computer or smartphone application, can be used to exchange information on e.g. logistics and products with customers and chain partners (Wognum & van Erp, 2013). However, such a system only could be realised when all actors within the supply chain collaborate and could create added value out of this information system. When chain partners can log in to find for them relevant information, the level of unambiguous intern communication is increased (Wognum & van Erp, 2013).

Creating, implementing and maintaining such an information system implies that investments should be done. It is logical that the parties who benefit from such a system also pay the costs. When more partners profit from the supply chain information system by e.g. a better product valorisation, the costs should be spread over the SC partners. It is however not known what the best way is to do this (Wognum & van Erp, 2013).

In the TIVO project, the possibilities for an integral information system in the organic pig supply chains were investigated (Wognum & van Erp, 2013). This project focussed at a central role of slaughterhouse “De Groene Weg” as the chain director.

Nowadays, partners in the supply chain use often information systems which are not always linkable to systems of other partners (Wognum & van Erp, 2013). An example is FarmingNET of VION, in which farmers can sign up pigs for slaughter and consult slaughter results (Wognum & van Erp, 2013). VION can use this information to make performance overviews. However, this is still only an exchange between two chain partners instead of a supply chain wide integrated information system. In figure 5.1, a vision on an integrated supply chain information system is given. Consumers and supermarkets are not included in this overview, but can also be added.

In the feed production industry, such integrated supply chain information system already exist (Wognum & van Erp, 2013). This system is called Trust Feed and works at a custom version of the ICT platform Chainpoint. Also Plukon, a big Dutch broiler slaughterhouse, makes use of Chainpoint to maintain their supply chain from feed production to retail.

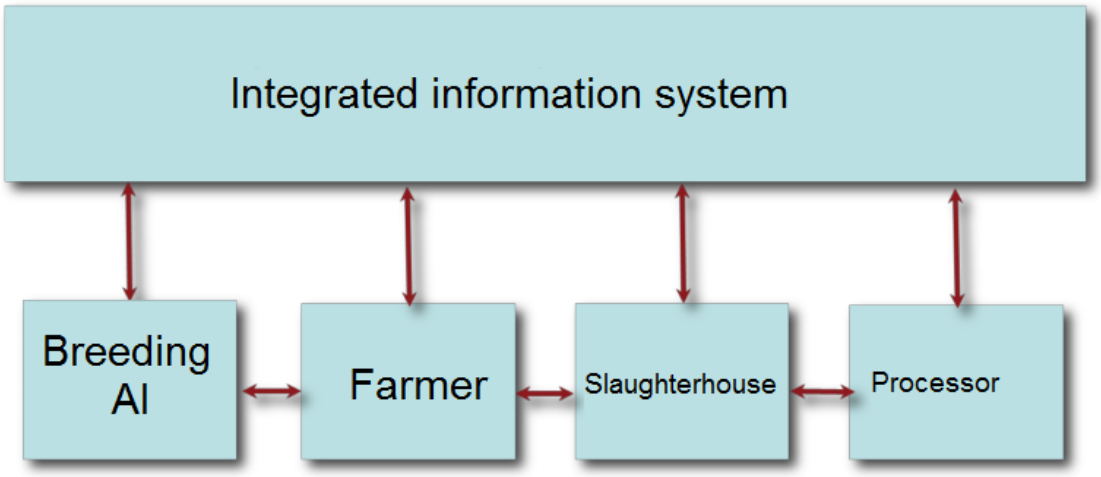

Figure 5.1: Vision on an integrated supply chain information system. Adapted from (Wognum & van Erp, 2013).

To increase traceability by using a central database, it might be necessary to further digitalise high quality data from supply chain processes (Balendonck et al., 2003). New digital data creates possibilities to track and trace pigs, meat and processes in the database. Input of data in data systems is however a time and thus money costing process, which chain partners only will do when there are advantages for them. However, by using a central database the total administrative pressure might decrease, since it is not necessary to put in the same data repeatedly. Therefore, using a central database might save costs for chain partners.

The high number of individual data systems that are not interlinked cause that every pig is registered in for about seven different databases which often lack interlinkage (Balendonck et al., 2003). Repeated input of data into the system costs a lot of time and decreases the possibility of mistakes. When products can be traced in a central database, intervention in case of emergencies can be done much quicker and adequate, which saves economical and reputational damage. Besides, it might have a positive effect on the reduction of fraud. When chance of fraudsters being caught increases, it is less attractive for parties to commit fraud.

5.8.2. INTERVIEWS

Currently, the use of central information systems to share information between chain partners in the pig business is not yet wide spread. One of the respondents mentions that until now, the time was not yet ready for it. Mobile phone applications to access data do exist, but those are however only linked to single databases.

Exchanging of data between different information systems is meanwhile often done, by using a protocol like e.g. EDI. For instance, data from sow management systems and slaughter measurements is exchanged using the EDI protocol with the database of a genetic company. This is different from collaboration in a central database, where more chain partners work together in a single database instead of working in each their own database.

One of the respondents gave a warning on hyping central information systems too much. As an example, he mentioned that after the 1997-1998 outbreak of Classical Swine Fever in the Netherlands, many chain partners thought about creating systems to get more insights by information gathering. However, when the point came that investments were necessary, most partners withdrawn. As possible reasons for this withdrawal, he mentions that the fear for the unknown or technical restrictions back then might have played a role.

Nowadays, there are some initiatives in which chain partners collaborate in a central information system. For instance, the PMMC of respondent C1 is using a system in which visitor reports of farms by chain partners are shared. Data from the slaughterhouse is shared with the other chain partners. Furthermore, sow farmers get reports of finishing pig farmers, and in reverse. The feed supplier has also access to this information. Protocols are used to check reports and progress systematically. For instance, stable climate is checked every year in the same time of the year. Advisors, like the veterinarian and feed advisor, know that this climate check have taken place and check at their next visit whether the recommendations have been taken into account. Advisors often visit farms together, so that their recommendations could strengthen each other instead of devaluating each other. Respondent C1 is currently trying to further improve the information sharing between chain partners, by setting up a new central information system which is blockchain supported.

One of the respondents mentions that in the current situation of data exchange, it sometimes is difficult to gather the right data together, and sometimes data is missing. However, while setting up a central information system, also many different problems may pop up. Those problems cannot always be foreseen in advance and might only pop up when parties are working on setting up a central information system.

Besides information on production variables, knowledge on how to produce according to the protocols of the PMMC is involved in a PMMC. Respondent C1 described that new entrants get subjected to an introduction trajectory, in which they get necessary information to produce in the PMMC, and a screening, in which points of improvement are mentioned that are require to fulfil in order to get started in production at the PMMC. Furthermore, chain partners within their PMMC share knowledge on study evenings.

TYPES OF INFORMATION TO SHARE BETWEEN CHAIN PARTNERS

In PMMC's, different types of information are shared with other chain partners. The most important rule is that only relevant information should be shared, all things that add nothing to a higher profit or higher security of the production process should be left away. Respondents have mentioned several types of information that are important to share between PMMC chain partners. Those are summarized in table 5.6. A list with the necessary types of information to share in PMMC's can help to formulate an answer on SRQ 2.

Table 5.6: Important types of information to share according to respondents.

Concept	Producer of information	Mentioned by
Number of pigs	Farmer, Slaughterhouse	F1
Genetic background of the pigs (sow used, boar used)	Farmer, Genetic Company	F1, C1
Number of doses of semen delivered to the farm	Genetic Company	C1
Grams of growth per day	Farmer	F1, G1
Medicine use	Farmer	F1
Stable cards	Farmer	C1
Welfare scores	Welfare app, farmer,	C1
Stable temperature	Farmer	C1
Damaged shoulders of sows	Farmer	C1
Damaged tails of piglets	Farmer	C1
Manure structure of piglets (too wet)	Farmer	C1

Slaughter statistics (carcass weight, lean meat percentage, muscle/fat ratio, level of intramuscular fat, abnormalities)	Slaughterhouse	G1, F1
Transport duration	Transport company	C1
Time information of slaughter process (resting time, slaughter time, time of entering cooling process, duration of cooling process, etc.)	Slaughterhouse	C1
Breeding values	Genetic company	G1
Feed content analyses	Feed company, suppliers of feed company	F1
GMP+ information of feedstuffs	Suppliers of feed company	F1

According to respondents, much information is currently exchanged indirectly. For instance, slaughter data goes via the farmer back to the feed company and the genetic company. Furthermore, information could be given to the next chain partner by e.g. a technical manual. Such a manual could also be made for e.g. breeding gilts, and would then include the ideal feed scheme, the ideal type of feed or the ideal environmental circumstances in order to reach the maximum genetic potential of that breed.

Respondents stated that measurement values are not always available per individual animal, for example because of difficulties and costs involved in individual registration of animals. However, respondent G1 mentioned that data on groups of animals also can be interesting, if for example the breed or breeding line of the group of animals is known. If performance data of groups of animals of different farms is compared in a central information system, analyses on the best environmental circumstances to keep e.g. a specific breed are easier to conduct. However, giving meaning on data of groups of pigs without knowing the individual members of that group is quite hard, as respondent G1 described.

One of the respondents, who already has experience with sharing information between chain partners, mentions that a lot of new insights can come up when data of farms is shared and compared with data of other farms. For instance, he mentioned that tail biting can pop up at several farms at the same time. Because all the cases of tail biting are centrally logged, it became possible to draw the conclusion that the responsible factor was present through the whole Netherlands instead of at a single farm only. Without central logging of this data, the relationship between simultaneously popping up tail biting pigs could have been stayed unnoticed. Furthermore, without central logging of data, farm visitors might act like they have nothing seen at other farms, because it is in favour for their own position.

OUTLINE OF A SYSTEM

The general opinion of the respondents is that data gathering, central information systems and also blockchain technology should serve PMMC's, and not in reverse. Data that does not add anything to the security or value of the product is not useful to put in a central information system. Furthermore, especially when a central information systems is just set up, it is important to keep it simple. Thus, it might not be important to know which sow had 13 piglets and which sow had 15 piglets, but the total week production of piglets of a farm is important to register. One respondent notes that it always keeps possible to find detailed information of the piglets in the sow management of the farmer, if there is a demand for that information. The assurance of the blockchain technology then however is not used on that data.

Often chain partners do not know which info other chain partners exactly use or produce, let alone the source of that data (gathered their self or processed from existing data). According to respondent G1, it is important to know which data is collected and at what location is data is stored, so that detailed information can be retrieved if necessary.

Using a central information system makes it easier for chain parties to plan their production and creating forecasts about the supply and demand they have at a certain moment. However, because pigs are life animals, always some uncertainties exist. From the moment of weaning of piglets on, forecasts can be made with a higher level of secureness. One of the respondents mention that the moment of weaning is currently in his favour to start forecasts on production numbers of pigs.

5.8.3. DISCUSSION

Literature describes that implementing a central chain information system can increase transparency of the supply chain. Communication between chain partners improve, and products might be valorised better. Setting up a central chain information system may result in the need for digitalize additional information, which can be time and money costly.

Respondents think that until now, time was not ready for central chain information systems. Nowadays data is exchanged between different data systems of individual chain parties. Literature stated however that databases are often not interlinked. This can be caused because the article that this described was already some years old and things might have changed in between.

Currently, there are some initiatives of PMMC's who share data in a central information system. Some parties even work on blockchain implementation. One of the respondents described that he got a lot of new insights about supply chain processes by such a central information system. Data shared in such a system should according to respondents be limited to a limited amount of high relevant data. However, the list of types of information that is mentioned important to share by chain partners is quite long. This might be caused by chain partners having different types of data have that are of their interest. Respondents mention that collecting metadata is important to get insight in which types of information are produced by different chain partners. Possibly, the difficultness of predicting demand levels based on data might have to do with fluctuations of sales and the cut in the supply chain at the slaughterhouse.

5.9. IDENTIFICATION OF ANIMALS: DNA AND RFID TECHNOLOGY

In order to be able to share information about pigs in a chain information system, it is necessary to give them a certain kind of identity. There are different ways to do this, individually or at animal group level. When individual animals can be identified and traced through the supply chain, the transparency of the supply chain can be increased. In this section, DNA and RFID techniques will be discussed that can support chain information systems in individual tracing of animals.

5.9.1. LITERATURE

There are two ways for individual pig identification which are usable in different supply chain steps: by use of DNA-tracing and by use of RFID techniques (Wognum & van Erp, 2013). RFID tags are automatically readable in the slaughtering process, which makes reliability and accuracy higher than manually reading of (non-RFID) tags. A disadvantage of RFID tags is that they are quite expensive compared to non-RFID tags (Wognum & van Erp, 2013). However, when RFID-tags are reused, prices of using those tags drop.

The tag is put in the ear short after birth of the piglet (Balendonck et al., 2003). By this tag, pigs are traceable until the moment of slaughter. An important issue is the loss of ear tags: during life of the pig and later on in the scratching machine in the slaughterhouse (Wognum & van Erp, 2013). When pigs have lost their ear tags, it becomes impossible to guarantee the identity of that pig for 100% by using only RFID technology.

In the slaughterhouse, the different parts of the pig are separated from each other. Comparable parts from different pigs are together groups as batches (Wognum & van Erp, 2013). Those batches again are traceable in the further supply chain by using RFID tags on meat crates. Tracing meat crates could also be done with bar codes, but that way of tracing is not as accurate as tracing with RFID tags (Wognum & van Erp, 2013).

In the pig meat supply chain, the Customer Order Decoupling Point (CODP) is in the slaughterhouse (Rijpkema, Van der Vorst, & Rossi, 2010). Because the units before (pigs) and after (meat pieces) the CODP are different and have a different RFID chip, another method should be used to trace meat in super markets back to the farmer.

DNA technology is very suitable for this (Wognum & van Erp, 2013). Furthermore, DNA traceability can improve customer relationships and create and maintain consumer trust. For example, customers can check at a website on which farm the pig has lived. A DNA-sample is obtained by taking an ear-punch while tagging the animal with a combined DNA/RFID tag (Caisley, 2017). Even baked or processed meat can be traced back to the animal of origin with DNA tracing (Wognum & van Erp, 2013).

The downside of DNA tracing technology is that it is quite expensive (around 40 euros) to analyse a DNA-sample of every single finishing pig (Van Haeringen Laboratorium, 2017; Wognum & van Erp, 2013). In order to decrease costs, only the DNA of the sires (which produce much more offspring than dams) of the slaughter pigs could be analysed. When analysing a meat sample from the supermarket, the DNA should then partly match the DNA of the sire. However, then it is important that those sires are exclusively used by the PMMC for which they are assigned, in order to prevent slaughter pigs unfairly be marked as PMMC pigs (Wognum & van Erp, 2013). The movement of semen from the Artificial Insemination station to the different pig farms then should be monitored and controlled very precisely. As a backup system, a DNA system from every dam could be taken but not directly be analysed. In case of a suspicion of fraud, those DNA samples could be analysed too in order to give clarity about the source of the meat (Wognum & van Erp, 2013).

5.9.2. INTERVIEWS

DNA TECHNOLOGY

By the use of DNA techniques individual pigs could be traced back from a batch of meat products. With DNA tracing, it is even possible to trace back pieces of minced meat to the pig they were once part of. When DNA of all delivered pigs is known, it should be possible to trace back all individual DNA profiles in a sample of minced meat, e.g. a sausage, to one of the pigs that were delivered in that batch. When unknown DNA profiles are found, there is somewhere a leak in the production process.

Those DNA techniques are a nice outcome to trace back meat products to the pig they were once part of, but also have their restrictions. Analysis of DNA samples is quite expensive, which makes it costly to trace back every individual pig that was produced. Furthermore, it is important to realise what you want to trace back and why you want it: transparency, traceability, or get some other information? If individual tracing is not necessary to reach this goal, it better should not be conducted.

Only when 100% of the boar and sow in the PMMC is DNA-typed and exclusively used for that PMMC, there could be given a waterproof warranty on origin of the meat in that specific PMMC. When only boars are DNA-typed, there is namely a chance of false-positives, when the AI station delivers left over semen from a boar intended for use in the PMMC to a non-participating farmer. Since it is costly to DNA-type all boars and sows, there should be a good revenue model or other underlying meaning to do this. However, according to the TIVO research, it is economically feasible to genotype the used boars.

One of the respondents describes the usage of DNA technology (and also RFID technology, sensors and other hardware developments) as following: it can surely support blockchain supported information systems in order to strengthen the link between the physical world and what is in the information system, but it is just like with blockchains themselves important to realise that applying those techniques is not a goal on itself.

Respondent C1 mentions that their concept already have implemented DNA techniques. He mentions that when the first test was conducted, only 50% of the meat at the retailers which was sold as concept meat of his concept could be traced back to pigs of the concept, which he mentions very disappointing. In three years, the percentage of traceable meat at the retailers has grown to more than 90%. This took however a lot of effort, and many things had to change.

Some of the respondents also described the possibilities of a DNA scanner, which would work comparable to a molecular scanner (like a SCIO). Such a scanner is for DNA not yet technical feasible, but might be the only way to implement active DNA tracking, i.e. real time location of the meat. This is different from DNA tracing, which is done afterwards.

RFID TECHNOLOGY

Besides DNA techniques, RFID techniques can be used to support central chain information systems, by strengthening the link between the information system and the physical world. Furthermore, automatically sensor data and barcode scanners can be used to strengthen this link. In this way, it becomes more difficult to fill in falsified data in the system by manipulation or mistakes.

For individual tracing of pigs through the supply chain (from birth to the moment the pig is slaughtered and cut into different pieces), RFID ear tags are very useful. Those can be read automatically without the necessarily for a person to check the number on the ear tag manually. However, tags are quite expensive and there should be a clear reason to make it possible to trace individual pigs through the supply chain. If there is a clear business case for individual tracing at the level of the farm, like e.g. better management or decreased feed costs, individual monitoring of pigs might be economical viable. Later on, chain concepts and breeding companies can use improve their products and production processes by using the tags and the information that is generated by using the tags.

A point that makes the connection between the pig and the meat of the pig more difficult, is the loss of ear tags. When piglets are tagged at a very young age, they lose their ear tag. Without an (RFID) ear tag, the data of the pig cannot be connected to the data of the meat, which leaves space for uncertainties and possibilities for person exchanges of pigs. An outcome may be that pigs without ear tag in a group of pigs from a certain farmer presumably belong to that group, or batch, too. However, the concept of individual tracing is then useless, because the tracing is not 100% correctly.

Because individual tracing of pigs is quite expensive, not always practical applicable, and there is not always a clear business case for this, working in batches might be more easy. First, a sow is the batch, thereafter a litter of piglets. Later, the whole week group of piglets becomes the batch. Every change of batch unit can be stored in the blockchain. Furthermore, information on location, owner and processes that took place are stored.

After the slaughter process, RFID could be used again. Then a piece of meat can e.g. be tracked through the process of a retailer. The RFID then correspondents to a batch of products, instead of a pig. Again, some issues are involved, because placing a tag at every consumer package of meat is quite expensive. Furthermore, it is difficult to link the RFID of a slaughtered pig to the batch of products that contains its products.

Because of the costs of implementing DNA and RFID techniques, those systems only should be used when there is a clear goal supported by implementing them. Furthermore, a respondent describes that it is necessary that there is a clear business case of implementing those techniques at the level on which the costs are made. So: if you make the costs, you need to have revenues on it. The respondent describes that it keeps difficult to create such a business case, so that there are not yet many working initiatives. However, this might become different with a blockchain system.

5.9.3. DISCUSSION

Technically, DNA sampling of all individual finishing pigs is a way to get a 100% assurance about whether a certain pig or piece of meat was produced in a PMMC. However, practically this is (yet) impossible because of too high costs. Literature and respondents agree that assurance by DNA technology can relatively cheap be implemented in a PMMC when DNA-sampled sires are exclusively used in a certain PMMC. It should be noted that this is only a 100% closed systems when the typed sires are really only used for producing piglets within the PMMC.

Both literature and respondents describe some issues that might be involved in implementing RFID technology in pig supply chains. RFID ear tags can get lost during the life of the pig. Literature describes that the CODP in the pig supply chain is at the slaughterhouse, where also the pig changes into pieces of meat. After that point, RFID systems also could be used when there is a good business model for them. The change of entity at the CODP is difficult to handle for RFID systems in which individual pigs are tracked, as also endorsed by respondents. RFID tracking of batches of pigs then might be a more viable alternative.

Respondents describe that implementing DNA technology and RFID technology in PMMC's is possible, but there should be a clear business goal to do so. Implementing those technologies should not be a goal at its own.

5.10. BLOCKCHAINS IN PMMC'S

In this section, applications of blockchain technology in PMMC's are discussed.

5.10.1. LITERATURE

As already stated, BT is a technology that is still in its infancy but has a high potential for disrupting existing processes in Agri-food (Tian, 2016). BT can create transparency in opaque, inefficient production chains in which counterfeit products circulate (Hofstede, 2017). Because of the increased transparency in the supply chain that is created by implementing BT, transaction costs decrease (Manski, 2017; Smit, 2017). Implementing smart contracts is a way in which BT can help to decrease transaction costs. Another application of BT is to increase traceability of products within the supply

chain (Smit, 2017). In this way, BT can e.g. help with the assurance of measures that increase product value but also result in a higher cost price, like e.g. mentioned in section 1.1 (Smit, 2017).

BT can help in solving problems like fraud in pig supply chains. Besides, by increasing transparency, the image of pig farmers and pig sector can be improved. Therefore, BT is an interesting technology for information sharing and assurance in pig supply chains. Because of the close collaboration between chain partners and the need for distribution of credible information through the supply chain, BT might be good applicable in PMMC's.

The more information systems of different levels in the supply chain are interlinked, the less easy it is to conduct fraud. Central information systems can interlink information and the application of BT prevents fraud with this data because of the inadaptability of existing nodes in the blockchain (Tian, 2016). Furthermore, in case of food frauds or food scandals products could be more easily traced back to the responsible chain partner in order to recover damages.

Another possible application of BT supported information systems is to track and control supply and demand within supply chains (Smit, 2017). This can help to solve problems of information insufficiency and inadequacy to decrease the bullwhip effect (Seebacher & Schüritz, 2017).

Implementing BT can help to trace pigs in the supply chain. In order to be able to do this, first of all information from the management system about the piglet is important. The piglet should have an unique identification number in order to trace it through the supply chain (Balendonck et al., 2003). Besides, the sire should be known in order to trace meat back for DNA tracing purposes (Wognum & van Erp, 2013). Furthermore, information about e.g. the date of birth can be added, in order for downstream supply chain partners to estimate the number of piglets they receive at a certain moment in time.

In a PMMC supply chain, BT supported information systems may have two functions on supply and demand controlling. On one hand, the number of available pigs at the slaughterhouse can be monitored and calculated by tracking the number of pigs at pig farms. Sows are inseminated for about eleven months before pigs are finished, so from that moment on the first supply calculations can be made (Baltussen et al., 2016; Bergevoet & Bondt en Marcel van Asseldonk, 2014). Downstream chain partners could use this information to work on promotions to sell more meat in cases of surpluses. On the other hand, when a too high supply is expected for a certain period, production might be limited.

5.10.2. INTERVIEWS

Blockchain technology can help to create a good overview over a production chain: the predictability, transparency and traceability of products and production processes improves. A pig can be tracked and traced through the supply chain from the moment that its mother was inseminated, until the moment of slaughter. After the moment of slaughter, blockchain technology can help to track and trace the products that are made from the meat through the further supply chain.

One of the respondents mentions an example about organic sheep meat in England: there was much more organic sheep meat at shops than the amount that could be produced by the number of organic sheep that was present. This was put in a blockchain, and it became easily visible where there were issues.

Respondent G1 mentioned that verifying origin on base of numbers of animals and amounts of products might be an alternative for taking DNA samples of meat in the supermarkets. Namely, DNA

samples are taken after something went wrong, while as blockchain monitoring is done active while production processes and product transportations take place.

The general opinion of respondents about applications of blockchain technology in the pig sector is clear: use of blockchains will only be useful in cases when chain partners work closely together, like in chain concepts or other situations in which more parties are involved. Respondent E1 described that in those situations of a non-consolidated supply chain, blockchains can help to share information in a good way and verify agreements that are made between many different parties. Collaborating with other parties is inherent on blockchain technology, so using the technique only within your own company is useless.

The respondents do not directly see viable cases of use in the pig sector in general. One of the respondents mentioned that the pig sector is very fragmented, so that the effort and costs to successfully implement a blockchain system are higher than the returns. Furthermore, respondents think that blockchain systems are a mean that should support the goal of a PMMC. Thus, applying blockchains should not become a goal at its own.

Chain partners only want to share information if it gives themselves also advantages. When it becomes compulsory to participate in a blockchain project for being allowed to participate in a certain PMMC, this already might be a good advantage to share the required information with other chain partners according to the respondents.

The expected potential of the technique is a reason for respondents to take part in blockchain pilots. Supplying information as input for the blockchain database is mentioned as a way to participate, as is helping to finance blockchain projects. A major incentive for respondents to participate in blockchain pilots is that it gives the possibility to acquire knowledge on the application of blockchain technology in pig business, what might be useful in the future. The respondents of the genetic company and the feed company do however not see it as their task to take the leading role in blockchain projects.

In order to be able to apply blockchains on data, it is necessary to centrally store this data. One of the respondents described that central storage of data only can improve already transparency in production chains, because it gets easier to compare data, analyse data and check which data is missing. When the second step, applying blockchains, is thereafter taken, the data gets protected for possible fraud.

One of the respondents states that blockchain systems might in the future be implemented in the backbone of standardized systems. Users then can use front-end applications without the need for knowing exactly how the blockchain running on the background is working. In this view, blockchains can be compared to internet: everyone is using it, without exactly knowing how it is working. The technology is then easy to use and does not ask many extras from the user.

APPLICATION OF BLOCKCHAIN TECHNOLOGY

Respondents stated that the application of blockchain technology in PMMC's makes it easier for consumers to verify whether the meat that they buy is really produced according to the rules that the PMMC prescribes itself. One respondent describes that the availability of better information might be the major added value of implementation of BT for consumers. It is not probable that all consumers become very active in checking out the additional amount of information, but at least they are provided with the possibility to check the origin of their piece of meat. One of the respondent mentions that by implementing BT in a central information system, a "meat passport" can be made. In

this passport, customers can find more information about the meat that they have bought or in store. This meat passport can be differentiated to different detail levels for different parties, the government is namely interested in other information then consumers or supermarkets.

Because of the increased transparency in the production process, PMMC's can give guarantees on that production process, e.g. on food safety or treatments of the pigs or meat that increase the value of the products. One of the respondents mentioned the example of a hospital, which chooses specifically for meat that is produced in a PMMC with a blockchain system implemented, because of the positive effects on food safety it expects.

CHAIN FINANCING, CRYPTOCOINS AND SMART CONTRACTS

One of the respondents described that banks are interested in financing pig stables, but often are reluctant to finance the pigs that grow in that stable. Namely, in case of a bankruptcy, the pigs are sold far under the optimal price. However, he thinks that by using blockchain technology, financing of pig farms might change radically.

As the respondent describes:

What continuous is produced by a supply chain is a kilogram of meat. The content of that kilogram of meat (the costs on feed, genetics, health, etcetera) differs always from a random other kilogram of meat. The only thing that is uniform is the euro. The kilogram of meat can be seen as a digital credit card, the guarantee that you every time keep producing. When meat is seen as a digital credit card, agreements can be made: if you buy a certain type of semen at a certain AI station, or if you buy a certain type of feed at a certain factory, or buy a certain type of disinfection liquid, you can pay it with your digital credit card. – (C1)

In fact, the system that the respondent describes can be compared to a cryptocoin. Thus, in this way a PMMC has its own cryptocoin that finances the products that are produced by the chain partners. The respondent thinks that by implementing such a system, the financial streams within a chain can be much easier. So farmers do not have to pay for feed, get paid for their piglets from the next farmer, who on his turn has to pay for feed, piglets and get paid for finishing pigs, etcetera. By the digital guarantee of the meat, the production chain can be financed. When the final supply chain partner is selling the product, the digital guarantee system of the blockchain pays out the chain partners before him in the chain. One of the respondents mentions that he already knows investors who are interested in financing pig supply chains with this system included. So, investors from outside the supply chain finance the supply chain as a whole, instead of a single supply chain partner.

Another respondent mentions that by this system, measurements can be financed which do not have a business model at the level of the party who have to conduct those measurements. The risk of "abuse", another party profiting from a measurement of a partner without paying that partner, decreases. On top of that, the value of the products increases, which is a major goal of PMMC's.

Furthermore, respondent C1 thinks that such a cryptocoin system can be used in more situations, like e.g. company takeover. Nowadays, it is very hard for new farmers to buy a farm when they do not have one, because of the high investment costs. Financing might be made easier when their animals and their feedstuffs are financed by the cryptocoin system of a PMMC they are part of.

Such a set of requirements that have to be fulfilled before a certain amount of money is released is known as a smart contracts. In those contracts, agreements are made in advance and pay-out is done automatically after the set of requirements is met. However, one of the respondents describe that this

theoretical is possible, but that there are not yet working practical examples. One of the reasons for this might be that it is very hard to quantify all the information that is required for a smart contract transaction. Furthermore, when financial data is handled in a blockchain, parties might get privacy related objections.

5.10.3. DISCUSSION

In table 5.7, the findings from this section are summarized.

Table 5.7: Applications of blockchain technology in PMMC's discussed in section 5.10.

Concept	Literature	Respondents
Assuring measurements that increase product value	Yes	E2, G1, C1
Implementing smart contracts	Yes	E2
Increase transparency of pig supply chains	Yes	F1
Decrease of fraud possibilities and impact	Yes	G1
Decrease transaction costs	Yes	F1, C1
Increase traceability of products within the pig supply chain	Yes	G1
Helping to track and control supply and demand within pig supply chain	Yes	
Information sharing in non-consolidated production chains		E1
Increasing possibilities for consumers to check origin of meat (e.g. setting up a meat passport)		E1, E2, G1
New financing models for pig supply chain partners, using e.g. a cryptocoin		C1, G1, E2

Another use of blockchain technology in Agri-Food might e.g. be in the verification of manure transports. Furthermore, there might be a role for blockchain technology in the production process of animal feed. The Dutch pig sector is very much depending on import of feed materials (van Vliet & van den Brink, 2011). Feed companies could apply blockchain technology to lay claims on their production process and every individual kind of raw material that they have used in their products. For instance, information about origin and content can be stored in a blockchain supported information system in order to assure the quality of produced feed and decrease the risk of feed contaminations and scandals.

Smart contracts might possibly contribute to assurance of extrinsic quality traits (see 3.5) in PMMC's. For example, a bonus per pig might only get paid out when the dropout of piglets is below a certain percentage. However, a lot of data should be quantified into the system, before such a smart contract could be automatically conducted.

5.11. SETTING UP A BLOCKCHAIN IN PMMC'S

In this section, issues in setting up a blockchain system in a PMMC's are discussed. In literature, not much information was found on this topic. However, a lot of information was derived from interviews.

5.11.1. LITERATURE

Results of monitored processes within the supply chain can be stored in the blockchain. However, in order to be able to store things in the blockchain, concepts should be operationalized into measurable variables (Kumar, 2011). After all, concepts are subjective and thus not measurable. Some concepts can directly be transferred into a variable, for others a set of indicators is necessary. The kind of variable that is derived (nominal, ordinal, interval or ratio) depends the accuracy rate of a variable (Kumar, 2011). An example of a concept is tail biting, a tail damage score derived by a standardized protocol is an example of a variable.

In order to successfully implement a blockchain system in a PMMC, processes within the chain should be standardised and digitalised (Smit, 2017). Furthermore, all partners should take part in the project,

because otherwise the added value of the BT system is lost. Some authors have doubts about how mistakes can be restored if necessary (Hofstede, 2017).

5.11.2. INTERVIEWS

All respondents described that process to set up a blockchain system is very time and effort costly. This process starts with realising what the possibilities of blockchain technology are, looking whether there are possible application in your own PMMC and, if that is the case, gain support of fellow chain partners. However, expectations should also not be raised too high. As one of the respondents describe:

At the moment, the general opinion is that setting up a blockchain is more than 50% talking, or social work. The real developing time, or programming time is quite limited. – E2

Before a working pilot version of a blockchain supported system can be launched, a lot of information analyses and situation analyses should be done. The fact that blockchain technology is relatively new makes this process even more difficult.

Different respondents described that when a system is set up, this needs to be done in small steps. Chain partners need to be convinced to take part in a blockchain project, which might sometimes be difficult. Some chain partners might even be replaced when they are not willing to or possible to collaborate in a blockchain supported information system. Furthermore, the systems that chain partners currently use need to be adapted and certifying organizations like the government should accept those adapted systems.

Respondent E2 mentioned that there might be different systems needed for different people with different roles in the system. For example, some people might only use the system for viewing data, and other people use the software to actively verify nodes. Furthermore, the software developing party needs to have the possibilities to improve the system if necessary, and the chain director might get some additional rights compared to normal supply chain partners.

Data needs to be quantified before it can be put in the system. Therefore, the information and format of the information needs to be standardized. Furthermore, agreements on ownership of original and modified data in the blockchain needs to be made between chain partners. Furthermore, one of the respondents describe that when a system is running, it might not be in favour of chain partners to directly change again a lot of things.

When the system is finally running, it is important to keep disciplined with filling in data into the system. Without a good discipline, the good effects of the blockchain system quickly drop.

One of the respondents compared blockchain technology to big data and machine learning techniques: many people say that those technologies are very disruptive. They mention plenty possible functions in which those techniques can be applied, but the number of real operational applications is not yet very high. So, it is not yet possible to say with a high level of secureness how e.g. the profit margin of a supply chain is shared in a blockchain supported system.

NO HIGHER SELLING PRICE

Many respondents think that it is difficult to find a clear business case for applying blockchain systems in supply chains. The value of the meat itself namely does not increase when blockchain is implemented. What changes when blockchain is implemented is that the quality of the meat is better

assured. However, according to respondent G1, there is no business model when there are no quality issues. As the respondent describes:

As long as everything goes all right, there is no business model. Only if it goes wrong, you (...) can quickly and adequate react on issues. However, 99% of the times everything goes right. So you doing it for that one percent, and then the business model always becomes somewhat more difficult. – (G1)

SYSTEM MANAGEMENT

System management can be split into two kinds of management: software developing and certifying and verifying content as a supervisor and director. Since most users presumably do not have much knowledge on programming, a third party will most likely conduct the software developing.

Most respondents agree that the chain director should manage the content of the system. This party can set the requirements to which the system should belong and furthermore fulfilling the role of supervisor. Preferably, the chain director should be a party who is financed by the whole supply chain. When the chain director would be a stakeholder which is involved in the production process itself, this party could get problem with the appearance of a conflict of interest. The other chain partners are involved in the BT system by verifying and providing data.

PAY FOR DEVELOPMENT OF SYSTEM

According to the respondents, chain partners should together pay the development and the maintenance of the blockchain supported information system. Again, the chain concept only should apply blockchains if there is a clear business model for it. Besides, good agreements should be made with the software developing company. For instance, it is important to discuss how development costs and maintenance costs exactly get rewarded.

What the right way is to spread the costs of the system over the different chain partners is a somewhat difficult question for the respondents. They think that this would presumably also depend on the general outline of the chain. In case a BT supported system is implemented in a PMMC, a chain director might play a leading role in sharing the system costs in a right way.

Furthermore, there might be a role for specific parties in investing in blockchain applications. If a system gives only added value to e.g. a government (in law enforcement in that case), the government might need to invest in a blockchain supported information system.

Blockchain technology offers new possibilities for investments by third parties, like e.g. by coin offering (Hofstede, 2017). One of the respondents mentioned that coin offering also might be a way in which PMMC's with a blockchain system can acquire new investment capital.

INFORMATION PROCESSING CAPACITY

Because a blockchain system that would be implemented in a PMMC is according to the respondents presumably a closed blockchain, there is not much calculation capacity needed. Respondent E2 mentioned that some simple desktop computers thus should be able to do the required calculations for the blockchain system, and so every chain partner can be involved in those calculations. It stays however important to have different parties involved in the calculation, because when a party has more than 50% of the calculation power there might be a chance of unverified changes in the system.

CONNECTING TO EXISTING SYSTEMS

Several respondents mentioned as an answer on the question "how could a blockchain system be connected to existing systems in the pig supply chain" that blockchain supported information systems

can easily communicate with existing data systems by using connecting software. By using protocols like EDI, data can be exchanged between different data systems. One of the respondents mention that it is good to make API's and interfaces that are referring to information in other systems, without copying everything what is e.g. currently already in a sow management system to the blockchain system. According to respondent E2, the development of data models thus becomes important to make those links between data systems more easy.

ERROR PROTOCOL

Because data entered into the blockchain supported information system cannot be changed afterwards, there needs to be a good protocol about how possible made mistakes in data entry can be fixed. Making a correction transaction afterwards might be a good way to resolve this problem according to respondent E2. Then, every user can see that there was a mistake in filling in information, and that it was resolved. This improves transparency.

One of the respondents mentioned that it firstly is important to prevent the possibilities to fill in incorrect data. In blockchain systems, the principle of garbage in, garbage out is also present: if the input data is of low quality, filling in data in a BT system would not improve the data. So verifying input data is very important, besides a good failure protocol. One of the ways to do this might be to save the raw data (i.e. on paper), so that later on this could be checked again.

DATA (UN) SUITABLE FOR SHARING

One of the respondents describe the information that should be put in the blockchain as "everything that helps for selling the products". Generally, this is data on transactions and identities of products. Most often, this is only quite general and basic information.

The general opinion of the respondents is that very detailed information (like e.g. exact daily weightings as respondent E2 mentioned) might not be relevant enough to store and share in a blockchain. This makes the system heavier and does not contribute to the goal of the system. So, only data that is for the whole supply chain of importance to share should be shared. This might e.g. be identity information, so when there are 1000 pig produced, is should not be possible to sell meat of 1500 pigs. Or there are more sows inseminated then doses semen produced. Furthermore, information on pig health can be included. Blockchain can support systems to check those things. In table 5.8, types of information are given that are according to respondents important to share between chain partners when using a BT supported central information system.

HIGHER DETAIL LEVEL OF SHARED DATA?

Nowadays, most blockchain projects are only stubborns yet. The level of detail of information shared is limited, but might be increased when there is a need for that. So, also the demand for information supply in PMMC's that use blockchain technology will grow quick in the next few years. For instance, a respondent described that it is not important that a certain sow had 12 piglets weaned and another sow 15 piglets. However, for genetic companies the exact mother and father of a pig might be important.

Furthermore, some information is only useful when it is stored with a level of detail in it. For instance, things that have happened during the life of a pig have an influence on the quality of its meat. Respondent C1 described that lung damage might be caused by a virus, but also a too low environment temperature during a few days. When the environment temperature is logged for a few times per day in the blockchain, the temperature can be checked afterwards when lung problems are

found during slaughter. In this way, it becomes easier to find causal relationships between certain factors that influence the end product.

Table 5.8: Important types of information to share in a BT supported information system according to respondents

Type of information	Respondent
Identity information of the pigs	E2
Number of used sires	G1
Number of doses of semen	G1
Number of produced finishing pigs	G1
Breeding values	G1
Feed type	F1, C1, G1
Feed conversion rate	F1, C1
Climate inside the stable	F1, C1, G1
Climate outside the stable	F1, G1
Genetics of the pigs	F1
Health information	C1, E2, G1
Antibiotics use	E2, G1
Transport information	C1
Disinfection of transportation vehicles	C1
Slaughter information	G1
Information from the retailer	G1

5.11.3. DISCUSSION

During the interviews, several topics were found that are according to the respondents important to take into account when setting up a blockchain supported system in PMMC's. Some factors also were found in the literature research. In table 5.9, the most important factors are mentioned.

Table 5.9: Important factors to take into account when setting up a BT supported information system in a PMMC.

Concept	Literature	Respondents
Operationalization of concepts into variables	yes	G1
Processes need to be standardized and digitalised	yes	
Broad participation of supply chain partners in the project	yes	
Building a good error protocol	yes	C1, E1, E2
Setting up a central information systems costs a lot of time and effort		C1, G1, E2
Setting up a system needs to be done in small steps		C1, G1
Discipline in maintenance of system		E1
Finding a clear business model for the BT system can be difficult		G1, E2
Stakeholders need to get different roles in the BT system		E2
Good distribution of costs of the system over supply chain partners		E2, G1, F1, C1
Developing a link to existing data systems		G1, E2, E1
Data put into the system should be limited to only high relevant data		E1, E2, G1

A note that should be made about the last point in the table, the level of detail in a blockchain data system, is that irrelevant for one party might be highly relevant for another party.

5.12. PRIVACY AND DATA OWNERSHIP

In this section, privacy and data ownership issues on the application of blockchain technology in PMMC's is discussed. The amount of literature found on this topic was limited, the respondents were however able to provide some more insights on this topic.

5.12.1. LITERATURE

According to literature, it is not very clear how to deal with privacy issues of blockchain technology (Ge et al., 2017). There are not yet legal frameworks present, which e.g. prescribe who is responsible for data in a blockchain system (Hofstede, 2017). However, some rules from European privacy laws might be applicable, like the GDPR. According to this legislation, the amount of personal information collected should be limited to a minimum. Furthermore, in the GDPR the right to modify or erase personal data is included (Hofstede, 2017). This is however difficult in blockchains, since information cannot be removed after it was entered into the blockchain. Users of open blockchains might not like the total transparency of data they provide by participating in an open blockchain system. Total transparency of data in a blockchain system might e.g. not be in favour from a business side of view, because some companies (like traders) are dependent on information asymmetry (Ge et al., 2017; Shrier et al., 2016). Some authors state that privacy issues in blockchain systems can be covered by using pseudonyms (Seebacher & Schüritz, 2017). However, when there is only a small amount of participants of the system, it might be easy to find out which party and which pseudonym belong together.

5.12.2. INTERVIEWS

VISIBLITY OF DATA FOR ALL CHAIN PARTNERS

The respondents think that there is currently no case of use for an open blockchain in the pig sector, because many firms will not be willing to share all information to everyone who is interested in it. In closed blockchains, data is shared between chain partners and consumers only can see the information that is given free at the exit of the system. In this way, customers can check e.g. the origin of the meat. On top of the privacy issues that are involved in an open blockchain, a closed blockchain is much more efficient than an open blockchain. According to respondent E2, during the initial phase of a BT system, open view access might be useful so that chain partners can experiment with how blockchains work.

Respondents state that making good agreements about a balanced level of data sharing between chain partners is of great importance. A high level of transparency is important, but on the other hand chain partners should have the convenience that chain partners doing the best for the whole supply chain. Thus, transparency also can have a limit.

Several respondents stated that the demanded level of transparency depends of the outline of the system. Factors like deciding which information is relevant, how this information is shared and which rights are granted to certain users are important to take into account. Some users can get write/read permissions on certain data, others only read permissions or even no permission to view certain information. Transparency by information sharing can give more insights in how the end product is influenced by different production factors.

DATA OWNERSHIP

According to respondents, there are two types of data involved in (blockchain supported) central information systems: original data and processed data. Original data is entered by a party into the system, processed data is original data processed by one of the chain partners. Every chain partner can process information different, in a way that the results are useful for them. Respondent E1 suggests that ownership of original data can be handled different than ownership of processed data. Respondent E2 mentions that chain partners should make clear agreements on this. Since every PMMC is different and there is not yet much experience with blockchain supported information

systems, a clear general solution is not present. However, the general opinion of respondents is that good agreements that are made in advance can help to prevent disagreements about data use.

One of the respondents mention that it is important to keep the amount of data that is gathered in the system limited. According to him, an information system should only contain metadata and have the outline of a data hub. Such a data hub is a central place at which chain partners can give each other access to their detailed information. In this way, it is not necessary anymore to create a new system for every single database link that is made between chain partners.

PRIVACY

An increased level of information sharing between chain partners offer a lot of different opportunities and advantages. However, the level of privacy decreases when more information is shared, dependent on what information is shared and how much information is shared. Therefore, it is good to think about privacy issues from the start of a blockchain system on. For instance, respondents describe that do not directly want to put financial information in a blockchain system. This information, like on profit margins, is competition sensitive and companies are not interested in sharing those (yet). For the same reason of privacy, respondents think that it is most likely that firstly, only closed blockchain systems will be implemented in PMMC's.

5.12.3. DISCUSSION

Literature states that open blockchains decrease the level of privacy of blockchain users. This may be conflicting with European privacy legislation like the GDPR. For example, the GDPR prescribes that collected data should be limited to a minimum, which might be conflicting with blockchain supported central information systems. Because of the total transparency that is involved in an open blockchain system, respondents see currently no business case for applying open blockchains in PMMC's.

Respondents described that good agreements should be made in order to determine the right level of data transparency. Furthermore, there might be different agreements made on ownership of original data and ownership of processed data within the system. Respondents are currently not interested in sharing financial data with supply chain partners, so presumably this would be left away from a blockchain supported system.

5.13. SUPPORT FROM ACTORS OUTSIDE PMMC'S

In this section, the need for support from actors outside PMMC's on setting up PMMC's and blockchain systems in PMMC's is discussed. Three main types of actors are identified, namely the government and/or politics, NGO's and retailers.

5.13.1. LITERATURE

New market concepts do not always fit perfectly in current legislation. Sometimes legislation is conflicting with certain traits of PMMC's, other times PMMC's enter a twilight zone in legislation. Organic pig farmers got a lot of support from politics in the starting phase of that concept (Verbong, 2006). The ministry of agriculture has an important role in creating supporting environments for new PMMC's, by e.g. changing laws and being flexible in issuing permits (van Galen et al., 2011). An example of laws that might be restricted are e.g. laws on competition (van Grinsven et al., 2014).

One of the most important PMMC's in the Netherlands is the "Beter Leven Keurmerk" (Better Life Quality Mark) of the Dierenbescherming, the Dutch Animal Rights Society. The Beter Leven Keurmerk started in late 2007 and was set up by the Dierenbescherming because they did not only want a better life for the few animals that are living in an organic system, but also a slightly better life for all the

other animals that were still living in a conventional production system (van Galen et al., 2011). Beter Leven works with three levels (stars) of meat products, in which one star means that the animals only had a slightly better life than animals in conventional systems, and three stars mean that the animals were kept in an organic system (van Vliet & van den Brink, 2011). The pressure of NGO's like the Dierenbescherming create possibilities for sustainable production of meat, and customers seem to want to pay more for "animal-friendly" meat.

Chain coordinators, in case of "Beter Leven" the Beter Leven Foundation, can help to decrease the threshold for moving to a differentiation strategy. Examples of ways in which this could be done is by helping in obtaining permits that are necessary for building an appropriate stable that is required for producing the PMMC products, or giving subsidies to decrease the costs of those permits for the farmer (van Galen et al., 2011).

5.13.2. INTERVIEWS

SUPPORT OF THE GOVERNMENT AND NGO'S

Respondents differ a lot in their opinion about the role of the government and NGO's in setting up blockchain supported information systems. Some respondents think that there will not be any support from those two kind of parties, others think that there might be some ways in which the government and NGO's could support blockchain supported information systems. Examples mentioned are providing subsidies or other kinds of financial support, sharing knowledge and expertise to provide support to open source platforms in the start-up phase.

One of the respondents thinks that PMMC's should be viable enough to pay the costs for a blockchain system themselves. However, the government might help when there would be a clear use for general purpose, like easier enforcement of laws. However, in this situation some respondents still have their doubts whether development of a general platform would be possible. Declaring a blockchain system general binding is an option for the government when there is a clear general purpose for it. However he thinks this would not be very likely. When easier enforcement of laws is the only reason for implementing a blockchain, there would presumably not be a business case in which consumers pay for the added value. The party which has an advantage of the blockchain system, so the government, should then pay for the system.

One of the respondents described that NGO's like the Dierenbescherming might like to support blockchain information systems in the Beter Leven PMMC, in order to improve transparency. Another respondent describes that NGO's might play a role in certifying processes and quantifying requirements on e.g. animal welfare.

SUPPORT OF RETAILERS

In contrast to a role for the government and NGO's, many respondents think that there might be a role for retailers in supporting blockchain supported information systems in PMMC's. Because of their power position, supermarkets can ask their suppliers to put information in a blockchain system. This can speed up the process of creating blockchain applications. A major incentive might be improving transparency, since retailers are afraid of getting involved in scandals. If someone states that mistakes are made within the production process, the retailer wants to be able to react quickly. Furthermore, retailers like to be possible to tell a positive story to consumers about the production processes in their supply chain. This openness forces to be integer, because every misstep is publically visible.

Because of the increased transparency that a blockchain supported system creates, possibilities to do a small delineated product recall in case of a scandal, instead of a big delineation program, grows.

5.13.3. DISCUSSION

In literature, support of the government is often described as changing legislation is such a way that there are more possibilities for collaboration between chain partners. In the literature, nothing was found about subsidies to set up blockchain systems in Agri-Food. From the interviews, we know that subsidies presumably only would be given when there is a clear general purpose of implementing blockchain systems in pig supply chains. Easier enforcement of laws might possibly be such a purpose.

NGO's who are involved in a PMMC might use their position to help farmers who enter their PMMC, and thus move to a differentiation strategy. Improving transparency in their PMMC's might be a reason to implement blockchain technology.

According to the respondents, retailers might be interested in helping to set up blockchain system in pig supply chains to limit the chance on food scandals that negatively affect their reputation.

6. DISCUSSION AND CONCLUSION

In this chapter, first the results from the literature research and interviews are discussed (6.1). Thereafter, the answers to the sub research questions (6.2) and main research question (6.3) are given. In paragraph 6.4, limitations, transferability and justifiability of this research will be discussed. Section 6.5 contains some directions for further research. Finally, in section 6.6, the improved version of the conceptual framework of figure 3.1 is given.

6.1. DISCUSSION

An interesting finding of this research is that respondents measure success of PMMC's in terms of creating valuable products for consumers, while as literature focusses more on generating profit. However, it is important to take both of those factors into account when success of a PMMC is about to be measured, because they are correlated to each other.

Literature describes great possibilities for applying blockchain technology in supply chains, but respondents were somewhat more conservative during the empirical part of this research. Several respondents stated namely that applying new technologies only would be a good idea when there is a business model for it. According to interviewees, a blockchain system should only be used to share basic data about products and production processes instead of putting in as much data as possible. Before putting in data in the system, it is necessary to quantify concepts into measurable variables. It might be difficult for some concepts (like e.g. animal welfare or stable climate quality) to do this in a secure and unambiguous way.

During the interviews, a lot of different types of information were found that are according to respondents important to share between chain partners. However, at the same time respondents stated that the amount of data sharing in a BT system should be limited. This is a little bit contradictory. It could be caused by the fact that every chain partner has different types of information that are relevant to them, and all those types of data together result in a lot of different types of information.

The management issues that were found during the literature research were different from the management issues that were found from the interviews. This might be caused by several different factors, like a lack of topical literature. Thus, respondents probably had more, newer and deeper insights in management issues in PMMC's compared to the literature (which was often more than eight years old). Furthermore, the respondents probably had a more practical approach on management issues than literature.

Some other topics were discussed by respondents, but not covered by literature. Those topics include outlines of PMMC supply chains and possibilities for communication towards consumers, technical issues in setting up BT systems in PMMC's and privacy issues in setting up BT systems in PMMC's. Possibly, this could be caused by the specificity of this information. Furthermore, because this is an exploratory research, it might be possible that unexplored terrain was found and entered.

Literature is most often focussing on applying open blockchain systems in Agri-Food supply chains. An advantage of such systems compared to closed blockchain systems is that information stored within the system is better assured. However, according to respondents there are not immediately applications of open blockchains systems in PMMC's. A major reason that was mentioned is privacy concerns on competitive sensitive information. Literature stated that applying open blockchains might be conflicting with the European GDPR legislation. This was not mentioned by respondents, but

is however important to take into account in setting up BT systems in general. Thus in fact, literature and respondents agree that there are privacy issues involved in open blockchains.

In contrast to open blockchains, respondents see possibilities to implement closed blockchain systems in PMMC's. An additional benefit of applying a closed blockchain system is that it requires much less processing capacity to maintain such a blockchain system compared to an open blockchain system. This saves costs for expensive computer equipment and electricity bills.

COSTS AND FINANCING OF A BT SYSTEM

Finding a clear business model for application of BT in PMMC's (and supporting technologies like DNA sampling and RFID) is another issue that was mentioned by respondents. Literature is optimistic about applications of those techniques, but respondents bother about finding a good business model in which the costs of those techniques are turned into profit. Possibly, increasing square valorisation by selling more minced meat products as PMMC products might be such a business case. Respondents generally do not think that consumers are interested in technical background information of meat. However, they agree that providing additional information about products and production processes shows confidence in integrity of those products and processes. Increasing transparency was mentioned by both respondents and literature as important for improving consumer trust in PMMC's. However, consumers will presumably take fraud prevention for granted, so respondents are not sure whether they are willing to pay a price premium for product and production process assurance by applying BT in a PMMC.

Literature described that the government, NGO's and supermarkets might possibly provide (financial) support for development of BT systems in Agri-Food. However, this is in contrast to the opinion of the respondents. They generally did not think that NGO's or the government will support BT systems in PMMC's financially, because there would most likely not be a clear case of general purpose for applying BT in PMMC's. Respondents however agree with literature on collaboration with supermarkets in implementing BT systems, because they think that supermarkets might implement BT systems in their supply chain because of decreasing possibilities food frauds and food scandals.

6.1.1. RESULTS IN RELATION TO THE THEORETICAL FRAMEWORK

Creating a better information supply through the supply chain decreases the level of information asymmetry between chain partners. This has a positive effect on product credibility. In this research, it turned out that applying BT in PMMC's has a positive effect on the information supply within the supply chain. So, the results of this study agree with the literature from the theoretical framework. Blockchain supported central information systems in PMMC's can decrease the level of opacity in supply chains by several different ways that Akerlof (1970) and Shrier *et al.* (2016) described. For example, BT supported information systems can provide guarantees on product quality, help to communicate the brand of the PMMC's and help to monitor companies that are licensed to use the brand of the PMMC. Thus, BT supported information systems can reduce the effort that consumers put in finding good quality products, thus decrease transaction costs and thus have advantages for consumers. Furthermore, better monitoring (by e.g. application of BT in PMMC's) results according to the agency theory, in lower transaction costs and an increase productivity, which are advantages for producers. On top of that, since contracts recorded in a BT supported information system are unchangeable, the risk of opportunistic behaviour (by e.g. opportunistic recontracting) of chain partners decreases. However, despite all advantages of applying BT in PMMC's, it is not sure whether there is a good business model for applying it in PMMC's and which party must bear the costs. By implementing BT in PMMC's, a central information system is developed in which intrinsic and

extrinsic quality traits can be assured better. Quality monitoring improves and producers are no longer anonymous producing mass products, which might encourage them to further improve product quality.

6.1.2. RELIABILITY AND TRANSFERABILITY

Reliability of a research means that the analysis of the qualitative data is done transparent, communicable and coherent (Auerbach & Silverstein, 2003). The used search terms for the literature research were included, which gives future researchers the possibility to repeat those search steps. Thus, in principle a researcher with basic academic knowledge would be able to repeat those steps to come to a comparable outcome.

Transferability of a research means that general lines of patterns found in a research could also be found in other contexts (Auerbach & Silverstein, 2003). Since this research was focussing on applying blockchain technology in PMMC's, patterns found in this research possibly also could be found in other cases in Agri-Food. Several arguments support transferability of this research. Firstly, one of the requirements for applying BT in a supply chain is close collaboration between chain partners. Some examples in other livestock sectors are Peter's Farm (veal meat), Rondeel (eggs) and Volwaard (chicken meat) (van Vliet & van den Brink, 2011). BT thus might be applicable in such chain concepts. Secondly, other livestock sectors also face fraud, like e.g. when horse meat was sold as beef (Havinga & Van Waarden, 2015). Thirdly, since this research was only focussing on Dutch PMMC's, the results might be transferable to other (European) countries. For instance, there are several concepts for beef (e.g. France Limousin) and chicken meat (Label Rouge) in France (Van Stokkom & Kamps, 2014). Fourthly, scandals like e.g. the horse meat scandal are not always limited to the Netherlands. In this specific case, the meat was sold to several other countries like France, Great-Britain, Sweden and Ireland (Huisman & Van Ruth, 2014). So, patterns found in this research also might be transferable to cross-border BT systems in Agri-Food.

6.2. CONCLUSIONS

The main research question of this thesis was: How can Blockchain Technology help to increase the success of Dutch Pig Meat Market Concepts (PMMC's)? Before answering this question, the sub research questions of this research will be answered.

SRQ 1: HOW CAN SUCCESS OF PMMC'S BE DEFINED AND MEASURED?

According to the respondents, a PMMC is successful when it creates products with additional value for consumers, so they buy the products produced by the PMMC. Respondents stated that generating profit for chain partners is only a second degree objective. However, literature described that generating profit is the most important success factor for PMMC's. So, respondents and literature do not agree on the definition of success for PMMC's.

SRQ 2: WHAT IS IMPORTANT INFORMATION TO SHARE BETWEEN PARTNERS IN PMMC'S?

By information sharing between chain partners, they can work together more efficient. This can save unnecessary costs. From the interviews, it was found that applying blockchain technologies might even not be the biggest improvement that saves costs: central storage and interlinkage of data that is currently already available might be an even more important first step. Different information streams are nowadays often badly connected to each other. Bringing those information streams centrally together increases transparency, which can help to improve existing processes. Furthermore, respondents described that it might be possible to create new management variables out of data of different sources. This also can help to get new insights that help to improve existing production processes.

Literature and respondents agreed that besides sharing know-how on how to produce in the PMMC, it is important to share production variables between chain partners. However, according to respondents data sharing should be limited to only high relevant data. Respondents described several types of information that are relevant to share between partners. Number of pigs is one of the most important, as are origin of the pigs, genetic background, feed type, grow rates, health information, antibiotic use and slaughter results.

Because it is according to respondents often technically not feasible and economically not viable to collect this data on individual animal level, this data is often collected at animal group level. Working with life animals always provide uncertainties in the production process. For example, animals can die or get ill, which decreases their productivity and value. However, developments on DNA and RFID technology might contribute to increased possibilities for tracking and tracing at individual animal level. One of the respondents described that central logging of data of different chain partners gives a better overview of the production chain and can lead to new insights about e.g. problems that emerge at several farms simultaneously.

SRQ 3: WHAT ARE THE CRITICAL FACTORS THAT DETERMINE THE SUCCESS OF DUTCH PMMC'S?

Literature described that in a PMMC, the interests of an individual chain partner are subordinated to the interest of the overall interest of the collaborating chain partners. A chain director could fulfil a leading role in a PMMC, i.e. taking the initiative for new innovations or checking whether the rules of the PMMC are followed.

Being efficient in the basic process of pig farming is according to respondents an important first requirement for PMMC's. Efficiency can be enlarged by a good information supply between chain partners, a limited number of supply chain partners, and a certain minimal production size. Furthermore, efficiency can be increased by a constant level of supply of pigs. When products are of a constant quality, consumers and customers know what to expect from the products they buy. Literature suggested that quality could be communicated to consumers via a quality label. Furthermore, literature stated that by innovating itself in small steps, a PMMC can stay relevant for consumers. When the PMMC is relevant for consumers, i.e. it creates added value for them, they might be willing to pay a premium for the products. However, the price difference of PMMC products compared conventional products consumers are willing to pay for is limited to about 25%.

Literature and respondents agreed that a good square valorisation is essential for having a successful PMMC. Additional costs can be spread over more kilograms of meat, which decreases the additional costs per kilogram of meat. Respondents stated that finishing barrows can increase the square valorisation, but has however a negative impact on animal welfare. Keeping in mind seasonal differences in demand of certain parts of a pig in production planning of meat products can contribute to a higher square valorisation. Furthermore, the production of more minced meat products has a positive effect on a higher square valorisation, which however set the requirement for a good product traceability through the supply chain.

Respondents furthermore agreed with literature that tracing of origin is a key factor that supports a successful concept. This decreases the possibilities for and impact of fraud and mistakes. A central chain information system helps to trace origin of products and separate PMMC product streams from the stream of conventional products. Furthermore, respondents described that strict working protocols contribute to this goal.

Respondents described that when products are traceable through the supply chain, guarantees on the production process of differentiated products can be given. Those can be communicated to consumers on the consumer package, possibly also in foreign countries. Furthermore, consumer trust is positively influenced by an increased supply chain transparency. Consumers might not be interested in technical production data, but providing the possibility to check information shows self-confidence of producers about integrity of production processes. However, in order to provide guarantees on the product process, it is necessary to link pigs and products to each other. DNA technique is likely to be able to contribute to this, but according to both literature and respondents individual tracing of pigs is (yet) quite costly.

SRQ 4: WHAT ARE CHALLENGES FOR DUTCH PMMC'S FROM INFORMATION MANAGEMENT POINT OF VIEW?

Respondents stated that pig farmers are difficult to group together, because of their individual mind-set. In literature it was found that the number of pig farms in the Netherlands is decreasing because of low product prices, aging of farmers, lack of successors and financial difficulties in starting up new farms or transferring existing farms to new farmers outside the family.

Literature and respondents agreed that setting up a PMMC is a long process which costs a lot of effort. Literature described that when switching from conventional production to production in a PMMC, there might be an income drop which might be difficult to overcome. Power relations might change, which might take time for chain partners to get used to. Respondents described that when producing for a PMMC, consumer knowledge is necessary but not always present at chain partners. Literature and respondents agreed that the willingness of consumers to pay a premium price for PMMC products is limited. Furthermore, it was found that the added value of PMMC's is corrosive. In other words, consumers perceive additional measurements after a few years as standard. This has the effect that PMMC's only have limited time to profit from the additional measures taken.

Respondents stated just like literature that DNA and RFID technology can support information systems in order to strengthen the link from the product in the physical world and the product in the information system. DNA technology is able to trace pigs and products from birth to plate. RFID tags can track and trace pigs from birth to slaughter, and products from slaughter to plate. However, both technologies have some issues, e.g. on cost price. DNA tracing could be made cheaper with only sampling of exclusive used sires, which however is not a 100% closed system. RFID ear tags can get lost, and linking products to individual animals is difficult.

SRQ 5: WHAT ARE APPLICATIONS OF BLOCKCHAIN TECHNOLOGY IN DUTCH PMMC'S?

During the research, no working applications of blockchain technology Dutch PMMC's were found. However, according to literature and interviewees, there are options to do so. However, the opinion of respondents about blockchain technology (and also about possible supporting technologies like RFID and DNA tracing) in PMMC's is that there are numerous possible applications, but applying blockchain technology should not be a goal at its own. Furthermore, respondents described that BT can only be applied in a situation of close collaboration between chain partners, like is done in a PMMC. Respondents currently work on blockchain pilots in PMMC's because of the expected high potential of the technique.

Both respondents and literature described that applications of BT can help to actively increase transparency in PMMC's. This can decrease transaction costs, by e.g. better supply and demand predictions and control. However, this requires that necessary data is digitalized and operationalized into variables that can be entered into the database. Furthermore, blockchains can help with the

assurance of measures that increase product value. The increased level of transparency decreases the possibilities for fraud and the impact of conducted fraud with e.g. those value increasing measures. Increased transparency and information supply (by e.g. a meat passport) on origin of meat will according to respondents probably have a positive impact on consumer trust in PMMC's.

Respondents and literature stated both that because of applications of BT in PMMC's, new finance models can come up in which pigs are e.g. financed by cryptocoins of the PMMC and pay-out is done with help of smart contracts. Those finance models can help to pay out premiums to parties that create added value within the supply chain which is not directly delivering profit to themselves, like farmers who are using RFID ear tags instead of conventional ear tags.

SRQ 6: WHAT ARE CHALLENGES IN APPLYING BLOCKCHAIN TECHNOLOGY IN DUTCH PMMC'S?

Setting up a blockchain system is time and effort costly. According to respondents, it is important that all chain partners collaborate and non-digital data is digitalized and operationalized into useful variables. Furthermore, links to existing data systems have to be made. Therefore, respondents described that the best way to implement a BT system is to do it in small steps. Furthermore, when the system is implemented, discipline in filling in data and maintain the system is needed. Most likely, a third party will be attracted to a PMMC which develops the BT software. Respondents and literature are not sure about the costs involved in developing a BT system for usage in a PMMC or, broader, Agri-Food.

According to respondents, it might be difficult to find a good business model for implementing a blockchain system. Decreased impact of fraud and less possibilities for fraud are advantages of BT, but respondents are not sure whether consumers will be willing to pay a premium for products of a PMMC because of this better assurance. Consumers expect that no fraud is committed with their food, also without paying a premium. So, they profit from the application of BT but are not likely to pay for this. For chain partners less fraud is profitable, because of e.g. a better product image which may lead to increased sales. When chain partners think that those factors lead to a profitable business model of applying BT in their PMMC, they thus will presumably have to pay the development and maintenance costs of the BT system their self.

Respondents stated that the outline of a BT system will to a large extent depend on agreements (e.g. on an error protocol) made by chain partners. Chain partners will most likely be holding back with providing complete open access to data they produce, because of privacy concerns. Therefore, it is likely that BT systems in PMMC's will firstly be closed blockchain systems. Consumers can get access to data which is released at the end of such a system. Using a closed blockchain system has also a positive effect on the required processing power to run the system. Furthermore, the processing power can be limited by sharing only high relevant data in the system. However, during the interviews it turned out that it depends on the role of a party within the supply chain what information they think is relevant. Respondents stated that it is important that chain partners make good agreements on what data is relevant to share and who is the owner of this shared data.

Respondents think that there probably would not be any support from the government in implementing BT systems in PMMC's, except when a case would exist in which implementing a BT system is of clear general purpose. NGO's might support implementation of BT systems in a PMMC which they are connected to when they can use it to increase transparency. Retailers might be interested in implementing BT systems in pig supply chains in order to prevent food scandals, which would negatively affect their reputation.

6.3. MAIN RESEARCH QUESTION

HOW CAN BLOCKCHAIN TECHNOLOGY (BT) HELP TO INCREASE THE SUCCESS OF DUTCH PIG MEAT MARKET CONCEPTS (PMMC'S)?

Success of a PMMC can based on literature research and interviews be defined as being relevant for consumers and generating profit for producers. Based on evidence of the literature review and interviews, closed blockchains systems can help to increase the success of PMMC's. However, finding a business model for applying BT in PMMC's might be difficult. Consumers profit from a better assurance of products and production processes, but presumably take a good assurance of products and production processes for granted. Thus, they might not be willing to pay a price premium for it. Third parties like the government and NGO's are according to respondents also not likely to provide financial support. So, chain partners together have to make agreements on financing the system and have to pay the costs involved their self when they think there is a business model (e.g. better assurance, less fraud, beter image) for applying BT in their PMMC.

Applying a closed blockchain system in a PMMC can lead to an increased supply chain transparency, which helps to assure and strengthen consumer trust by sharing more supply chain information with them. Literature and respondents stated that DNA and RFID techniques could contribute to this assurance, by increasing possibilities for origin tracing. Furthermore, by increased tracing possibilities through the supply chain, the square valorisation might increase. However, for all three technologies (BT, DNA and RFID) it applies that they are not panaceas which solve all problems in PMMC's.

Centrally collecting data from different sources is needed when setting up a BT system in a PMMC. This step can already give a lot of insights in the processes within the PMMC, which can help to increase supply chain efficiency and decrease cost price. A low cost price is necessary in order to be profitable as a PMMC. Furthermore, consumers might get access to information in a central information system, which can increase their PMMC credibility. Finally, from both interviews and literature it was found that applying BT in PMMC's might create space for new finance models, e.g. with help of smart contracts.

6.4. LIMITATIONS

In this section, the limitations in relation to the conclusions drawn are discussed.

LIMITED AMOUNT OF RELEVANT SCIENTIFIC LITERATURE

Since the blockchain technology is new, a limited amount of scientific literature was available. As of 29-11-2017, 647 articles in Scopus matched the search query "Blockchain", which grew to 779 English articles at 31-01-2018 and 1885 English articles at 05-09-2018. For the search query "Blockchain AND Agriculture", four articles are present, while for the search query "Blockchain AND food" only eight articles are present. The limited amount of scientific literature available has as a result that a lot of information had to be gathered via professional literature and interviews. However, the expected potential of BT in combination with the lack of scientific knowledge about applications of BT endorsed the opportunities for research on applications of blockchains in PMMC's and, in a broader perspective, Agri-Food as a whole.

RESPONDENT SAMPLE SIZE

A low number of respondents may cause problems on transferability. Thus, a good purposive sampling of interviewees is necessary for having a transferable research. However, since this is an exploratory research, finding out how concepts work is more important than statistical correct proof of how those concepts are interrelated. Because of problems with acquiring competition-sensitive

information, results might be incomplete. It was tried to reduce this risk by guaranteeing anonymity of sources.

The amount of respondents was relatively limited, which poses limitations on the generalizability of the research. A reason for the limited amount of respondents is that some people who were approached were not willing to participate in the research. Furthermore, the number of potential relevant interviewees was limited because Dutch PMMC's that collaborate with an increased level of information sharing are low in number.

However, some of the respondents fulfilled other roles in the production chain in the past. For instance, one of the respondents formerly was involved in trading, another respondent worked at a meat processing company and a third in the financial world. They thus were able to imagine what the view of partners with that role in the production chain would be.

6.5. SUGGESTIONS FOR FURTHER RESEARCH

This research focused at applications of blockchain technology in pig meat market concepts (PMMC's). Since it was shown that BT is applicable in this livestock sector, future research might focus on application of BT in other livestock sectors, like in dairy farming, layer farming, broiler farming or organic farming of e.g. goats and sheep. A requirement for applying BT in supply chains is close collaboration between chain partners, so future research should select a situation of close collaboration between chain partners in those other livestock sectors.

Furthermore, there might be options for applying BT in other parts of agriculture, like in manure accounting. Currently, there is a manure oversupply in the Netherlands and legislation is complex (Lauwere et al., 2016; van Grinsven et al., 2014). This results in opacity in manure transports and possibilities for mistakes and fraud. Therefore, applying blockchain technology in a central chain information system for manure accounting might be a possibility. However, then it is necessary to be able to quantify all relevant factors in reliable variables.

Another possible use of BT in agriculture can be in arable farming. Besides products for human consumption, a lot of animal feed products are produced. Feeding contaminated products to animals can result in food scandals (König & Voormolen, 2014). Therefore, it is necessary that there is a good assurance of feed ingredients through the supply chain. Such systems nowadays already exist, like GMP and Trustfeed (Trienekens & Zuurbier, 2008; Wognum & van Erp, 2013). However, they might be improved by the application of BT in the feed supply chain. Feed companies might play a role in this application.

6.6. CONCEPTUAL FRAMEWORK

The results of the literature review and the interviews could be used to improve the preliminary conceptual framework. In figure 6.1, the revised conceptual framework is given. A direct effect is drawn with a continuous line, an indirect effect with a dashed line. BT is having an indirect effect on quality management, because intrinsic and extrinsic quality traits can be assured better in an information system with BT applied. However, the quality of the products itself does not further increase by applying BT.

By increasing transparency (by e.g. applying BT) within a supply chain, information asymmetry decreases or even disappears. Besides, an increased level of transparency decreases the possibilities for fraud, and being transparent have a positive effect on credibility of the PMMC towards consumers. PMMC credibility was added between fraud in supply chains and success of PMMC's to make it possible to show the influence of supply chain transparency on this relationship in the model.

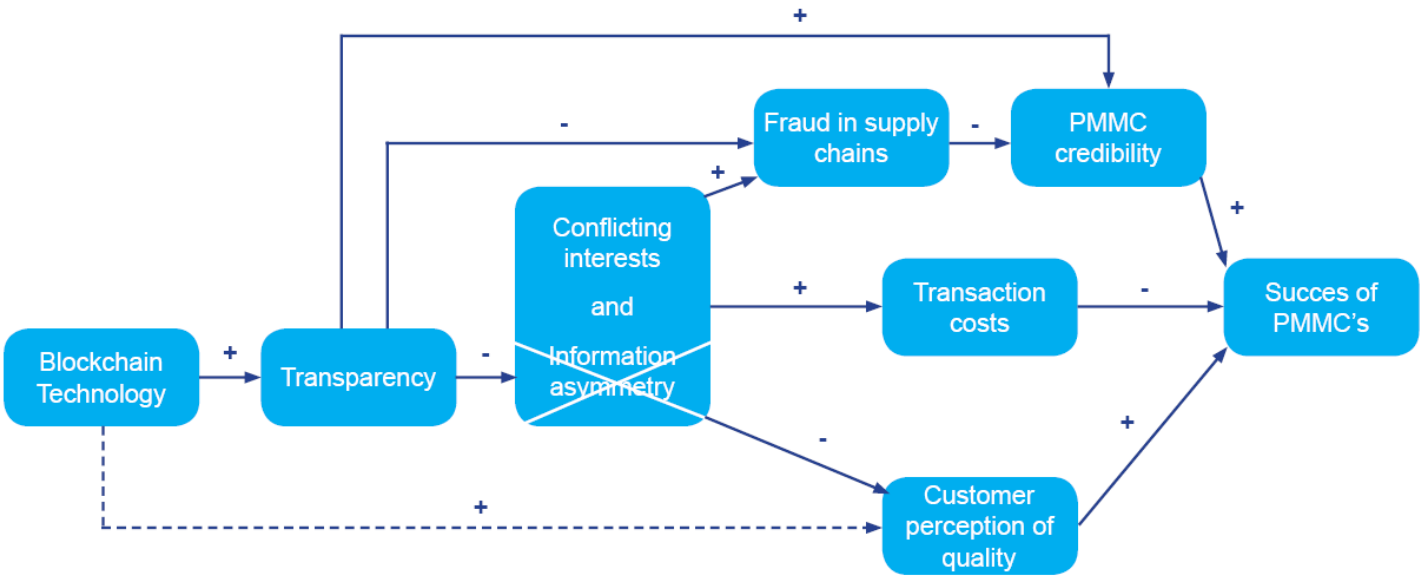

Figure 6.1: Revised conceptual framework. Source: own elaboration.

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APPENDIX I: USED INTERVIEW QUESTIONS

The interviews were conducted in Dutch, using Dutch interview protocols. Since translation might lead to small differences in meaning of questions, it is chosen to show the interview protocols here also in Dutch. The codes behind the questions are the codes from the preliminary (or top down) code book that correspond to that questions. This code book was made after the literature review and used to set up the interview questions and code and analyse the results using a top-down approach. The meaning of all those codes can be found in Appendix II.a.

I.a: INTERVIEW QUESTIONS BLOCKCHAIN EXPERTS (E1) AND (E2)

Blockchain in de varkenshouderij

1. Hoe denkt u dat de blockchain toegepast kan worden in ketenconcepten in de varkenshouderij en de varkenshouderij in het algemeen? ***(APP-PMC) (APP-PSG)***
2. Wat is volgens u het effect van de implementatie van blockchains in varkenshouderijketens op de verdeling van de winstmarge binnen de keten? ***(EFF-PRO)***
3. Hoe kunnen systemen met blockchain geïmplementeerd worden in varkenshouderijketens als grote ketenpartijen tegenwerken omdat zij hun machtspositie hierdoor kunnen verliezen? ***(PBP-PBC)***
4. Welke steun zou er vanuit de politiek en NGO's gegeven moeten worden bij de ontwikkeling van toepassingen van blockchain technologie in de varkenshouderij? ***(SUP-POL) (SUP-NGO)***
5. Welke toegevoegde waarde zou toepassing van blockchain technologie aan consumenten kunnen bieden? ***(SUC-AVC)***
6. Hoe denkt u dat de vierkantsverwaarding van het conceptvlees verder vergroot kan worden d.m.v. het gebruik van blockchains? ***(CHA-VAL)***

Data-eigendom

7. Hoe denkt u dat het eigendom over de in de blockchain opgeslagen data geregeld moet worden? ***(DOW-OWN)***
8. Wie zou het beheer over het ketensysteem moeten hebben? ***(DOW-MAN)***
9. Wat zouden volgens u de gevolgen van het implementeren van blockchaintechnologie op de machtsverhoudingen binnen de keten kunnen zijn? ***(DOW-POW)***
10. Hoe kan gewaarborgd worden dat grote ketenpartijen ingevoerde data van kleine ketenpartijen niet misbruiken (door bijvoorbeeld hun macht)? ***(DOW-ABU)***

Techniek

11. Hoe denkt u dat DNA- en RFID- technieken de blockchain kunnen ondersteunen? ***(TEC-DNA) (TEC-RFI) (PBP-IND) (APP-TRA)***
12. Welke partijen zouden de benodigde rekencapaciteit moeten leveren? En hoe groot zou deze rekencapaciteit moeten zijn? ***(TEC-PCP) (TEC-SCP)***
13. Hoe kunnen gemaakte fouten bij het invoeren van gegevens hersteld worden? ***(TEC-ERR)***
14. Wie moet het opzetten en onderhouden van het blockchain-ondersteund keteninformatiesysteem betalen? ***(TEC-PAY) (PBP-PRI)***

Informatie in de keten

15. Welke informatie is geschikt om in een blockchain-ondersteund keteninformatiesysteem tussen ketenpartners gedeeld te worden en welke informatie is hiervoor ongeschikt? ***(TEC-SUI) (TEC-UNS)***
16. Hoe kunnen blockchaintoepassingen aansluiten op reeds bestaande managementsystemen in de varkenshouderij (bijvoorbeeld Pigmanager of Farmingnet) ***(TEC-EXI)***
17. Zou iedere ketenpartij informatie tussen alle verschillende schakels in moeten kunnen zien? ***(DOW-IAP)***

I.b: INTERVIEW QUESTIONS GENETIC COMPANY (G1)

Introductie en informatie in de keten

1. Hoe draagt u met uw bedrijf bij aan ketenconcepten en wat is hierbij voor uw bedrijf het verdienmodel? ***(CTR-CCP) (CTR-REV) (CHA-CAV)***
2. Welke informatie wordt met ketenpartners gedeeld, en hoe wordt deze informatie gedeeld? ***(INF-WIN) (INF-HOW)***
3. Hoe kan uw bedrijf bijdragen aan de waarborging van het vertrouwen van consumenten in ketenconcepten? ***(CHA-ASU)***
4. Hoe kan uw bedrijf bijdragen om de vierkantsverwaarding van conceptvlees verder te vergroten? ***(CHA-VAL)***
5. Maakt u gebruik van een gecentraliseerd computersysteem waarin ketenpartners gezamenlijk informatie delen? ***(CIS-CUR)***
    a. Zo ja, hoe ziet dit systeem eruit? ***(CIS-OUT)***
        i. Wordt informatie van partijen aan het begin van de keten door gekoppeld naar partijen aan het eind van de keten ten behoeve van planningsdoeleinden? ***(CIS-PLA)***
        ii. Welke informatie wilt u graag als terugkoppeling van uw afnemers ontvangen? ***(INF-CUS)***
        iii. Krijgt u terugkoppeling van informatie van andere ketenpartijen uit de periferie? ***(CIS-FPH)***
    b. Zo nee, hoe zou een dergelijk systeem er volgens u uit moeten komen te zien? ***(CIS-OUT)***
        i. Welke problemen verwacht u mocht er zo'n systeem ingevoerd worden? ***(CIS-UPC)***
6. Welke toegevoegde waarde zou implementatie van een centraal ketenconceptsysteem volgens u aan consumenten kunnen bieden? ***(SUC-AVC) (CHA-CAV)***

Data-eigendom

7. Hoe kan volgens u gewaarborgd worden dat grote ketenpartijen ingevoerde data van kleine ketenpartijen niet misbruiken (door bijvoorbeeld hun macht)? ***(DOW-ABU)***
8. Zou iedere ketenpartij informatie tussen alle verschillende schakels in moeten kunnen zien? ***(DOW-IAP)***

Techniek

9. Hoe denkt u dat DNA- en RFID-technieken centrale keteninformatiesystemen kunnen ondersteunen? ***(TEC-DNA) (TEC-RFI) (PBP-IND) (APP-TRA)***
10. Wie moet het opzetten en onderhouden een centraal keteninformatiesysteem betalen? ***(TEC-PAY) (PBP-PRI)***
11. Wie zou het beheer over het ketensysteem moeten hebben en wie zou de benodigde rekencapaciteit moeten leveren? ***(DOW-MAN) (TEC-PCP)***
12. Hoe denkt u dat het eigendom over de data in een centraal keteninformatiesysteem geregeld moet worden? ***(DOW-OWN)***
13. Hoe kunnen centrale keteninformatiesystemen aansluiten op reeds bestaande managementsystemen in de varkenshouderij (bijvoorbeeld Pigmanager of Farmingnet)? ***(TEC-EXI)***

Nieuwe informatietechnologie: Blockchain

14. *Bent u bekend met de blockchaintechnologie?*
15. Denkt u dat de blockchain toegepast kan worden in ketenconcepten in de varkenshouderij en de varkenshouderij in het algemeen? ***(APP-PMC) (APP-PSG)***
16. Wat zou de rol van uw bedrijf bij het implementeren van blockchaintechnologie in de varkenshouderijketen kunnen zijn? ***(APP-ROL)***
17. Zou er volgens u vanuit de overheid, retail en NGO's steun (financieel, facilitair) gegeven moeten worden bij de ontwikkeling van toepassingen van blockchaintechnologie in de varkenshouderij? ***(SUP-POL) (SUP-RTL) (SUP-NGO)***

I.c: INTERVIEW QUESTIONS CHAIN DIRECTOR (C1)

Succesfactoren

1. Wanneer vindt u het concept succesvol? ***(CSF-SUC)***
2. Wat vindt u zelf belangrijke factoren die het succes van het concept verklaren? ***(CSF-ISF)***
3. Waar liggen de uitdagingen voor het concept? ***(CHA-GEN)***

Businessmodel

4. Wie is verantwoordelijk voor de acquisitie van nieuwe ketenpartners? ***(CSF-ACQ)***
5. Hoe worden nieuwe ketenpartners van specifieke kennis voorzien die nodig is om in het concept te kunnen produceren? ***(INF-NEC) (CHA-CHA)***
6. Wie heeft de macht binnen de keten? En waaruit blijkt die macht? ***(CHA-PWR)***
7. Welke rol heeft steun vanuit de overheid en NGO's gespeelt bij de totstandkoming van het ketenconcept (bijvoorbeeld subsidies, beschikbaar stellen van faciliteiten? ***(SUP-POL) (SUP-NGO)***
8. Hoe zijn retailers (supermarkten, maar ook slagerijen) en consumenten bij het concept betrokken? ***(CSF-RET) (CSF-CON)***
9. Wat zijn manieren waarop u het concept blijft vernieuwen? (Bijvoorbeeld door middel van onderzoek, aanscherping eigen eisen, nieuwe verkoopkanalen, enzovoorts) ***(CSF-INN) (CHA-CAV)***
10. Hoe is de vierkantsverwaarding van het conceptvlees en kunt u deze verder te verbeteren? ***(CHA-VAL)***

Informatie in de keten

11. Welke informatie wordt met de ketenpartners gedeeld, en hoe wordt deze informatie gedeeld? ***(INF-WIN) (INF-HOW)***
12. Welke informatie wilt u graag specifiek van uw directe leveranciers ontvangen? ***(INF-SUP)***
13. Welke informatie wilt u graag als terugkoppeling van uw afnemers ontvangen? ***(INF-CUS)***
14. Hoe wordt het vertrouwen van consumenten in het concept gewaarborgd? ***(CHA-ASU)***
15. Maakt u gebruik van een centraal computersysteem waarin ketenpartners gezamenlijk informatie delen? ***(CIS-CUR)***
    a. Zo ja, hoe ziet dit systeem eruit? ***(CIS-OUT)***
        i. Wie heeft het beheer over deze informatie en het systeem? ***(DOW-DAT) (DOW-MAN)***
        ii. Kan iedere ketenpartij informatie tussen verschillende schakels inzien? ***(DOW-IAP)***
        iii. Wordt informatie van partijen aan het begin van de keten door gekoppeld naar partijen aan het eind van de keten ten behoeve van planningsdoeleinden? ***(CIS-PLA)***
        iv. Vindt er terugkoppeling plaats van onderin de keten naar bovenin de keten? ***(CIS-FEE)***
    b. Zo nee, waarom niet? ***(CIS-NOT)***
        i. Welke problemen verwacht u mocht er zo'n systeem ingevoerd worden? ***(CIS-UPC)***
        ii. Hoe zou een dergelijk systeem er volgens u uit moeten komen te zien? ***(CIS-OUT)***

Nieuwe informatietechnologie: Blockchain

16. *Bent u bekend met de blockchaintechnologie?*
17. Denkt u dat de blockchain toegepast kan worden in de varkenshouderij en zo ja, hoe? ***(APP-PSG)***
18. Denkt u dat de blockchain toegepast kan worden in het concept waar u deel van uitmaakt? ***(APP-PMC)***

I.d: INTERVIEW QUESTIONS FEED COMPANY (F1)

Introductie

1. Hoe draagt u met uw bedrijf bij aan ketenconcepten en wat is hierbij voor uw bedrijf het verdienmodel? ***(CTR-CCP) (CTR-REV) (CHA-CAV)***
2. Wanneer vindt u een concept succesvol? ***(CSF-SUC)***
3. Waar liggen de uitdagingen voor varkensvleesconcepten? ***(CHA-GEN)***
4. Hoe kan uw bedrijf bijdragen om de vierkantsverwaarding van conceptvlees verder te verbeteren? ***(CHA-VAL)***
5. Hoe kunt u bijdragen aan de waarborging van het vertrouwen van consumenten in concepten? ***(CHA-ASU)***

Informatie in de keten

6. Welke informatie wordt met de ketenpartners gedeeld, en hoe wordt dit gedeeld? ***(INF-WIN)***
7. Welke informatie wilt u graag specifiek van uw directe leveranciers ontvangen? ***(INF-SUP)***
8. Welke informatie wilt u graag als terugkoppeling van uw afnemers ontvangen? ***(INF-CUS)***
9. Maakt u gebruik van een centraal computersysteem waarin ketenpartners gezamenlijk informatie delen? ***(CIS-CUR)***
    a. Zo ja, hoe ziet dit systeem eruit? ***(CIS-OUT)***
        i. Wie heeft het beheer over deze informatie en het systeem? ***(DOW-DAT) (DOW-MAN)***
        ii. Kan iedere ketenpartij informatie tussen verschillende schakels inzien? ***(DOW-IAP)***
        iii. Wordt informatie van partijen aan het begin van de keten door gekoppeld naar partijen aan het eind van de keten ten behoeve van planningsdoeleinden? ***(CIS-PLA)***
        iv. Vindt er terugkoppeling plaats van onderin de keten naar bovenin de keten? ***(CIS-FEE)***
    b. Zo nee, waarom niet? ***(CIS-NOT)***
        i. Welke problemen verwacht u mocht er zo'n systeem ingevoerd worden? ***(CIS-UPC)***
        ii. Hoe zou een dergelijk systeem er volgens u uit moeten komen te zien? ***(CIS-OUT)***
10. Hoe denkt u dat DNA- en RFID-technieken centrale keteninformatiesystemen kunnen ondersteunen? ***(TEC-DNA) (TEC-RFI) (PBP-IND) (APP-TRA)***
11. Wie moet het opzetten en onderhouden een centraal keteninformatiesysteem betalen? ***(TEC-PAY) (PBP-PRI)***
12. Wie zou het beheer over het ketensysteem moeten hebben? ***(DOW-MAN)***
13. Hoe denkt u dat het eigendom over de data in een centraal keteninformatiesysteem geregeld moet worden? ***(DOW-OWN)***
14. Zou iedere ketenpartij informatie tussen alle verschillende schakels in moeten kunnen zien? ***(DOW-IAP)***

Nieuwe informatietechnologie: Blockchain

15. *Bent u bekend met de blockchain technologie?*
16. Denkt u dat de blockchain toegepast kan worden in ketenconcepten in de varkenshouderij en de varkenshouderij in het algemeen? ***(APP-PMC) (APP-PSG)***
17. Wat zou de rol van uw bedrijf bij het implementeren van blockchaintechnologie in de varkenshouderijketen kunnen zijn? ***(APP-ROL)***
18. Zou er volgens u vanuit de overheid, retail en NGO's steun (financieel, facilitair) gegeven moeten worden bij de ontwikkeling van toepassingen van blockchaintechnologie in de varkenshouderij? ***(SUP-POL) (SUP-RTL) (SUP-NGO)***

APPENDIX II: USED CODE BOOKS

II.a: TOP-DOWN CODE BOOK

The top-down code book was formulated after the literature research and was used to set up the lists with interview questions, and during the analysis of the interviews. In the question lists (appendix I), behind the questions the codes of the categories and sub categories the question corresponds to can be found.

Category	Sub category	Code	Freq
Contribution of company to PMMC's	In general	CTR-CCP	9
	Revenue Model	CTR-REV	4
Important information to share in PMMC's	Info specific from customers	INF-CUS	2
	How to share this information	INF-HOW	2
	Necessary knowledge for producing in PMMC	INF-NEC	3
	Info specific from suppliers	INF-SUP	2
	Which info	INF-WIN	6
Central Information System	Currently using a central computer system	CIS-CUR	3
	Reason why not	CIS-NOT	2
	Outline central information system	CIS-OUT	6
	Planning: information link through supply chain	CIS-PLA	2
	Upcoming problems creation central information systems	CIS-UPC	2
Success Factors for success of PMMC's	Party responsible for acquisition	CSF-ACQ	2
	Connection with consumers	CSF-CON	7
	Continuous Innovation	CSF-INN	2
	Having a distinctive character	CSF-ISF	6
	Connection with retail (supermarkets/slaughters/restaurants)	CSF-RET	4
	General: when successful?	CSF-SUC	5
Challenges PMMC's	Assurance of Consumer Trust	CHA-ASU	3
	Creating additional value	CHA-CAV	5
	Chain collaboration	CHA-CHA	3
	General: what are challenges?	CHA-GEN	2
	Power distribution in chain	CHA-PWR	5
	Square valorisation	CHA-VAL	14
Effects of applications of BT	Distribution of Profit Margin	EFF-PRO	1
Applications blockchain	General in PMMC's	APP-PMC	8
	General Pig Sector	APP-PSG	7

	Role company	APP-ROL	3
	Tracking through the supply chain	APP-TRA	4
Problems with BT in PMMC	Individual tracing	PBP-IND	6
	Non-collaborating companies	PBP-PBC	7
	No higher selling price	PBP-PRI	4
Success factors strengthen by BT in PMMC's	Added value for consumers	SUC-AVC	3
Support	support NGO	SUP-NGO	7
	support politics	SUP-POL	12
	support retail	SUP-RTL	5
Data Ownership	Data Abuse	DOW-ABU	3
	Data Management of current system	DOW-DAT	1
	Visibility of data for all chain partners	DOW-IAP	7
	System Management	DOW-MAN	7
	Ownership	DOW-OWN	7
	Changing of Power Relations	DOW-POW	3
Technical issues	DNA technique application	TEC-DNA	9
	Error Protocol	TEC-ERR	4
	Connection to existing systems	TEC-EXI	6
	Pay creation and maintenance of system	TEC-PAY	6
	Provider calculation power/server capacity	TEC-PCP	4
	RFID technique application	TEC-RFI	8
	Size calculation power	TEC-SCP	3
	Data suitable for sharing	TEC-SUI	15
	Data unsuitable for sharing	TEC-UNS	5

The column "Freq" (Frequency) states how often a quote of a respondent could be linked to this code. Because respondents probably mention factors which they think are important more often, the values in this column are correlated to the importance of the factor according to respondents.

II.b: BOTTOM-UP CODE BOOK

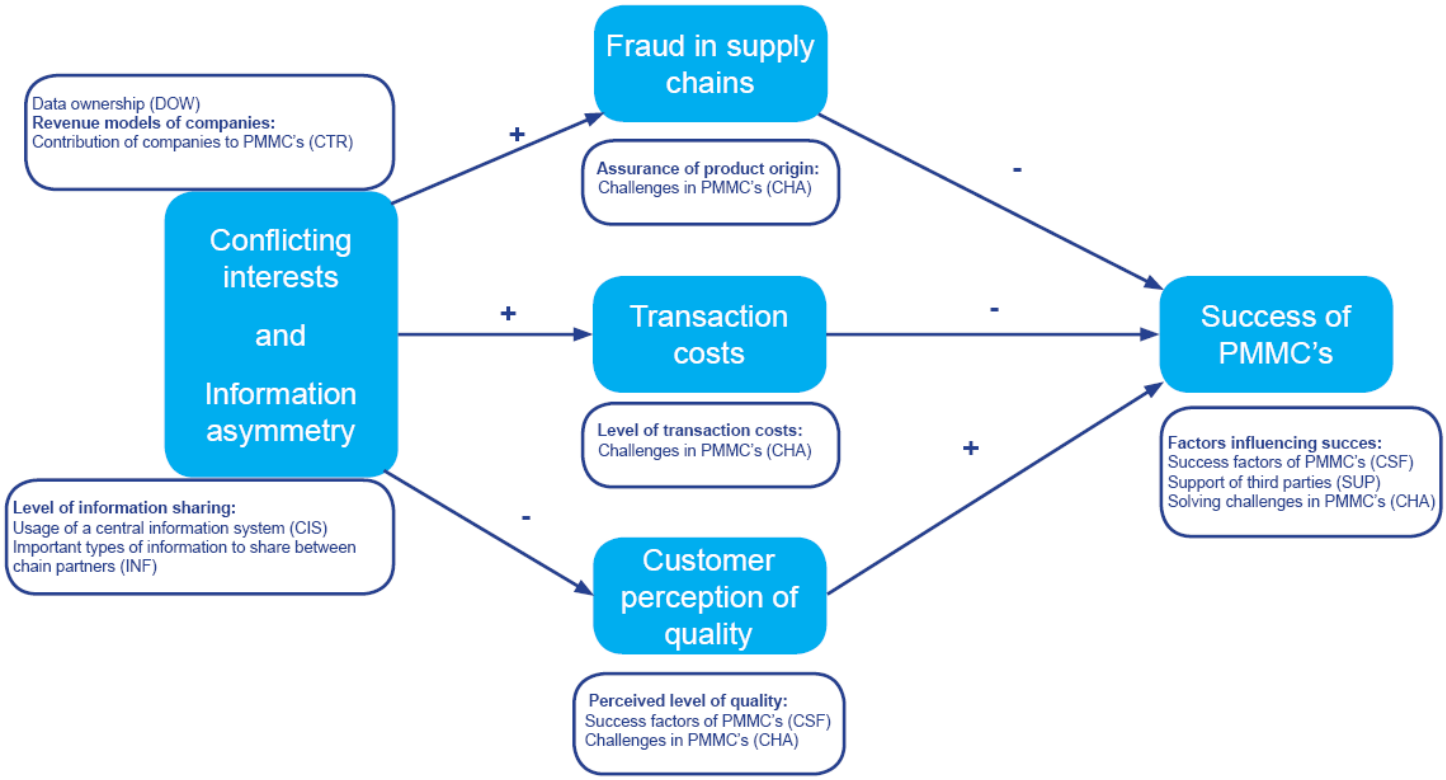
The bottom-up code book was created while analysing the interview transcripts. When an, according to the researcher, interesting and relevant quote was found in a transcript which could not be coded with a code from the top-down code book, a new piece of code was formulated and added to the following table.

Category	Sub category	Code	Freq
Success Factors for success of PMMC's	Being able to set additional production rules	CSF-APR	1
	Balanced farming (People, Planet, Profit)	CSF-BAL	2
	Continuous Product Quality	CSF-CPQ	3
	Having a critical production size	CSF-CRI	2
	Think from the demand side instead of the supply side	CSF-DSF	4
	Being efficient in the process of pig farming	CSF-EPF	3
	Having an efficient supply chain	CSF-ESC	5
	Health & Welfare of pigs	CSF-HWF	2
	Farms have to be relatively small because of image	CSF-NTB	1
	Keep overview over supply chain distribution	CSF-ODB	3
	Assurance of own production processes	CSF-SUR	2
	Meat Taste	CSF-TAS	1
	Trust in supply chain partners	CSF-TSC	1
Challenges PMMC's	Active controlling of production	CHA-ACP	3
	Butchers don't want to certify for a BLK star	CHA-BCH	1
	Selling boar meat	CHA-BOA	2
	Consumers are often not interested in technical background of products	CHA-CNI	4
	Added value of PMMC is corrosive	CHA-COR	1
	Cut in supply chain at slaughterhouse is difficult to deal with	CHA-CSC	4
	Complete secure via DNA technique is expensive	CHA-CSE	2
	Difference between consumer and citizen	CHA-DCC	1
	Banks don't want to finance pigs	CHA-FIN	1
	Farmer is the weakest party in the chain	CHA-FWC	1
	Meat sector is not used to selling brand meat	CHA-MBM	2
	Knowledge about selling meat to consumers	CHA-MTC	4
	Further supply chain does not know much anymore about farming	CHA-MTF	1
	Some Chain partners may get another business model	CHA-NBM	1
	New responsibilities and knowledge when producing in PMMC's	CHA-NEW	2

	Pig sector is changing	CHA-PSC	1
	Loss of slaughter ear tag	CHA-SLA	4
	Creating a PMMC costs a lot of time	CHA-TIM	1
Effects of applications of BT	Chain partners want to collaborate to get known to BT	EFF-CHP	4
	A new standard software program could come up	EFF-NSP	1
Applications blockchain	Recording data by batch of pigs	APP-BAT	2
	Decrease unnecessary production costs	APP-DUP	3
	Applications of BT In feed production chains	APP-FPC	2
	Providing guarantees and transparency to customers	APP-GUA	9
	Improving production process with help of new management information	APP-IPP	4
	Applications of BT in manure	APP-MNR	2
	Creating a "meat passport"	APP-MPP	2
	Finding causes for meat quality issues	APP-MQI	1
	New finance models for pig supply chain	APP-NFM	8
	Creating a good overview over a production chain	APP-OVE	4
	Smart Contracts	APP-SMA	1
Problems with BT in PMMC	Good discipline in filling in data needed	PBP-GDD	1
	Steps in building a system cannot be to big	PBP-SMS	4
	Understanding possible impact of BT and setting up a blockchain costs a lot of time	PBP-UBT	12
Success factors strengthen by BT in PMMC's	Customers choose for PMMC because BT is applied	SUC-BTP	1
Data Ownership	Privacy issues	DOW-PRV	5
Technics	Setting up a Joint data Hub	TEC-JDH	2
	Open or closed blockchain system	TEC-OPE	3

The column "Freq" (Frequency) states how often a quote of a respondent could be linked to this code. Because respondents probably mention factors which they think are important more often, the values in this column are correlated to the importance of the factor according to respondents.

APPENDIX III: FROM CONCEPTUAL MODEL TO INTERVIEW QUESTIONS



In the figure, the preliminary conceptual framework from figure 3.1 with variables included can be found. The variables served as a basis for the literature review: they show the direction in which relevant literature was searched for. The codes from the variables (between brackets) correspond to categories from the top-down code book, which can be found in appendix II.a. During the literature review, the categories were further sub-divided into sub-categories. Those sub-categories were the actual codes that were used to set up the interview protocols. It turned out to be difficult to find literature about transaction costs PMMC's. Therefore, it was not possible to include codes about this topic in the top-down code book. Since blockchain technology (BT) was not present in the preliminary conceptual framework, but information was found in literature, some additional categories were added in the top-down code book which cannot be found in the figure above (categories APP, PBP, EFF, SUC and TEC). Some concepts were moved from a category present in the figure above to one of those new categories, because they fit there better according to the researcher. For example, tracking of products (APP-TRA) is set under the new category APP. This code is derivated from assurance of product origin, which is in the figure however set as a challenge in a PMMC (CHA).