Adoption of Multiple Dairy Farming Technologies – Issues and Opportunities for Smallholder Dairy Farmers in West Java, Indonesia

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Abstract

Increasing domestic demand for dairy products presents market opportunities for smallholder dairy farmers in Indonesia. However, low productivity and poor milk quality prevent most smallholder dairy farmers from benefitting from these opportunities. The adoption of improved dairy farming technologies and practices can increase smallholder dairy farmers' milk productivity and milk quality. There have been many dairy development programs in Indonesia attempting to increase technology adoption; yet, adoption of key technologies remains low.

This thesis attempts to understand Indonesian smallholder dairy farmers' awareness of technologies, their adoption behaviour, and their main barriers to adopting multiple technologies. It also examines the effects of technology adoption on smallholders' milk production. The thesis has three main analytical chapters, which address the research objectives through multiple methods: descriptive analysis, cluster analysis and econometric modelling. The analytical chapters use a primary cross-sectional dataset from a survey of 600 dairy farming households located in four dairy producing districts in West Java Province, Indonesia.

A Latent Class cluster analysis is used in the first analytical chapter to identify two unique subgroups of dairy farming households based on their awareness and adoption patterns (adoption, dis-adoption, and continued adoption) of multiple on-farm dairy technologies. Relative to the 'High awareness/high adoption' cluster, households in the 'Low awareness/low adoption' cluster have significantly lower levels of awareness of all technologies; and, among 'aware' households, technology adoption rates are also significantly lower. Farmers in the Low awareness/low adoption cluster are older, have less formal education, manage fewer dairy cows, have less productive and profitable dairy enterprises, live further away from the cooperative and farmer group leader, and

have fewer contacts with dairy extension staff. Farmers face multilayered and heterogenous constraints to adopting dairy technologies. Thus, technology dissemination programs need to ensure they meet the unique needs of subgroups of farmers.

A Multinomial Endogenous Switching Regression (MESR) approach is used in the second analytical chapter to estimate the effects of three feed technology bundles on milk production. The adoption of feed technology bundles is significantly associated with smallholder farmers' ownership of capital. Further, the adoption of technology bundles has positive and robust effects on milk production per cow, with greater effects if the technology bundle includes high protein feed concentrates. We suggest improving farmers' awareness of the benefits of complementary technologies and improving access to inputs, such as high-quality feed concentrates.

The final analytical chapter uses a new institutional economics lens to understand factors contributing to the dis-adoption of key technologies. Farmers' reasons for dis-adoption centred on limited availability and affordability of inputs, as well as limited knowledge and lack of improved skills required for adoption. Current institutional arrangements for milk and input quality assessment and institutions provision of dairy farm inputs and services are ineffective, and contribute to dis-adoption. Programs and policies aiming to increase farmers' adoption of technologies need to address constraints at both a farm and an institutional level.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Chapter 1: Introduction

1.1 Background

The increasing demand for milk products in Indonesia puts pressure on domestic milk production, yet, at the same time, creates a market opportunity for milk producers who are mainly smallholder farmers. Milk consumption per capita has increased by 28.6% per capita per year from 2009 to 2018 (Ministry of Agriculture Indonesia 2019). The growing demand has resulted from a rapid structural transformation in Indonesia. This transformation is a common trend in developing countries (Alexandratos & Bruinsma 2012; Delgado 2003; Knips 2005), and features population and income growth, urbanisation, rising number of middle-income earners, changes in dietary patterns, a food system transformation, and technological change in farming systems (OECD-FAO 2017; Reardon & Timmer 2014; Thornton 2010).

Dairy production is a vital source of livelihood for many rural farm households in Indonesia's dairy producing regions. Increasing their productivity remains a critical development agenda for the government as outlined in the blueprint for the development of the Indonesian dairy farming industry published by the government, that set a target of achieving 60% self-sufficiency by 2025 (Coordinating Ministry for Economic Affairs of Indonesia 2014). Currently, the country meets 77.5% of domestic milk demand from imported milk and deficiencies in domestic milk production meeting this demand are projected to continue to increase until 2023 (Ministry of Agriculture Indonesia 2019).

As the primary fresh milk producers in Indonesia's dairy value chain (Priyanti & Soedjana 2015), smallholder farmers face multifaceted challenges to keep up with market demands. These include inefficiencies and a high cost of milk production, lack of access to land to grow forages, low availability of quality feed, poor milk quality due to unhygienic milking and handling conditions, lack of skill in management, low educational levels of farmers, poor infrastructure, and marketing issues, lack of access to credit, to improved dairy breeds, and to dairy farm innovations (Daud, Putro & Basri 2015; Ilham 2001; Morey 2011; Priyanto & Rahmayuni 2020; USDA 2019). These challenges have constrained smallholder farms' milk production, and there is a concern that vulnerable smallholder farmers could be displaced by multinational dairy companies, which have been investing in milk production facilities in some dairy producing regions in Indonesia.

Various investments in dairy development and policy programs have targeted smallholder farmers, aiming to increase their milk productivity and quality by improving their access to dairy farming technologies, in line with the priority strategies stated in the blueprint for the development of the Indonesian dairy industry. These include adopting technologies and improved practices that could improve the nutritional intake of dairy cows (e.g., high protein content concentrates), improved milk hygiene (e.g., using detergents on milking utensils), better cow health (e.g., teat dipping after milking practices), and farm business management (e.g., record keeping). However, there is little information about which technologies have been adopted by smallholder dairy farmers and which technology options translate into enhanced milk production and/or quality.

In the Indonesian case, there is an inadequate exploration of agricultural technology adoption by smallholder farmers, especially in the dairy farming context. While some studies examine the level of adoption of different technologies, such as artificial insemination, silage, complete feed, biogas, and automatic milking machines (e.g., Mulatmi et al. 2016; Roessali, Eddy & Marzuki 2014), there has been limited comprehensive analysis on the main barriers to adoption and few studies have examined the relative effects of adopting multiple dairy farming technologies on milk production. Other studies in the Indonesian dairy farming context are on the topics of the dairy value chains (Nugraha 2010; Susanty et al. 2018; Susanty et al. 2019), farm performance (Sembada, Duteurtre & Purwanto 2016; Setiawan 2019; Utami & Seruni 2014), and incentives for milk quality improvement (Treurniet 2021).

It is against this background that this thesis aims to understand the heterogeneity in technology adoption, multilevel barriers (at the farm and institutional levels) to initial and continuing adoption, and to examine the effects of the adoption of multiple technologies on milk production. Analytical chapters are presented and, to some extent, are ordered to reflect the sequence of the stages of adoption. The first analytical chapter profiles smallholder dairy farmers based on the different stages reached (including awareness, adoption and dis-adoption or continued adoption) in the adoption process for multiple technologies. The following analytical chapter focuses on adoption decisions, explicitly examining the factors affecting the adoption of multiple technologies and their effects on milk production. The last analytical chapter focuses on institutional issues that have led farmers to discontinue, or dis-adopt, technologies.

The compilation of analytical chapters in this thesis offers a comprehensive understanding of the adoption of agricultural technologies by focusing discussion on the farm-level context as well as on institutional issues that are external to farmers, but which are significant factors in their technology adoption process. Besides contributing to the literature, this thesis contributes to providing information and suggestions for designing workable recommendations and extension programs to improve strategies in disseminating dairy technologies and thereby increase adoption rates by smallholder farmers in Indonesia.

1.2 Research gaps and motivation

The typical approach used by most empirical studies defines adoption as a binary process, and limits the discussion to adoption and non-adoption (Brown, Nuberg & Llewellyn 2017; de Oca Munguia et al. 2021; Jones-Garcia & Krishna 2021; Weersink & Fulton 2020). This approach, however, does not reflect the complexities of the adoption process, obscuring the actual reality of adoption decisions, and potentially yielding misleading conclusions in providing recommendations that are intended to increase adoption rates (Brown, Nuberg & Llewellyn 2017; Floyd et al. 2003; Kabunga, Dubois & Qaim 2012; Lambrecht et al. 2014; Weersink & Fulton 2020). In response to this gap, this study explores heterogeneity in smallholder dairy farmers' multi-stages of adoption, including awareness, adoption, and dis-adoption or continued adoption, of different technologies. This study is needed for Indonesia, because smallholder dairy farmers have been introduced with varying technology options. However, the status of the adoption and the characteristics of farmers who are aware of technologies and/or those who choose to adopt technologies are not well understood.

Farmers are faced with different technology options, and their decisions to adopt particular technologies, or technology bundles, are rational in that they expect to maximise expected benefits, despite a varied range of agricultural production constraints (Dorfman 1996; Feder, Just & Zilberman 1985; Kassie et al. 2013; Manda et al. 2016). While the literature on the adoption of multiple agricultural technologies is growing, most of it has investigated the factors that predict the likelihood of adopting multiple technologies, the number of technologies adopted, and the different technology combinations, or packages adopted (Kassie et al. 2015; Kpadonou et al. 2017; Tsinigo & Behrman 2017; Wainaina, Tongruksawattana & Qaim 2016; Ward et al. 2018). Only a few studies have analysed the relative effects of adopting multiple technologies on farm performance (e.g., agricultural yield), as suggested in a meta-analysis by Ogundari and Bolarinwa (2018).

Chapter 3 contributes to the literature by examining the effects of the adoption of dairy feed technology bundles on milk production by smallholder dairy farmers. The motivation for focusing on dairy feed-related technologies is that their adoption is basic yet important for improving milk productivity. Unlike previous adoption studies comparing the effects of adoption with non-adoption, this study also compares the effects of the adoption of specific technology bundles, relative to or in comparison to other bundles, to estimate which bundles potentially drive more significant outcomes. In identifying which technology bundles are the most productivity-enhancing, this information is important in supporting dairy farmers to increase their milk production, and therefore, provides insight on which bundles should be promoted for adoption by farmers. To better design technology dissemination programs, the chapter also analyses the factors that may enhance the adoption of the technology bundles.

The literature on the adoption of agricultural technologies has been dominated by understanding the drivers of farmers' decisions to adopt agricultural technologies (for a review of the literature see, e.g., Feder, Just & Zilberman 1985; Liu, Bruins & Heberling 2018; Pannell, et al. 2006; Ruzzante, Labarta & Bilton 2021). However, there has been little exploration in the literature on why farmers discontinue their adoption of (dis-adopt) agricultural technologies, including examining the motives underpinning farmers' decisions to discontinue use of a technology (Beissinger et al. 2017; Chinseu, Dougill & Stringer 2019; Sietz & Van Dijk 2015).

While studies on dis-adoption are growing, most of them focus on understanding issues at the farm level and place less emphasis on market and institutional factors that are also significant in encouraging or discouraging the adoption of technology. The final analytical chapter, Chapter 4, focuses on examining the current institutional arrangements in which farmers operate and that have the potential to discourage continuous adoption of technologies by farmers. Understanding the issues that have led farmers to dis-adopt technologies is another crucial aspect explored in this thesis in order to gain a comprehensive understanding of the barriers that prevent promoting wider uptake and continuous adoption of technologies.

In addition to contributing to the literature by addressing identified research gaps (discussed above), this thesis also contributes by adding new insight focused on the smallholder dairy farming context. Most adoption studies focus on "green revolution" type technologies (improved seed varieties and fertilisers) and agricultural conservation practices in the context of farming crops such as maize. This attention is reasonable because the food crop sector plays a vital role as the primary source of staple foods, providing labour opportunities for many people and contributing to achieving food security in many countries. On the other hand, the dairy sector is gaining more attention, especially in developing countries, due to the increasing demand for protein-based foods, including milk. However, fewer studies have been conducted in the smallholder dairy farming context, which has some unique characteristics.

Dairy farming in smallholder conditions is consistently labour intensive (Janssen & Swinnen 2019; Kumarasekara & Edirisinghe 2009), while other farming sectors (e.g., food crops) are seasonally labour intensive, specifically in the planting and harvesting seasons. Dairy farmers need to milk their cows twice a day and deliver the milk to the milk collection point straight away. Cows need to be washed to ensure better milking hygiene and hence milk quality. After delivering the milk, farmers need to go to grass fields, cut and carry the grasses to animal houses and feed the cows. Farmers also need to clean the animal houses.

Dairy farming produces milk daily, and it is a highly perishable product. The milk should be distributed to the milk collection point in a timely way to avoid the growth of bacteria, which can reduce milk quality. This is especially important because most smallholder dairy farmers do not have milk refrigerators to store their milk. Therefore, smallholder dairy farmers need strong institutional support, which is often provided through dairy cooperative membership, to address milk distribution issues and their small economies of scale (Ariningsih, Saliem & Erwidodo 2019).

1.3 Research questions

To understand the heterogeneity in adoption decisions and the barriers at the farm and institutional levels to the adoption of multiple technologies by smallholder dairy farmers in Indonesia, and to examine the effects of the adoption of technologies on milk production, this thesis addresses the following research questions:

(i) Are there any unique patterns of adoption categories, or subgroups of farmers, based on stages of technology adoption? How are the characteristics of subgroups of farmers associated with their patterns of technology adoption?

(ii) What feed technology bundles are being adopted by smallholder dairy farmers in Indonesia? What factors affect farmers' adoption decisions? How does the adoption of the feed technology bundles affect smallholder milk production?

(iii) What are the main reasons farmers decide to dis-adopt some dairy technologies that have the potential to improve milk production? How do prevailing institutional arrangements prevent continuous adoption of agricultural technologies?

1.4 Description of data and methods

This thesis utilises quantitative data from a primary dataset collected from a survey of 600 dairy farm households and qualitative information gathered from semi-structured interviews with board members from local village dairy cooperatives. The study location is four-dairy producing districts in West Java, Indonesia. The survey and interviews were conducted in August-September 2017 and in December 2017-January 2018, respectively. The research was part of a large multi-year Indonesian smallholder dairy development project (IndoDairy) funded by the Australian government, through the Australian Centre for International Agricultural Research (ACIAR), in partnership with the Government of Indonesia. The survey and qualitative interviews were conducted collaboratively with the Indonesian Centre for Agricultural Socio-Economic and Policy Studies (ICASEPS), Institut

Pertanian Bogor (IPB University) and with the Centre for Global Food and Resources at the University of Adelaide (lead organization for the IndoDairy development project).

Milk production in Indonesia is centred on Java Island, which accounts for 97% of Indonesia’s dairy cow population and 98% of its milk production (Statistics Indonesia 2021). West Java, the study location, contributes 31% to national fresh milk production (Statistics Indonesia 2021). Most dairy farmers in Indonesia reside in West Java, which has the advantage of proximity to potential consumers living in key urban areas, mainly Jakarta (Indonesia’s capital), Bandung and Bogor, where the consumption of fresh milk and dairy products (e.g., sweet condensed milk) is high (Statistics Indonesia 2018a, 2018b). A growing number of food service businesses (e.g., cafés, restaurants), that are also located in these cities, sell food and bevarage products that require fresh and/or high quality dairy products. Additionally, eight of fourteen milk processing companies that source their milk from local dairy farmers are located in West Java (Ministry of Industry Indonesia 2017). Three of them are the dominant players in the dairy industry in Indonesia.

The majority of dairy farm households in Indonesia are members of dairy cooperatives (Statistics Indonesia 2015). The cooperatives play an important role in the Indonesian dairy value chain. They act as hubs, connecting smallholder dairy farmers with milk processing companies, which are the main milk buyers, and are the main dairy farm input providers and service providers for farmers (Priyono & Priyanti 2015). Of the 141,989 dairy farm households in Indonesia, almost 60% are members of dairy cooperatives; 17% are not members, possibly because no cooperatives exist in their village, and 19% are not interested in becoming members (Statistics Indonesia 2015). Of the 26,121 dairy farm households in West Java (Statistics

Indonesia 2015), around 71% are dairy cooperatives members.[1] Given this level of membership, the household respondents in this study are all members of dairy cooperatives.

The sampling method used to select dairy farming households for the survey was purposive proportional random sampling. Five dairy cooperatives, distributed within four dairy-producing districts in West Java, were purposively selected after a consultation process with the key stakeholders in the dairy value chain and according to several criteria. Cooperatives had to share an interest and commitment to the project's goals and objectives during the project period (four years) and they had to be willing to share information. There had to be a likelihood of only low-level intervention from other development projects and a low likelihood of the project competing with existing activities. Cooperatives had to be interested in the project's extension topics (dairy feed, milk quality, herd health, and business management), and there had to be a willingness to improve milk quality and incentivise farmers. Finally, there had to be a likelihood of spill-over effects to 3,000 farmers, in line with the overall goal of the project.

The number of smallholder dairy farm households selected from each district was proportional to the region's total dairy farm population. Given the number of respondents for Cianjur and Bogor districts was very small, it was decided to oversample farmers in both locations to ensure sufficient observations for analysis. In addition, for the purpose of analysis, the project had an interest in learning more about the characteristics of farmers' from Cianjur and Bogor districts known to be close to popular tourist destinations. This proximity creates market opportunities, but at the same time creates challenges for farmers with respect to land (for growing forages) because of competition with the tourism industry.

[1] Data collected by personal communication with the Indonesian Dairy Cooperatives Union (GKSI) in November 2016.

Dairy farmers were randomly selected from each of the districts, and farmers were proportionately sampled according to the total number of dairy farmers in each of the four districts. The distribution of the sample is available in Table 2.1 in Chapter 2.

The process of selecting dairy farmers to be included in the sample followed several steps. The list of active dairy farmers was provided to the research team by the cooperatives in each region. The research team ensured that the cooperatives provided the lists of all active farmers to avoid cooperatives only providing lists of farmers with well-performing farms, hence reducing potential selection bias. The research team generated a unique number assigned to each farmer. Farmers were randomly selected to be in the primary list of respondents, with the numbers of farmers selected per district described in the previous paragraph. A 10% reserve (backup) of farmers from each list was identified in case farmers in the primary list were not available for interview on specified days. The reserve list was also randomly selected from the lists of farmers who were not selected in the primary lists.

The survey was conducted by enumerators who had extensive experience in implementing household surveys in Indonesia. The enumerators were Indonesian and could speak Bahasa Indonesia fluently, and they were from areas that were not surveyed in this study. Before the survey implementation, a five-day enumerator training course was carried out in July 2017 to ensure the enumerators understood every question in the questionnaire and the overall implementation of the survey. The interviews were conducted face-to-face with the head of dairy farm households (or other household members who made most of the economic and management decisions regarding the dairy business), after receiving their consent to participate.

The structured questionnaire was prepared and delivered in a mobile-based application, CommCare version 2.36.1 (Dimagi, Cambridge, MA), allowing the data entered by the enumerators to be monitored in near real-time. The questionnaire was translated into Bahasa

Indonesia (the local language) and pre-tested twice with dairy farm households to identify possible issues.[2] It was refined, based on the feedback from the pre-tests and in consultation with dairy cooperative board members, to ensure the questions addressed and fit with the regional context.

The questionnaire compiled information about farmers' socioeconomic, household, dairy farm production characteristics, and decision-making about adopting multiple technologies (the complete questionnaire is available in Appendix 3 of the thesis). This PhD study focuses on twelve (12) technologies that are considered high priority ones in improving farm production and milk quality, including technologies and management practices related to animal feed nutrition, health, milk quality and business management (the list of technologies is available in Table 2.2, Chapter 2).

This study considers different stages of farmers technology adoption process as informed by the earlier decision-making process framework described by Rogers (2003). A growing number of studies considers adoption as a complex process, reflecting adoption decision is not a binary decision (adoption and non-adoption) (Brown, Nuberg & Llewellyn 2017; de Oca Munguia et al. 2021; Lambrecht et al. 2014). This study conceptualises the adoption process, which commences with technology awareness, followed by adoption, and subsequent dis-adoption or continued adoption. Awareness is the stage of the adoption process where a farmer has heard of, been exposed to, becomes familiar with the technology, and have some understanding of its features. The adoption stage is where the farmers experiment with the technology and test the suitability of the technology to their farming system. In this stage, farmers generally have information about the expected benefits of the technology, including

[2] Questionnaire pre-testing was first conducted in May 2017 and the final pre-test took place during the enumerator training in July 2017. During the pre-tests, questions were refined multiple times to ensure good flow, relevance and that they were able to be easily answered by farmers. This process was repeated until the research team believed that questionnaire worked well. Dairy farm households that were interviewed during the pre-tests were not included the final dataset.

yield, profitability, and/or input savings from adoption. After experimenting with the technology, farmers may decide to continue adopting the technology if it meets their expectations (e.g., increased productivity, improved quality, lower costs). On the other hand, farmers may also decide to discontinue the adoption of the technology if their expected benefits are unmet (e.g., inadequate outcomes for the farm system or lower than expected yields), and/or if they have issues continuing to gain access to the technology (e.g., lack of financing, discontinued support from development agents, limited availability of the technology, and/or complementary inputs).

To reflect the adoption process explained above, farmers were asked a series of questions about their decisions relating to adopting the technologies; for each technology, respondents provided information regarding three adoption stages: awareness, adoption, and dis-adoption or continued adoption as shown in Figure 2.1 in Chapter 2. The binary responses (1=Yes, 0=No) to each of these questions were transformed into four different adoption categories: (1) not aware of the technology, (2) aware but did not adopt, (3) dis-adoption, and (4) continued adoption. Besides asking farmers about the adoption categories of different dairy technologies, the questionnaire also collected information on the agents who introduced the technologies and provided assistance regarding adoption, the types of assistance received by farmers, and the main reasons for adoption, non-adoption, and or dis-adoption (if relevant) of technologies.[3]

One of the analytical chapters, Chapter 4, utilised a mixed-method approach that combined the quantitative dataset from the household survey and qualitative information from semi-structured interviews with the village dairy cooperative board members. The reason for considering the opinions of the cooperative boards was to better understand the roles and responsibilities of dairy cooperatives as the main input supplier and service providers for

[3] The questionnaire module that asked the adoption related questions is Module I. Adoption of Technology and Management Practices, available in Appendix 3 of the thesis).

farmers, and to explore issues at the cooperative level that may also constrain technology adoption at the farm level. This information provides insight into the institutional arrangements operating within cooperatives. Nine participants, who were leaders and secretaries of the five cooperatives, were involved in the interviews. The cooperatives involved in the interviews are the cooperatives whose members participated in the household survey. These interviews were part of the value chain studies conducted by the project, with the aim of better understanding the roles and responsibilities of the cooperatives as the main input supplier for farmers and to understand the issues at the cooperative level regarding the adoption of technologies by dairy farmers. The interviews were recorded and guided by a pre-designed planned question (interview instrument) that contained questions on the themes of the provision of inputs and services to cooperative members, issues at the farm and cooperative levels, and challenges in the adoption of technologies by dairy farmers (questions included in the interviews are available in Appendix 4 of the thesis).

1.5 The structure of the thesis

The remaining four chapters of this thesis are explained in the following paragraphs. It is important to note that Chapters 2-4 (the main analytical chapters) address the main research objectives outlined in the previous sub section (1.3). The chapters are designed to be "stand-alone" papers, written in a manuscript style, and the goal is to submit them to different, reputable journals for publication. Therefore, the data collection methods explained in each paper entail some repetition but are paraphrased to avoid verbatim duplication.

Chapter 2 explores heterogeneity in the adoption process of multiple dairy farming technologies to better understand the technology adoption process of smallholder dairy farmers. Using Latent Class cluster analysis, two distinct clusters of farmers are identified, mainly differentiated by their level of awareness and adoption patterns of multiple dairy farming technologies. Most of the sampled farmers (56.7%) are categorised in the Low awareness/low adoption cluster, which has a higher proportion of farmers who are not aware of dairy technologies. The remaining farmers (43.3%) are categorised in the second cluster, which is referred to as the High awareness/high adoption cluster because a significantly higher proportion of farmers in this cluster were aware of all technologies and had continuous adoption of several technologies. The significant differences in farmers' socioeconomic status and the characteristics of their dairy farms, as well as their access to dairy farming services help explain the differences in the adoption decisions of the clusters. The analysis concludes that farmers are faced with multilayered adoption constraints. For example, being aware of technologies does not necessarily translate into adoption; farmers still face other constraints, such as access to capital and improved skills to adopt technologies. This suggests the importance of considering where farmers are in the stages of the adoption process, and to ensure that technology dissemination strategies are targeted and align with farmers' unique needs.

Chapter 3 examines the drivers of the adoption of technology bundles and the effects of adoption on milk production. The results present the heterogeneity of feed technologies adopted by farmers, which can be adopted individually or in a bundle. The multinomial logit analysis reveals that farmers' characteristics, such as age, education, access to capital through credit, and ownership of productive and non-productive assets are the main drivers of adopting technology bundles. Further, a Multinomial Endogenous Switching Regression (MESR) approach was employed to examine the effects on milk production by the adoption of feed technology bundles. The Inverse Probability Weighted Regression Adjustment was used to test the robustness of the results generated from MESR. The results are robust and suggest that higher milk production is realised from the adoption of bundles of feed technologies. The highest effect on milk production is achieved if high protein concentrates are included in the technology bundle. In relation to the results, the chapter emphasises the importance of increasing farmers' awareness of complementary technologies and increasing the likelihood of adopting them in order to increase milk production. To improve milk production, particular attention should be paid to improving farmers' access (affordability and availability) to high protein concentrates as part of their adoption portfolio.

Chapter 4 investigates how institutional arrangements could lead farmers to discontinue their adoption (dis-adopt) of four dairy technologies. Using a mixed-method approach, the analysis finds that the current institutional arrangements concerning the assessment of milk and farm input quality and the provision of dairy farm inputs and services, are ineffective and have discouraged farmers from continuously adopting technologies. The chapter emphasises that programs to increase adoption rates should not only focus on addressing adoption constraints at the farm level but also address institutional issues. To ensure sustained adoption, a greater understanding of current institutional constraints is required to improve access, availability, consistency and affordability of complementary inputs, to provide mechanisms to measure and provide information about quality of key inputs and outputs, and to ensure continuous capacity building for extension workers as well as farmers.

The final chapter, Chapter 5, provides a summary, general discussion and presents the implications of the findings and the analyses. It also includes policy recommendations, research limitations and raises potential topics for future research.

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Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	4 August 2021

Co-author contributions

By signing the statement of authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of co-author	Professor Wendy Umberger		
Contribution to the paper	Project leader responsible for conception and design of the smallholder dairy farm household survey, acquisition of funding for data collection, led the design of the household questionnaire, guided the development of the manuscript, data analysis, and critically edited the manuscript.		
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Chapter 2: Understanding heterogeneity in technology adoption among Indonesian smallholder dairy farmers

Abstract

This study explores heterogeneity in smallholder dairy farmers' multi-stages of adoption, including awareness, adoption, and dis-adoption or continued adoption, of different technologies. We collected data from 600 smallholder dairy farming households located in West Java, Indonesia. A Latent Class cluster analysis identified two unique subgroups of smallholder dairy farmers' based on their awareness and adoption patterns of multiple dairy farming technologies. Cluster 1 (Low awareness/low adoption) had significantly lower awareness of all technologies, and among "aware" farmers technology adoption rates were also significantly lower compared to Cluster 2 (High awareness/high adoption). The Low awareness/low adoption cluster was older, had less formal education, managed fewer dairy cows, had less productive and profitable dairy enterprises, lived further away from their cooperative and the farmer group leader, and had fewer contacts with dairy extension staff. Farmers' responses to questions regarding reasons underpinning non-adoption decisions suggest that farmers face multilayered and heterogenous constraints to adopting dairy technologies. This insight can assist government, policymakers and development professionals in designing technology dissemination programs that meet the unique characteristics and needs of subgroups of farmers, ultimately improving the adoption of technologies.

Keywords: Adoption, multiple technologies, Latent Class cluster analysis, smallholder farmers, dairy West Java, Indonesia

2.1 Introduction

In Indonesia, domestic demand for dairy products is rapidly outpacing domestic supply, creating opportunities for the Indonesian dairy sector. However, the development of the Indonesian dairy farming sector has been challenged by the low productivity of domestic producers, who are mostly smallholder dairy farmers. Smallholder dairy farmers' capacity to benefit from the Indonesia's growing demand for dairy products is limited by several factors: small scale operations, with an average herd size of two to three cows per farm; low productivity (less than 10 litres of milk/cow/day)[4]; poor availability of quality feed; low quality milk, due to unhygienic milking and handling practices; and low educational levels of farmers (Daud, Putro & Basri 2015; Priyanto & Rahmayuni 2020). Combined, these factors limit smallholders' ability to implement technologies and innovative production and management practices that may improve farm productivity and milk quality.

Encouraging smallholder adoption of dairy farming technologies and practices (hereafter collectively referred to as technologies) is one of the top priorities outlined in the Government of Indonesia's blueprint for the development of the Indonesian dairy industry 2013-2025 (Coordinating Ministry for Economic Affairs of Indonesia 2014). As such, various government agencies, NGOs, universities, and the private sector have delivered extension and capacity building programs to smallholder dairy farmers in an attempt to encourage the adoption of dairy technologies that are believed to offer the greatest potential to improve their milk productivity and quality.

In Indonesia, conventional extension and development programs have generally been designed to target as many farmers as possible, with the aim of widespread technology dissemination (Sadono 2008). In addition, the dissemination programs tend to be carried out

[4] Milk production of dairy cows in Indonesia is considerably low compared to dairy cows in Australia with average productivity of 20.57 litres/cow/day (Dairy Australia 2021).

with a “supply-push approach” resulting in the technologies are not well accepted as they are not in line with the specific need of farmers (Indraningsih 2017). This one-size-fits-all approach to agricultural extension tends to be the norm, particularly in developing countries (Birner et al. 2009; Oyinbo et al. 2019; Wossen et al. 2017). However, this general approach does not take into consideration that smallholder farmers’ are likely to be heterogeneous in their production goals, farming systems, assets, constraints, and networks (Hammond et al. 2020; Zobeidi et al. 2016). Ruzzante, Labarta and Bilton (2021) suggest that programs aiming to encourage agricultural technology adoption must be designed to fit the unique agricultural and cultural contexts of the farmers. Tailored technology dissemination strategies that take into account how specific farmers access information to increase their awareness of technologies, and also consider the heterogenous needs of farmers, may increase smallholder farmers’ technology adoption rates (Kaliba et al. 2020; Oyinbo et al. 2019; Umberger et al. 2015).

Despite technology adoption being a priority of the Government of Indonesia to increase the development of the dairy sector, there is limited information about the rates of adoption among Indonesian smallholder dairy farmers, and the characteristics of farmers who are aware of technologies and/or those who choose to adopt them. Therefore, the aim of this study is to gain understanding of the process of technology adoption by smallholder dairy farmers.

To do this, we collected data from 600 smallholder dairy farming households located in West Java, Indonesia. We used a Latent Class Cluster analysis to identify subgroups of smallholder farmers’ based on their awareness and patterns of adoption of multiple dairy farming technologies. A post-hoc analysis of variance (ANOVA) was performed to determine if there were significant differences between subgroups with respect to farmers’ adoption categories and their socio-economic, network, and biophysical charactersitics. This analysis allowed us to develop profiles of smallholder dairy farmers to better understand the heterogeneity in the adoption process of different technologies. This insight could aid in the design of technology dissemination programs suited for the unique characteristics and needs of subgroups of farmers, ultimately improving the adoption of technologies (Bizimungu & Kabunga 2018).

The present study contributes to the literature on agricultural technology adoption in three ways. First, this study considers adoption decisions as a complex process involving multiple stages. Most empirical studies investigating aspects of farmers' adoption of agricultural technologies have limited these decisions to adoption or non-adoption (Brown, Nuberg & Llewellyn 2017; Jones-Garcia & Krishna 2021; Weersink & Fulton 2020). However, this approach does not reflect the complexities of the process, which other studies suggest are important to take into account (Brown, Nuberg & Llewellyn 2017; Floyd et al. 2003; Kabunga, Dubois & Qaim 2012; Lambrecht et al. 2014; Weersink & Fulton 2020).

Second, the analysis focuses on the adoption of multiple technologies. Most empirical studies that examined different stages of adoption have only considered the adoption of individual technologies, e.g., mineral fertiliser (Lambrecht et al. 2014), tissue culture bananas (Kabunga, Dubois & Qaim 2012), and organic farming (Läpple 2010). However, farmers are likely to adopt more than one technology to address various production constraints and maximise the expected utility from their adoption decisions (Dorfman 1996; Kassie et al. 2013; Manda et al. 2016). Technologies may be adopted simultaneously, due to their complementary features, or in a stepwise manner (Byerlee & De Polanco 1986; Feder, Just & Zilberman 1985). The adoption of multiple technologies, rather than a single one, has the potential to improve farm performance (e.g., agricultural yields and incomes) (Kumar et al. 2020; Marenya, Gebremariam & Jaleta 2020; Tambo & Mockshell 2018), suggesting the importance of encouraging farmers to adopt multiple technologies. However, adopting multiple technologies may require access to capital (Kpadonou et al. 2017; Teklewold, Kassie & Shiferaw 2013), which may be challenging for smallholder farmers due to lack of collateral (Fan & Rue 2020; Khanal & Omobitan 2020).

Third, this study presents unique empirical evidence from West Java, Indonesia, which has been little studied, especially in relation to the adoption of multiple technologies by smallholder dairy farmers. West Java province contributes 31% to national milk production (Statistics Indonesia 2021). Smallholder farmers in West Java have advantages in terms of their closer proximity to potential consumers living in cities such as Bandung, Bogor, and Jakarta (the capital city of Indonesia), where the consumption of fresh milk and dairy products are relatively high (Statistics Indonesia 2018a, 2018b). A growing number of modern food service businesses (e.g. cafés, restaurants) are now using and selling food and beverage products, which require high-quality dairy products. Additionally, eight of the fourteen milk processing companies that source their milk from domestic dairy farmers are located in West Java.

For the most part, the on-farm challenges faced by smallholder farmers in Indonesia are similar to those faced by domestic smallholder dairy farmers in other developing countries experiencing growing demand for dairy products Ngeno (2018). Thus, the implications of this study will be applicable to the development of the dairy farming sector in Indonesia as well as other countries where smallholder farmers are the dominant milk producers in the value chain.

Our Latent Class cluster analysis results identified two unique clusters of smallholder dairy farmers that are mainly differentiated by their level of technology awareness and adoption. We conclude that consideration of different adoption stages, rather than focusing on adoption /non-adoption decisions is likely to provide a better understanding of the constraints face by farmers at each stage and to improve the design of agricultural development and extension interventions.

2.2 Stages in the adoption process

This study considers different stages of farmers' technology adoption process: awareness, adoption, and dis-adoption or continued adoption. Most previous adoption studies have only considered farmers' decisions to adopt or not to adopt (Afolami, Obayelu & Vaughan 2015; Ntshangase, Muroyiwa & Sibanda 2018; Selejio, Lokina & Mduma 2018). This approach usually assumes that farmers are aware of, and have complete information about the attributes of the technologies (Shiferaw et al. 2015). Consequently, the estimates of both adoption rates and their determinants can be biased because awareness of technology is not controlled for (Diagne & Demont 2007; Kathage et al. 2016; Simtowe, Asfaw & Abate 2016). The different stages in the adoption process reached by farmers may occur due to farmers' differing socioeconomic statuses, personal characteristics, and access to information, finance, capital, and training, services (Lambrecht et al. 2014; Marenya & Barrett 2007; Moser & Barrett 2006; Wendland & Sills 2008).

2.2.1 Awareness

Awareness is an important precondition for adoption to occur (Diagne & Demont 2007; Lambrecht et al. 2014). Awareness is the stage of the adoption process where a farmer has heard of, been exposed to and becomes familiar with the technology. It means that farmers can identify the technology and have some understanding of its features (Pannell et al. 2006). Factors that may influence farmers' awareness of technologies include participation in development and extension programs promoting agricultural technologies, educational levels, participation in collective action[5], social networks, and distance to markets (Lambrecht et al. 2014).

[5] In this study, collective action refers to activities or actions by a group of smallholder farmers to achieve a common goal. A couple of examples include farmer groups meetings to leverage training activities or to negotiate prices.

2.2.2 Adoption

In the adoption stage, farmers generally have information about the expected benefits of the technology, including expectations on yield, profitability, and/or input savings from adoption. This information may be acquired in different ways, such as exposure to information through extension activities, through social networks and contact with government agents (Lambrecht et al. 2014; Marenya & Barrett 2007; Moser & Barrett 2006; Wendland & Sills 2008).

Adoption entails farmers' experimenting with the technologies to test their suitability to their farm and farming system. Aditional information is acquired "learning by doing" to decide to continue or discontinue the use of the technology. The ability of farmers to experiment with a new technology is determined by the characteristics of the technology. Experimentation may be easier with variable inputs such as high-quality grass varieties, and less likely with longer term investments such as building a barn.

2.2.3 Dis-adoption or continued adoption

After farmers gain experience and information on the technology's benefits relative to their farm, they may decide to continue the technology if it meets their expectations (e.g., increased productivity, improved quality, lower costs). Conversely, farmers may discontinue the technology if they are unsatisfied with the results (e.g., inadequate outcomes for the farm system or lower than expected yields), and/or if they have problems continuing to gain access to the technology (e.g., lack of financing, discontinued support from development agents, limited availability of the technology, and/or complementary inputs) (Grabowski et al. 2016; Pedzisa et al. 2015).

2.3 Methods

2.3.1 Data and sampling

This study utilised a cross-sectional dataset of 600 smallholder dairy farming households located in four dairy-producing districts in West Java Province, Indonesia. The research was part of a smallholder dairy farmer development project funded by the Australian government in partnership with the Government of Indonesia.

The sampling method was purposive proportional random sampling. Five dairy cooperatives, distributed in four districts in West Java (Table 2.1). Most dairy farming households in Indonesia are members of dairy cooperatives (Statistics Indonesia 2015). Dairy cooperatives market farmers' milk to dairy processors, provide access to dairy inputs and extension services.

The number of smallholder dairy farming households selected from each district was proportional to the total dairy farm population in the region. However, because the proportion of farmers in Cianjur and Bogor was relatively small, the research team decided to interview 80 farmers in each district to derive a valid statistical comparison. Finally, dairy farmers were randomly selected from each district according to the proportion that had been identified.

Table 2.1 Distribution of respondents by districts

Districts	Farmer population	Initial proportion	Final proportion	Respondents
Bandung	2860	62.13	50.00	300
Garut	1268	27.55	23.33	140
Cianjur	170	3.69	13.33	80
Bogor	305	6.63	13.33	80
Total	**4603**	**100.00**	**100.00**	**600**

2.3.2 Dairy farming household survey

Individual face-to-face interviews with household members were conducted between August and September 2017 using a structured questionnaire. To improve the efficiency and quality of data collection, the survey instrument was programmed in a mobile-based application, CommCare version 2.36.1 (Dimagi, Cambridge, MA). The use of CommCare allowed data to be entered and monitored in near real-time.

The survey instrument was pre-tested several times to identify possible issues, and it was refined based on the feedback from the pre-tests. The interviews were conducted by 12 trained enumerators, fluent in the local language and with extensive experience conducting farm household surveys in West Java, Indonesia. Before beginning data collection, a five-day enumerator training course was held (July 2017) to ensure the enumerators understood the aim of each part of the questionnaire.

The questionnaire compiled information about socioeconomic characteristics and assets of the smallholder farmers and their household members, dairy farm characteristics and assets, marketing of dairy products, access and use of various sources of information and services, and their awareness of and decision to adopt 12 different dairy farming technologies including included technologies and management practices related to animal nutrition, health, milk quality, and business management. These “technologies” (listed in Table 2.2) were considered by local stakeholders to be high priority technologies for adoption.

Table 2.2 Dairy technologies selected for the analysis of this study

No.	Technologies	Description
	Dairy feed	
1	High protein concentrates (16% or higher)	Concentrates are a feed supplement, generally in the form of pellets or coarse mix, which contain highly nutritious and highly digestible forms of protein, energy, and minerals to support milk production.
2	High-quality grass varieties	High quality grasses that generally require shorter growing time with more yields and better nutritional content (e.g., *Brachiaria brizantha*, *B. Mulato*, and *B. mutica*)
3	Fertiliser to grow grass	Fertilizers (organic and chemical) are used to stimulate grass growth to obtain higher grass yields in a shorter time.
4	Unrestricted access to drinking water	Cows have unrestricted access to drinking water at all times – "24 hours a day, seven days a week".
5	Forage conservation for the dry seasons (hay, silage)	Conservation of forages consists of a series of techniques and processes to conserve or preserve grasses and forages for a long time. This can be achieved through: (1) drying and compacting (hay) or (2) by lowering the pH (making it acidic) compacting and extracting the air (silage). Hay is obtained by dehydrating the grass through heat and air. Silage is obtained by cutting the grass or forage to a certain size, add some source of energy that can lead to fermentation and in some cases, beneficial microorganisms
	Milk quality-enhancing	
6	Detergents on milking equipment	Use of alkaline and acidic detergents, some of this chlorine-based, to clean the fat and proteins that remain in the containers that are used in the milking and transportation of the milk.
7	Improved milking hygiene to reduce total plate count (TPC)	Total plate count (TPC) is a milk quality measure that quantifies the bacteria contamination of milk. To reduce TPC a series of practices and techniques must be adopted, including washing hands with soap before miking or using disposable gloves, cleaning cows' udders, ensuring no water is running down through the udder, and discarding the first few bits of milk accumulated in the teats of the cow because this milk contains a high percentage of bacteria and microorganisms.
8	Stainless steel milking equipment	All utensils that touch the milk should be food-grade quality stainless-steel.
	Animal health	
9	Teat dipping after milking	Self-filling cup with an iodine liquid to prevent mastitis. Each of the four teats is dipped into the cup after milking.
10	Mastitis testing	This test is a practical and fast way to determine if a cow has mastitis. It consists of a pallet with four compartments and a reactive that is mixed with milk from each of the four teats of the udder.
11	Rubber floor mat for the barn/cage	Rubber floor mats are used to protect the cows from cement floors and to prevent lameness.
	Farm management	
12	Record keeping	Writing in a notebook, board, or form, all the data regarding production, reproduction and milk yields, sales, expenses and additional data that come from the dairy business.

Farmers were asked a series of questions about their decisions relating to three stages of technology adoption: awareness, adoption, and dis-adoption or continued adoption (Figure 2.1). Their binary responses (1=Yes, 0=No) to each of these questions were transformed into categorical variables, resulting in four different adoption categories: (1) not aware of the technology, (2) aware but did not adopt the technology, (3) dis-adoption, and (4) continued adoption of the technology, as shown in Figure 2.1.

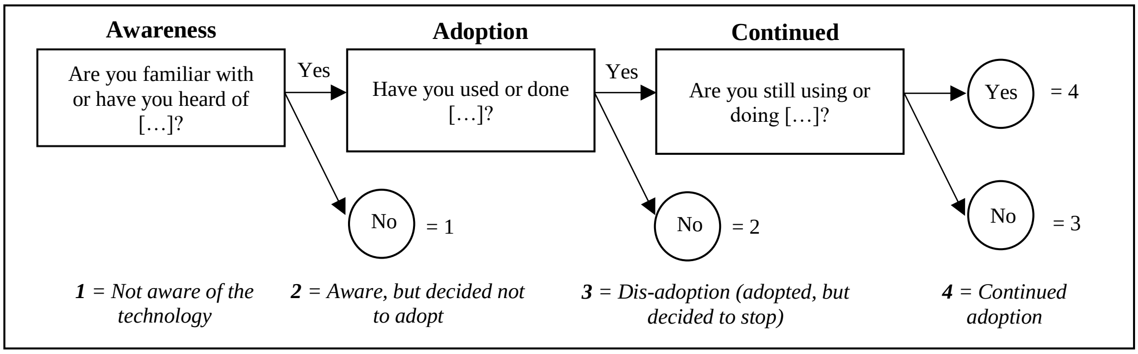

Figure 2.1 Construction of categorical adoption variables

2.3.3 Data analysis

2.3.3.1 Latent class cluster analysis

Farmers' adoption categories for each of the 12 technologies shown in Table 2.4 were used as "indicator variables" in a latent class (LC) cluster analysis to determine the optimal number of classes or subgroups. Full details of the LC analysis employed in this study are provided in the results section. LC cluster analysis is a technique used to categorise samples into subgroups which share common characteristics (Nylund, Asparouhov & Muthén 2007). This analysis method offers advantages compared to other traditional cluster analysis methods, including model selection criteria, probability-based classification and direct estimation of membership probabilities to assign each sample to the identified class (Vermunt & Magidson 2005). The LC cluster analysis was performed in Latent GOLD 5.1 (Statistical Innovations, Belmont, MA).

The LC cluster analysis technique has been employed extensively in the literature, especially by studies that explore heterogeneity in their sample, such as the heterogeneity of dairy farmers' attitudes towards different attibutes in milk marketing contracts (Schlecht & Spiller 2012), the potato farmers' marketing channel choice measured by buyers' attributes (Umberger et al. 2015), and consumers' preferences for purchasing slice packed fresh pears (Ikiz et al. 2018). In the adoption literature, however, to our knowledge, the LC cluster analysis has only been applied by Bizimungu and Kabunga (2018) and Jordán and Speelman (2020) when identifying the classification of farmers based on the combination of improved agricultural technologies adopted by farmers and irrigation technologies respectively. Yet, both studies only considered binary decisions (adoption or non-adoption).

2.3.3.2 Characterisation of the subgroups

An analysis of variance (ANOVA) was conducted to determine significant differences between the subgroups from the LC cluster analysis with respect to the individual farmer, household, dairy farm, and marketing characteristics, as well as farmers' use of information and dairy farming services. The null hypothesis was that the mean of each variable was similar across subgroups. The only variables discussed in the results section are the variables that are statistically significantly different between the subgroups. The full list of variables considered in the ANOVA is provided in Table A5-5 in the Appendix. The characterisation of the subgroups was performed in Stata 16.0 (Stata Corp, College Station, TX).

2.4 Results

2.4.1 Sample characteristics

The variables included to described farmers characteristics are informed by the adoption literature. The different stages in the adoption process reached by farmers may occur due to farmers' heterogeneity in their socioeconomic, personal characteristics, capital ownership, and access to information through social networks, and group membership (Amsalu & de Graaff 2007; Lambrecht et al. 2014; Marenya & Barrett 2007; Moser & Barrett 2006; Srisopaporn et al. 2015; Wendland & Sills 2008). A recent metanalysis of the published literature on the adoption of agriculture technologies by Ruzzante, Labarta and Bilton (2021) found that, "on average, farmer education, household size, land size, access to credit, land tenure, access to extension services, and organisation membership positively correlated with the adoption of many agricultural technologies".

The summary statistics of the sample is presented in Table 2.3. The average age of farmers was 46.2 years old, with 6.4 years of school completed and 19.1 years of experience in dairy farming. The average household size was 4.0 members. Farmers managed, on average, 5.6 dairy cows, with 39.0-litres of milk produced per day and 14.8-litres of milk produced per cow per day.

About 24% of farmers in the sample used credit for dairy farming purposes. On average, farmers hired 0.4 labourers for farm work, indicating that many farmers relied on family members as their primary labour source. On average, farmers sold their milk to more than one buyer (with a maximum of three buyers), with the average milk price paid by their main buyer being USD 0.3 per litre. Only about one-half of the sample were familiar with milk quality indicators. Farmers frequently attended meetings at their cooperative or with their main farmer group. On average, over the prior 12 months, farmers contacted their cooperative's extension staff three times to access information related to dairy farming. Dairy farmers' utilisation of the services provided by the cooperative varied, with the support for feed supplements being the highest (63%). On average, farmers had to travel for 33.4 minutes to reach their dairy cooperative office and 6.6 minutes to reach the home of the leader of their main farmer group.

Table 2.3 Summary statistics for the sample of smallholder dairy farming households (n=600)

Variables	Description	Mean	SD	min	max
Individual, household and farm characteristics					
Age	Age of the respondent (years)	46.24	11.54	21.00	84.00
Education	Education of the respondent (years)	6.44	3.11	0.00	18.00
Experience	Experience in dairy farming (years)	19.08	10.40	1.00	52.00
Household size	Number of household members	3.95	1.44	1.00	11.00
Herd size	Total dairy cows managed	5.63	5.02	1.00	42.00
Farm milk production	Total farm milk production (litres/day)	39.02	35.24	2.00	340.00
Cow productivity	Cow milk production (litres/cow/day)	14.75	3.89	2.00	26.25
Dairy farm profit	Profit from all lactating cows managed (USD†/year)	1,964.11	2,337.56	-6,293.44	19,779.38
Credit	1 = Farmer have credit used for dairy farming purposes	0.24	0.43	0.00	1.00
Labour	Total hired labourers on the farm	0.35	0.87	0.00	9.00
Distance to cooperative	Distance in minutes	33.35	25.51	2.00	120.00
Distance to farmer group leader house	Distance in minutes	6.64	8.14	1.00	120.00
Marketing and familiarity with milk quality concepts					
Milk buyers	Number of different buyers farmers sold milk to	1.06	0.24	1.00	3.00
Milk price	Average milk price (USD†/litre)	0.31	0.03	0.24	0.55
Familiar with total plate count (TPC)	1 = Farmer was familiar with the concept of total plate count (TPC)	0.58	0.49	0.00	1.00
Familiar with total solids (TS)	1 = Farmer was familiar with the concept of total solids (TS)	0.41	0.49	0.00	1.00
Familiar with fat content	1 = Farmer was familiar with the concept of fat content	0.57	0.50	0.00	1.00
Familiar with milk density	1 = Farmer was familiar with the concept of milk density	0.40	0.49	0.00	1.00

†Exchange rate 1 USD = 14,459.50 Indonesian Rupiah on 27 July 2018

Table 2.3 (Continued) Summary statistics for the sample of smallholder dairy farming households (n=600)

Variables	Description	Mean	SD	min	max
Group participation, contacts and use of dairy farming services					
Attend meetings with cooperatives	1 = Farmer always attended meetings with cooperative	0.55	0.50	0.00	1.00
Attend meetings with farmer group	1 = Farmer always attended meetings with farmer group	0.48	0.50	0.00	1.00
Number of times contacted (in the last 12 months) dairy cooperative extension to access information about […]					
Milk quality	Number of contacts	1.79	3.23	0.00	24.00
Milk yield	Number of contacts	1.18	2.93	0.00	36.00
Information on new technology	Number of contacts	0.09	0.41	0.00	4.00
Value addition	Number of contacts	0.15	1.45	0.00	24.00
Feed supplement	Number of contacts	0.19	1.55	0.00	24.00
Utilisation of support from the dairy cooperative for [….]					
Forages	1 = Farmers utilised the support	0.28	0.45	0.00	1.00
Information on new technology	1 = Farmers utilised the support	0.43	0.50	0.00	1.00
New management practices	1 = Farmers utilised the support	0.26	0.44	0.00	1.00
Government program	1 = Farmers utilised the support	0.28	0.45	0.00	1.00
Feed supplement	1 = Farmers utilised the support	0.63	0.48	0.00	1.00
Mastitis testing	1 = Farmers utilised the support	0.28	0.45	0.00	1.00

2.4.2 Adoption categories

The adoption categories for the 12 dairy technologies for the sample of smallholder dairy farmers are presented in Table 2.4. Over 40% of farmers were not aware of mastitis testing (59.8%); high protein concentrates (59.0%); record keeping (53.5%); unrestricted access to drinking water (43.0%); forage conservation for the dry season (42.7%); and teat dipping after milking (41.7%). On the other hand, a high share of farmers adopted detergents for washing milking equipment (84.7%), improving milking hygiene to reduce bacterial contamination (80.8%), improved grass varieties (73.3%), and used fertiliser to grow grass (70.2%). The adoption of practice to improve drinking water availability, using stainless-steel milking equipment and laying rubber floors was only adopted in moderate numbers.

The adoption rate of forage conservation was the lowest, considering all technologies; the proportion of farmers who were not aware of it was 42.7%, while the percentage who were aware but did not adopt it was 44.8%. Concerning the rate of dis-adoption, the proportion for all the technologies was low (<20%), with teat dipping practice having the highest rate of dis-adoption (16.5%).

Table 2.4 Adoption categories of technologies by smallholder dairy farmers (n=600) (percentages)

Technologies	Not Aware	Aware, but not adopted	Dis-adoption	Continued adoption
Dairy feed				
High protein concentrates (16% or higher)	59.00	21.33	11.67	8.00
High-quality grass varieties	15.83	9.17	1.67	73.33
Fertiliser to grow grass	11.00	14.33	4.50	70.17
Unrestricted access to drinking water	43.00	21.33	0.67	35.00
Forage conservation for the dry seasons (hay, silage)	42.67	44.83	11.17	1.33
Milk quality-enhancing				
Detergents on milking equipment	12.17	2.33	0.83	84.67
Improved milking hygiene to reduce TPC	14.17	4.17	0.83	80.83
Stainless steel milking equipment	19.50	35.17	3.00	42.33
Animal health				
Teat dipping after milking	41.67	22.67	16.50	19.17
Mastitis testing	59.83	20.00	8.50	11.67
Rubber floor mat for the barn/cage	4.50	33.33	3.83	58.33
Farm management				
Record keeping	53.50	25.67	5.17	15.67

On average, farmers have been continuously used the technologies at the minimum of 3.43 years (Table A5-6 in the Appendix).

2.4.3 Results of LC cluster analysis: Adoption profile of smallholder farmers

This study employed two steps of LC cluster analysis. The 12 indicator variables were coded 1-4 based on an individual farmer's adoption categories to determine the stage in the technology adoption process for each technology. The first-step estimation involved running LC models with one to six classes using all 12 technologies as indicator variables. The Bayesian Information Criteria (BIC) was used to determine the model with the best fit (Hagenaars & McCutcheon 2002; Vermunt & Magidson 2005). In the first step, the two-cluster model was found to be the most parsimonious model with the lowest BIC. Different random seed numbers were also used to check the consistency of this result. One technology (detergents on milking equipment) did not significantly contribute to the formation of clusters in the first stage (insignificant *P*-value).

After determining the number of clusters and checking the significance of all indicator variables, we checked the bivariate residuals (BVR) to ensure the local dependency assumption was not violated (Vermunt & Magidson 2005). A BVR larger than 3.84 indicates a correlation between pairs of indicator variables that have not been explained by the model and violates the local dependencies assumption of the latent class model (Vermunt & Magidson 2005, 2016). To deal with this, the local dependency assumption was relaxed by introducing a direct effect relationship between pairs of indicator variables with BVRs above 3.84 (Vermunt & Magidson 2016). [6] After introducing direct effects, we checked the *P*-values for the indicator variables and the BVRs. All the BVRs were lower than 3.84 as a result of the direct effects.

The second step of the LC cluster analysis involved a similar process to the first stage (running LC models with one to six clusters). However, in the second step, the indicator variable (detergents on milking equipment) that had an insignificant *P*-value (0.61) in the first step was dropped from the estimation. Therefore only 11 indicator variables were used in the second step of the LC analysis. Removing detergents may be reasonable because less variation in the adoption process of this technology was found. For example, 85% of farmers adopted this technology and were still using it.

The results reported in this section are from the second step of LC cluster analysis. The second-step results showed that the model with two latent clusters was the optimal solution based on the lowest value of BIC statistics, which generated an improved model with local

[6] Four pairs of indicator variables were introduced with direct effects: (1) fertiliser to grow grass and high-quality grass varieties; (2) stainless steel milking equipment and detergents on milking equipment; (3) improving milking hygiene to reduce TPC and detergents on milking equipment, and (4) record keeping and stainless-steel milking equipment.

dependencies among indicators variables (Table 2.5). All indicator variables contributed well to the formation of the clusters (*P*-value < 0.05) (Table A5-1 in the Appendix).

Table 2.5 Model fit evaluation information

Model	LL	BIC(LL)	Npar	Class. Err.
1-Cluster	-6634.63	13595.50	51	0.00
2-Cluster	**-6314.58**	**13172.90**	**85**	**0.07**
3-Cluster	-6241.41	13244.05	119	0.12
4-Cluster	-6188.51	13355.76	153	0.13
5-Cluster	-6148.49	13493.22	187	0.15
6-Cluster	-6116.18	13646.08	221	0.17

LL: Log-likelihood; BIC: Bayesian Information Criteria; Npar: Number of parameters, Class.Err.: Classification error

Distinguished technology adoption profiles of the two latent clusters generated from the LC cluster analysis is depicted in Figure 2.2. ANOVA was performed to test differences in each cluster's adoption patterns for the 11 technologies (Table A5-2 in the Appendix). Cluster 1 was 56.7% of the sample (340 farming households), and compared to Cluster 2 (43.3% of the sample, 260 households) had a significantly higher proportion of farmers who were not aware of most of the technologies (solid black in Figure 2.2).

Additionally, comparing those farmers who indicated they were "aware" of technologies across both clusters, a significantly higher share of "aware" farmers in Cluster 1 decided not to adopt seven of the technologies: high protein concentrates; high-quality grass varieties; fertiliser to grow grass; forage conservation; unrestricted access to drinking water; teat dipping; and rubber floor mat (Table 2.6). Considering the significantly higher share of farmers who were not aware of the technologies and the significantly lower rates of adoption among "aware" farmers, Cluster 1 was labelled the **"Low awareness/low adoption cluster**".

Conversely, Cluster 2 had a significantly higher proportion of overall awareness of all technologies and also had a significantly higher adoption and continued adoption for several of the technologies (white bars in Figure 2.2). Therefore, Cluster 2 is named the **"High awareness/high adoption cluster"**.

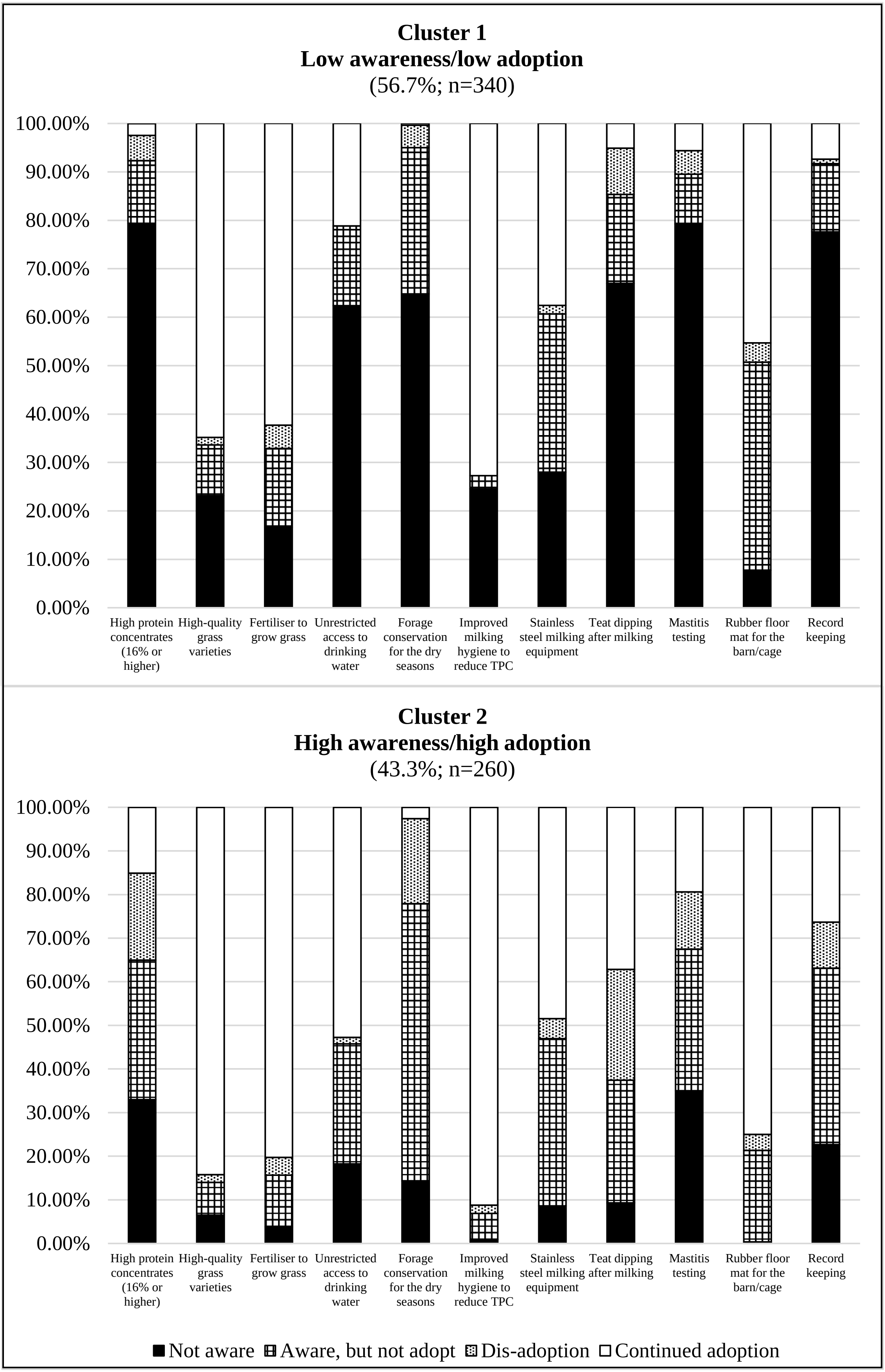

Figure 2.2 Conditional probability of adoption decisions of multiple technologies for latent class clusters

Table 2.6 Comparison of farmers who were "aware" but decided not to adopt for each cluster

Technologies	Cluster 1	Cluster 2	Sig.
High protein concentrates (16% or higher)	63.77%	47.46%	**
High-quality grass varieties	14.18%	7.38%	**
Fertiliser to grow grass	19.08%	12.75%	*
Unrestricted access to drinking water	45.60%	32.72%	**
Forage conservation for the dry seasons (hay, silage)	87.18%	73.57%	***
Improved milking hygiene to reduce TPC	2.72%	6.98%	**
Stainless steel milking equipment	45.31%	42.02%	
Teat dipping after milking	56.88%	30.71%	***
Mastitis testing	46.97%	50.86%	
Rubber floor mat for the barn/cage	46.50%	20.85%	**
Record keeping	61.33%	52.94%	

Sig. = Significance level from ANOVA tests; * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ indicate significance at the 10%, 5% and 1% levels respectively.
Percentages are derived from the number of farmers aware but not adopted divided by total farmers who were aware of the technology (including farmers who were aware but not adopted, dis-adopted and continued adoption)

It is worth noting, that both clusters were relatively high adopters of high-quality grass varieties, fertiliser to grow grasses, and improved milking hygiene to reduce TPC (>60%), while the adoption of high protein concentrates, forage conservation, and mastitis testing were less frequently adopted (<25%) by both clusters.

It is interesting to consider the diverse reasons behind each cluster's decisions not to adopt specific technologies despite being aware of them (Table A5-3). Both clusters highlighted high costs of adoption as the main reason for the non-adoption of high protein concentrates, stainless steel milking equipment, and rubber floor mats. However, the reasons for non-adoption of other technologies extended and varied beyond concerns about high costs. Farmers in both clusters indicated that the complexity of forage conservation and record keeping limited their adoption of the technologies. Both clusters mentioned complexity and limited availability of inputs as factors limiting their adoption of teat dipping. With regards to mastitis testing, the main reasons for both clusters were satisfaction with current practices, lack of information, and the complexity.

For some technologies, there were interesting differences between the two clusters in reasons for non-adoption. A higher share of farmers in Cluster 1 (compared to Cluster 2) raised concerns related to the lack of information about forage conservation. A higher share of farmers in Cluster 2 said the complexity of implementing unrestricted drinking water was a primary reason that they did not adopt the practice. A higher share of farmers in Cluster 2 said lack of information was the main reason for the non-adoption of teat dipping, while a higher share of farmers in Cluster 1 said being happy with their current practices kept them from adopting teat dipping.

In the case of dis-adoption of technologies (Table A5-4), both clusters said the high cost of high protein concentrates, and the limited availability of inputs for teat dipping after milking were the main factors leading to dis-adoption. Again, there are some interesting differences observed between clusters. For example, farmers in Cluster 1 responded that the complexity of forage conservation is the main reason for dis-adoption, while farmers in Cluster 2 said the limited availability of inputs and satisfaction with current practices were the main reasons. On the other hand, farmers in Cluster 2 dis-adopted record keeping due to its complex implementation, while farmers in Cluster 1 dis-adopted because they were satisfied with their current practice.

2.4.4 Results of characterisation of the latent classes

The key characteristics that are significantly different between the clusters are presented in Table 2.7. Compared to farmers in the Low awareness/non-adoption cluster (Cluster 1), farmers in the High awareness/adoption cluster (Cluster 2) were younger, and more endowed with human capital (e.g., had completed higher levels of education, had more dairy farming experience, and had greater access to labour). They also had greater access to financial capital (i.e., credit), were more profitable, and had more farm assets. Farmers in Cluster 2 sold their milk to a greater number of buyers. They were also more familiar with measures of milk quality.

Farmers in the High awareness/adoption cluster (Cluster 2) were more likely than those in Cluster 1 to participate in group discussions, as indicated by their more frequent attendance at cooperative and farmer group meetings. The closer distance to the cooperative office and the home of the farmer group leader may be a reason for Cluster 2's more frequent participation in group meetings. Additionally, farmers in Cluster 2 utilised the dairy farming services provided by cooperatives, as seen by their significantly higher number of contacts with cooperative extension staff and significantly higher utilisation rate of support provided by cooperatives.

Table 2.7 Key characteristics for the latent class clusters

Variables	**Cluster 1 (56.7%)** *Low awareness/ low adoption* (a)	**Cluster 2 (43.3%)** *High awareness/ high adoption* (b)	**Differences** (b-a)	**Sig.**
Individual, household and farm characteristics				
Age (years)	47.15	45.06	-2.09	**
Education (years)	5.69	7.42	1.73	***
Experience (years)	18.10	20.37	2.27	**
Household size (members)	3.85	4.07	0.22	*
Herd size (cows)	4.39	7.26	2.87	***
Farm milk production (litres/day)	30.56	50.10	19.54	***
Cow productivity (litres/cow/day)	14.42	15.19	0.77	**
Dairy farm profit (USD/year)	1,579.86	2,468.97	889.11	***
Credit (1 = Yes)	0.18	0.31	0.13	***
Labour (people)	0.21	0.51	0.30	***
Distance to cooperative (minutes)	36.45	29.32	-7.13	***
Distance to farmer group leader house (minutes)	7.32	5.74	-1.58	**
Marketing and familiarity with milk quality				
Milk buyers (number of buyers)	1.04	1.09	0.05	**
Milk price (USD/litre)	0.30	0.32	0.02	***
Familiar with TPC (1=Yes)	0.45	0.76	0.31	***
Familiar with TS (1=Yes)	0.27	0.59	0.32	***
Familiar with fat content (1=Yes)	0.46	0.70	0.24	***
Familiar with milk density(1=Yes)	0.31	0.52	0.21	***

Table 2.7 (Continued) Key characteristics for the latent class clusters

Variables	Cluster 1 (56.7%) *Low awareness/ low adoption* (a)	Cluster 2 (43.3%) *High awareness/ high adoption* (b)	Differences (b-a)	Sig.
Group participation, contacts and use of dairy farming services				
Attend meetings with cooperatives (1=Yes)	0.50	0.62	0.12	***
Attend meetings with farmer's group (1=Yes)	0.42	0.54	0.12	***
Number of times contacted (in the last 12 months) dairy cooperative extension to access information about […]				
Milk quality (contacts)	1.48	2.18	0.70	**
Milk yield (contacts)	0.97	1.44	0.47	*
Information on new technology (contacts)	0.04	0.15	0.11	***
Value addition (contacts)	0.06	0.27	0.21	*
Feed supplement (contacts)	0.02	0.41	0.39	***
Utilisation of support from the dairy cooperative about [….]				
Forages (1=Yes)	0.24	0.32	0.08	**
Information on new technology (1=Yes)	0.35	0.53	0.18	***
New management practices (1=Yes)	0.20	0.34	0.14	***
Government program (1=Yes)	0.21	0.36	0.15	***
Feed supplement (1=Yes)	0.55	0.73	0.18	***
Mastitis testing (1=Yes)	0.16	0.43	0.27	***

Sig. Significance level from ANOVA tests; * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ indicate significance at the 10%, 5% and 1% levels respectively.

2.5 Discussion

The LC cluster analysis generated two distinct subgroups of farmers (clusters). The clusters are unique in their awareness and adoption patterns of key dairy technologies, individual, household and farm characteristics, and the main constraints faced at different stages of the adoption process.

Farmers in both clusters have relatively high levels of adoption of high-quality grass varieties, fertiliser to grow grasses and improved milking hygiene to reduce TPC. However, the adoption rates of three technologies, namely high protein concentrates, forage conservation and mastitis testing, are relatively low for both clusters. Farmers in Cluster 1 face constraints to adopting these three technologies, as well as teat dipping after milking, record keeping, and unrestricted access to drinking water at the awareness stage due to remoteness (distance to information source, e.g., cooperative/lead farmer). On the other hand, farmers in Cluster 2 face challenges to adopting high protein concentrates and forage conservation due to their high costs of adoption, mastitis testing due to lack of information about its benefits, record keeping, and unrestricted access to drinking water due to limited skills to implement the technologies. These findings suggest the need for different technology diffusion strategies which consider the heterogeneous constraints and unique production scenarios that farmers face and how those relate to different stages of the adoption process.

The design of technology dissemination programs targeted at farmers classified in Cluster 1 (Low awareness/low adoption) requires "reach-out" strategies to increase farmers' awareness of key technologies. For example, farmer to farmer (F2F) extension approaches have been effective in increasing familiarity (awareness) of agricultural conservation practices among farmers in Malawi (Fisher et al. 2018) and knowledge about improved seed varieties in northern Uganda (Shikuku 2019). A similar approach could be implemented in Indonesia to increase farmers' awareness of the six technologies mentioned above. Lead farmers are trained by extension organisations and are encouraged to communicate their knowledge to other farmers or neighbours by different means, including informal training sessions or by establishing demonstration plots at a distance of easy access to farmers (De Janvry, Sadoulet & Rao 2017; Fisher et al. 2018; Shikuku 2019).

The use of information and communication technologies (ICT) is an additional proven strategy to disseminate information among farmers located in remote areas. The use of mobile technology to deliver information using text/voice messages or short videos constitutes a demonstrated cost-effective option to increase farmers technology awareness (Cole & Fernando 2021; Voss et al. 2021). However, awareness alone is not enough for encouraging adoption (Fisher et al. 2018; Voss et al. 2021). Therefore, extension programs addressing "next-stage" constraints such as limited capital and improved skills are required.

In the case of farmers who are aware but unable to adopt key technologies[7], including farmers in Cluster 2 (High awareness/adoption), overcoming the "next-stage" challenges include improving farmers' access to capital to invest in the new technologies and training to improve farmers skills and knowledge (Makate et al. 2019). Dairy cooperatives generally have credit programs for their members with minimum collateral in cow ownership and/or obligation to sell milk to the cooperatives. But these credit lines do not seem to respond to farmers' financial needs. It is also possible that farmers do not see clear financial incentives (e.g., profitability) from the adoption of technologies (Foster & Rosenzweig 2010) due to lack of financial literacy (Balana & Oyeyemi 2020), limiting farmers adequate management of their cash flow plan and their ability to calculate their costs and revenues, let alone their return to investment. The inclusion of farmers' financial literacy in the extension programs for smallholder dairy farmers in Indonesia could help overcome farmers' constraints to adoption.

As some of the technologies such as forage conservation, record keeping and unrestricted access to drinking water are perceived as "complex" to implement, the development of methods and practices that are less complicated could be more effective. In addition, extension programs could not only provide information on how to use technologies, but also on the technologies' benefits, i.e., "why the technologies are important" (Anderson & Feder 2007). For example, the combination of in-person extension and videos explaining the underlying principles of integrated soil fertility management technology packages (a complex technology practice) led to increased adoption among farmers (Hörner et al. 2019).

[7] Without splitting the sample into two clusters, farmers who were aware but not adopted may be targeted for extension programs. The average characteristics of these farmers could be categorised as "middle farmers" as they are slightly younger (46 years old) with 7 years of education, 19 years of dairy farming experience, and managed middle size farm (5 dairy cows) (Table A5-7).

Most importantly, smallholder farmers as the potential technology users need to participate in the development of the technologies (so-called – participatory approach) to ensure that the technologies address farmers' specific issues and needs (Pamuk, Bulte & Adekunle 2014), where farmers could learn and improve their knowledge during the technology development process, which is part of farmer capacity building (Muhammad 2011).

2.6 Conclusions

The overall results of the study highlight the need for adoption studies to consider the different stages of adoption rather than focusing on only adoption and non-adoption. Although the availability of panel data would have provided a more in-depth understanding of the dynamics of adoption decisions, this study still offers important insight allowing for a better understanding of the constraints that farmers face at each stage of adoption with the used of cross-sectional data. The study emphasises the importance of considering different types of technologies in the analysis to better understand the typical but specific constraints at different adoption stages. The constraints faced by farmers in different adoption stages are associated with heterogenous characteristics of farmers socioeconomic, productive assets, and access to and use of dairy farm services. The results from this study still entail some specific implications for the design of extension programs aiming to increase technology adoption at the smallholder farmers level. The typical extension approach that usually applies a "one-size-fits-all" standard may not be an effective strategy to increase adoption rates among smallholder dairy farmers. Targeting the design and implementation of extension strategies to farmer groups according to the constraints imposed by technologies with different characteristics, and that consider the challenges that farmers face at different stages of adoption need to be prioritised in order to increase adoption rates and to improve milk productivity and milk quality.

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By signing the statement of authorship, each author certifies that:

iv. the candidate's stated contribution to the publication is accurate (as detailed above);
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Chapter 3: Adoption of dairy feed technology bundles improves smallholder dairy farmers' milk production

Abstract

In many developing countries such as Indonesia, the growing demand for milk and dairy products presents market opportunities for smallholder dairy farmers. Smallholders' ability to benefit from these opportunities is hampered by productivity and poor milk quality. Development and extension programs and policies introduce technologies and management practices to smallholder dairy farmers to address these issues, however, little is known about which technology bundles are being adopted and their impact on milk production. We used Multinomial Endogenous Switching Regression (MESR) to estimate the effects of the adoption of three feed technology bundles on milk production, using data we collected from 518 farm households located in West Java Province, Indonesia. Our findings suggest that the adoption of feed technology bundles is highly associated with farmers' ownership of capital. Further, we find positive and robust effects of the adoption of technology bundles on milk production, with greater effects if the technology bundle includes high protein feed concentrates. We suggest increasing farmers' awareness of the benefits of adopting complementary technologies and improving the availability and affordability of inputs, such as high-quality feed concentrates, to improve smallholder dairy farmers' milk production in Indonesia.

Keywords: adoption, Indonesia, Multinomial Endogenous Switching Regression (MESR), smallholder dairy farmers, technology bundle

3.1 Introduction

Globally, fresh milk consumption is expected to increase significantly over the next decade, with the largest increase projected to come from developing countries (OECD-FAO 2017). This growing demand for fresh milk represents a market opportunity for smallholder dairy farmers, the dominant producers in the developing world (FAO 2010; Knips 2005). However, smallholder dairy farmers have a limited ability to take advantage of this market growth countries due to relatively low educational levels, low milk production per cow, poor quality milk, and limited access to quality inputs, capital, and finance (Daud, Putro & Basri 2015; De Vries, Kaylegian & Dahl 2020; Morey 2011; Ngeno 2018). These limitations restrict farmers' adoption of improved farm management practices and technologies.

Dairy production is a vital income source for many smallholder dairy households (Duncan et al. 2013; FAO, GDP & IFCN 2018; Knips 2005). Thus, improving milk production and quality is likely to contribute to poverty alleviation and rural development. Previous research suggests that the adoption of dairy feed technologies and improved management practices (e.g., new forage varieties, improving cows' access to drinking water, supplementing cows' diets with high protein concentrates) can ensure balanced nutrition of dairy cows and increase milk production (Daros et al. 2019; Martínez-García, Dorward & Rehman 2013; Salem & Smith 2008; Tricarico, Kebreab & Wattiaux 2020). Ultimately, greater milk production will increase smallholders' market opportunities (Asfaw et al. 2011; Awotide, Karimov & Diagne 2016; Janssen & Swinnen 2019).

There are two main options to improve dairy cow nutrition to improve milk production: (i) increasing availability of good-quality forage and (ii) supplementing feed with high protein concentrates formulated to meet the unique nutritional needs of lactating dairy cows (Moran & Chamberlain 2017). Individual smallholders must make informed decisions about combining different sources of protein supplements with feed technology bundles to increase production

(Moyo & Veeman 2004). However, common obstacles can limit farmers' ability to adopt beneficial feed technologies and management practices, including information asymmetry (Foster & Rosenzweig 1995; Kabunga, Dubois & Qaim 2012; Munshi 2004) and access to credit (Makate, Makate, Mutenje, et al. 2019; Mukherjee 2020).

There has been a research bias towards analysing the effects of the adoption of single versus multiple complementary technologies (Ogundari & Bolarinwa 2018). However, farmers are more likely to adopt multiple complementary technologies simultaneously in a bundle, or in a stepwise manner (Byerlee & De Polanco 1986; Feder, Just & Zilberman 1985; Moyo & Veeman 2004; Rauniyar & Goode 1992) with demonstrated benefits (Khonje et al. 2018; Kotu et al. 2017; Manda et al. 2016; Marenya, Gebremariam & Jaleta 2020; Tambo & Mockshell 2018). Technologies are complementary if synergistic benefits, such as productivity improvements, arise from simultaneous adoption (Canales, Bergtold & Williams 2020; Perry, Moschini & Hennessy 2016). For example, the benefits for yield and quality from the adoption of improved seed varieties (IVs) were found when IVs were adopted together with fertiliser (Kassie et al. 2018).

The literature on the adoption of multiple technologies mainly focuses on the effects of crop technologies and environmental conservation. Less is known about the benefits of adopting multiple technologies for dairy production outcomes, particularly for smallholders. Recent studies have analysed the effects of the adoption of individual technologies on milk yield of smallholder dairy farms in sub-Saharan African (e.g., Kebebe 2017; Maina et al. 2020; Ngeno 2018) and South Asia (e.g., Bayan & Dutta 2017; Ravichandran et al. 2020). However, little is known about the Indonesian context where most studies focus on value chains (Nugraha 2010; Susanty et al. 2018; Susanty et al. 2019), farm performance (Sembada, Duteurtre & Purwanto 2016; Setiawan 2019; Utami & Seruni 2014), and incentives for milk quality improvement (Treurniet 2021). Greater understanding of constraints in smallholder dairy production is needed because seventy-seven percent of Indonesia's fresh milk is supplied by smallholder dairy farmers, and the development of Indonesian dairy industry has been significantly limited by low productivity and milk quality issues (USDA 2019).

This paper hypothesises that Indonesian smallholder dairy farm households that adopt dairy feed technology bundles experience greater increases in milk production compared to those which adopt individual feed technologies. This study examines (i) the factors which explain the adoption of critical feed technologies by smallholder dairy farming households in Indonesia and (ii) the synergistic effects of the adoption of multiple technologies on milk production in this context.

To understand the potential benefits of adopting technologies in bundles, this study analyses outcomes from adoption of three feed technology bundles from the combination of four preferred feed technologies: high-quality grass varieties; fertiliser to grow grass; unrestricted access to drinking water; and high protein concentrates (16% or higher). Since the adoption of feed technologies is not random, we estimate the effects of adoption on milk production using Multinomial Endogenous Switching Regression (MESR) to control for selection bias based on observable and unobserved characteristics in the adoption decision. We test for the robustness of our results using Inverse Probability Weighted Regression Adjustment (IPWRA). Other studies have used these methods to compare the adoption of multiple technologies with non-adoption (Danso-Abbeam & Baiyegunhi 2018; Marenya, Gebremariam & Jaleta 2020; Tambo & Mockshell 2018). We use these methods to draw comparisons between technology bundles to determine which ones produce the greatest benefits from adoption.

Our findings suggest that the adoption of feed technology bundles is highly associated with ownership of capital. Further, we find positive and robust effects of the adoption of technology bundles on milk production, with greater effects if the technology bundle includes high protein feed concentrates. We suggest increasing farmers' awareness of the benefits of adopting complementary technologies and improving the availability and affordability of inputs, such as high-quality feed concentrates, to improve smallholder dairy farmers' milk production in Indonesia.

The remainder of this chapter is organised as follows. The following sections describe this study's conceptual framework (3.2), methodology (3.3) and dataset (3.4). Section 3.5 presents the results and discussion of the study. Finally, Section 3.6 concludes the study and provides possible strategies to enhance the adoption of critical feed technologies and increase the milk production of smallholder dairy farms in Indonesia.

3.2 Conceptual framework

The adoption literature suggests that farmers adopt technologies, or technology bundles, to maximise the expected present value of a stream of benefits under various agricultural production constraints (Dorfman 1996; Kassie et al. 2013; Manda et al. 2016). A number of studies have found that the adoption of agricultural technologies in a bundle requires human and physical capital (Kpadonou et al. 2017; Prakash et al. 2018; Teklewold, Kassie & Shiferaw 2013) and that adoption of these bundles have significantly greater effects on farm performance than the adoption of a single technology (Khonje et al. 2018; Kotu et al. 2017; Manda et al. 2016; Marenya, Gebremariam & Jaleta 2020; Tambo & Mockshell 2018; Teklewold et al. 2013; Wainaina, Tongruksawattana & Qaim 2017). For example, adopting green-revolution type technologies, such as high yielding varieties, is expected to increase yield if adopted together with fertiliser.

The adoption of bundles of dairy feed technologies has the potential to improve milk production. The adoption of four dairy feed technologies is studied here:

(i) High-quality grass varieties: Growing improved varieties of grass, such as *Brachiaria brizantha*, *B. Mulato*, and *B. mutica*, can benefit farms' performance by reducing growth periods, increasing yields and improving nutritional content. These strategies address the challenge of feed scarcity experienced by smallholder dairy farmers (Maina et al. 2020).

(ii) Fertiliser to grow grass: Smallholder dairy farmers in developing countries have limited access to large land areas to graze their cows (Moran & Chamberlain 2017) and most apply cut-and-carry feeding systems for permanently housed stock (Chagunda et al. 2016; Maleko, David et al. 2018). However, this system potentially depletes soil fertility as animal manures are not all returned to the land (Mannetje 1993; Stur & Horne 2001), increasing the potential for fertiliser applications to increase grass yields.

(iii) Unrestricted access to drinking water: Inadequate water supply decreases dairy cows' body weight and dry matter intake (DMI)[8], leading to a low level of milk production (Little et al. 1984; Meyer et al. 2004; Salem & Smith 2008).

(iv) High protein concentrates: The supplementation of feed with high crude protein concentrates (CP) (16% or higher) complements the nutrients from forages and ensures sufficient protein, energy, and minerals to support a high level of milk production (Garg 2012; Salem & Smith 2008).

Synergistic benefits for increased milk production can be realised if complementary technologies are adopted simultaneously, rather than singly (Canales, Bergtold & Williams 2020; Feder 1982; Perry, Moschini & Hennessy 2016). For example, adopting improved varieties of grass, together with the adoption of fertiliser, is expected to increase grass yields

[8] DMI is the amount a cow consumes per day after subtracting moisture content from the wet feeds.

for fodder more effectively than adoption of either technology on its own. We also hypothesise that the effects of technology bundle adoption on milk production differ depending on the technology mix within the bundle.

3.3 Methodology

Smallholder dairy farm households' decisions to adopt individual technologies, or technology bundles, may not be random; households may endogenously self-select in decision choices. Therefore, adoption decisions may be attributed not only to observable characteristics (e.g., individual, household, farm, and institutional characteristics) but also to unobserved characteristics (e.g., motivation, risk aversion and managerial skills) that may be correlated with the outcome of interest, which is milk production in this study.

Conceptually, technology adoption could be measured in terms of the amount of input used, for example, quantity (kg) of fertiliser. Since this study focuses on estimating the synergistic effects from the adoption of technologies in bundle, a binary variable representing adoption is used as is commonly done in the adoption literature (Suri 2011).

To control for selection bias based on observable and unobserved characteristics in adoption decisions and their effects on the outcome of interest, we applied the Multinomial Endogenous Switching Regression (MESR) method. This method controls for endogeneity in the outcome equation by using multinomial logit. Estimation of the effects of the adoption of agricultural technologies using MESR involves two simultaneous stages. The first stage estimates farmers' decisions to adopt technology options using a multinomial logit (MNL) model. The Inverse Mills Ratio (IMR) is calculated from the estimated probabilities using MNL. The second stage calculates the effects of adopting each technology option using ordinary least squares (OLS) by including the IMRs estimated from the MNL model as additional covariates. Several studies have previously applied this method, such as Issahaku and Abdulai (2019), (Khonje et al. 2018), and Teklewold et al. (2013).

3.3.1 Multinomial logit (MNL) selection model

It is conceptualised that a smallholder dairy farm household adopts multiple agricultural technologies to maximise its expected benefits (B_i). A household is assumed to adopt a technology option, whether a single technology or technology bundle (Table 3.2), by comparing the expected benefits generated by k alternatives. A household i decides to adopt a particular technology option (m) over any alternative k if $B_{im} > B_{ik}$. The expected benefits (B_{im}^*) that the household generates from the adoption of m is a latent variable determined by the observable individual, household, farm, and institutional characteristics included in X_i and unobserved characteristics $\mathcal{E}_i$:

$$B_{im}^* = X_i + \mathcal{E}_i \qquad (1)$$

Let B be an index that denotes the dairy farmer's choice of a technology option, such that:

$$B \begin{cases} 1 \; if \; B_{i1}^* > \max\limits_{k \neq 1}(B_{ik}^*) \; or \; \eta_{i1} < 0 \\ \vdots\vdots\vdots & for \; all \; k \neq m \\ m \; if \; B_{im}^* > \max\limits_{k \neq M}(B_{ik}^*) \; or \; \eta_{im} < 0 \end{cases} \qquad (2)$$

where η_{im} = $max_{k \neq m}(B_{ik}^* - B_{im}^*) < 0$ (Bourguignon, Fournier & Gurgand 2007), meaning that household i will adopt m to maximise their expected benefits if the expected benefits of m are greater than the expected benefits than any other alternative k. Assuming that $\mathcal{E}_i$ is identically and independently Gumbel distributed, the probability that dairy farm household i

with characteristics X will choose technology option m can be specified by the following multinomial logit model (McFadden 1974):

$$B_{im} = \text{Br}\ (\eta_{im} < 0 | X_{im}) = \frac{\exp(X_{im}\beta_m)}{\sum_{k=0}^{M}\exp(X_{ik}\beta_k)}, for\ m = 0, .., M \qquad (3)$$

3.3.2 Second stage: Multinomial endogenous switching regression

In the second stage, the effects of adopting a technology option are estimated using OLS with the IMRs as additional covariates. This second stage assesses the relationship between milk production as the outcome of interest and a set of explanatory variables Z. The relationship is estimated for each technology options $m = 0, 1, 2, 3, 4, 5$. Milk production outcomes for each possible technology bundle can be modelled as follows:

$$\begin{cases} Regime\ 1: \ y_{i0} = \beta_1 Z_{i0} + \mu_{i0} & if\ B = 0 \\ \quad\vdots & \\ Regime\ M: \ y_{im} = \beta_m Z_{im} + \mu_{im} & if\ B = M \end{cases} \qquad (4)$$

$$for\ m = 0, \dots, M$$

Where y_{im} is milk production for household i's in regime m. The error terms μ_{im} are distributed with $E(\mu_{im}|X, Z) = 0$ and variance $(\mu_{im}|X, Z) = \sigma_m^2$. If the error terms ε_{im} in Equation (1) and μ_{im} in Equation (4) are correlated, the OLS estimation of Equation (4) will be biased. Therefore, consistent estimation of β_m requires the inclusion of correction selection terms for each of regime m in Equation (4). There will be $m - 1$ selection correction terms in a multinomial choice setting. The second stage of the MESR with the inclusion of selection correction terms is as follows:

$$\begin{cases} Regime\ 1:\ y_{i0} = \beta_1 Z_{i0} + \sigma_1 \vartheta_{i0} + \omega_{i0} & if\ B = 0 \\ \vdots & \\ Regime\ M:\ y_{im} = \beta_m Z_{im} + \sigma_m \vartheta_{im} + \omega_{im} & if\ B = M \end{cases} \quad (5)$$

$$for\ m = 0, \ldots\ldots, M$$

where ω_{im} is the error term with an expected value of zero, σ is the covariance between ε'_{im} and μ'_{im}, and ϑ_{im} is the IMR or selection correction term estimated from the multinomial logit model in Equation (3).

3.3.3 Estimation of average treatment effects on the treated (ATET)

The above estimation is used to obtain the average treatment effects on the treated (ATET). As this study assessed multiple comparisons of the effects of different technology options, the ATET are estimated as the difference between the outcomes for adopters compared to the outcomes for counterfactual scenarios of adoption of other technology options as well as non-adoption. The estimation of the ATET can be performed for observed and estimated counterfactual scenarios, as follows:

Adopters

$$E\left(y_{im} \middle| U = m, z_{im}, \hat{\vartheta}_{im}\right) = \beta_m z_{im} + \sigma_m \hat{\vartheta}_{im} \qquad (6a)$$

Adopters had they decided not to adopt (counterfactual)

$$E\left(y_{i0} \middle| U = m, z_{im}, \hat{\vartheta}_{im}\right) = \beta_0 z_{im} + \sigma_0 \hat{\vartheta}_{im} \qquad (6b)$$

Adopters had they decided to adopt other technology options (counterfactual)

$$E\left(y_{ik} \middle| U = m, z_{im}, \hat{\vartheta}_{im}\right) = \beta_k z_{im} + \sigma_k \hat{\vartheta}_{im} \qquad (6c)$$

The expected value of milk production is estimated to predict the actual value of the Equation (6a) and the counterfactual value of the Equation (6b) and (6c). This study calculates the effects of the adoption of each technology option in milk production for adopters of technology bundles $m = 1, \ldots\ldots, M$ with respect to non-adoption $m = 0$, which is the difference between (6a) and (6b) as shown in Equation (7a). This study also calculates the effects of the adoption of technology options in milk production for adopters m to other technology options k, where $k \neq m$, which is the difference between (6a) and (6c) as shown in Equation (7b).

$$ATET = \left(y_{im} \middle| B = m, z_{im}, \hat{\vartheta}_{im}\right) - \left(y_{i0} \middle| B = m, z_{im}, \hat{\vartheta}_{im}\right) \qquad (7a)$$

$$= z_{im}(\beta_m - \beta_0) + \hat{\vartheta}_{im}(\sigma_m - \sigma_0)$$

$$ATET = \left(y_{im} \middle| B = m, z_{im}, \hat{\vartheta}_{im}\right) - \left(y_{ik} \middle| B = m, z_{im}, \hat{\vartheta}_{im}\right) \qquad (7b)$$

$$= z_{im}(\beta_m - \beta_k) + \hat{\vartheta}_{im}(\sigma_m - \sigma_k)$$

where $\hat{\vartheta}_{im}$ controls for unobserved heterogeneity. The MESR was performed using *selmlog* in Stata 16 by Bourguignon, Fournier and Gurgand (2007).

3.3.4 Robustness check using Inverse Probability Weighted Regression Adjustment

This study employed the Inverse Probability Weighted Regression Adjustment (IPWRA) to check for the robustness of the results generated from the MESR. The IPWRA estimates both the selection and outcome equations simultaneously. The procedure uses weighted regression coefficients in the outcome equation to compute treatment effects, where the weights are the estimated inverse probability of adoption obtained from estimating the selection equation (Imbens & Wooldridge 2009). This method has been implemented recently by Kebebe (2017), Tambo and Mockshell (2018), and Makate, Makate, Mango, et al. (2019).

3.4 Data

The sample in this study was 518 dairy farm households located in West Java Province, Indonesia.[9] The majority of dairy farm households in Indonesia are members of dairy cooperatives.[10] Of the total of 26,121 dairy farm households in West Java (Statistics Indonesia 2015), around 71% of them are members of dairy cooperatives.[11]

The sampling design consisted of proportional random sampling. Five dairy cooperatives were purposively selected based on their interest in increasing milk production in the region. Dairy farm households that are members of these cooperatives are distributed within four districts, as shown in Table 3.1. The number of farmers selected from each district reflects the proportion of each district's share of the total population of dairy farmers in the region. As the proportion of Cianjur and Bogor farmers was below 7%, we oversampled farmers from these two districts. The final sample distribution by districts is presented in Table 3.1. Because we are interested in estimating the effects of the adoption of technologies on milk production among the sample, and we are not seeking to derive inferences to the wider population, this oversampling is not a concern (Cameron & Trivedi 2009). Farmers were selected randomly from each district using lists of dairy farmers provided by the dairy cooperatives.

The survey was conducted between August and September 2017. This corresponds to the dry season and is therefore likely to coincide with limits on the availability of forages and

[9] Only 518 of the 600 respondents were included in the analyses in this study. There were 50 farmers excluded from the analysis as the farmers adopt "other combination", consisting of various combinations of technologies that have very small numbers of farmers adopting them (e.g. less than 23 farmers), which is not meaningful to be included in the analysis. In addition, 32 observations were dropped due to missing values for some of the independent variables. We compared characteristics between the sample included in the analysis (518 farmers) and the ones that were dropped (82 farmers). Overall, there are no significant differences between the two samples in their main characteristics such as farmers' age, education, herd size, ownership of productive assets, credit, access to information about technologies and milk production per cow (Table A6-1 in the Appendix).

[10] Of a total of 141,989 dairy farm households in Indonesia, about 98% are located on Java Island. Almost 60% of them are members of dairy cooperatives, 17% are not members possibly because no cooperatives exist in their villages and 19% are not interested in becoming members (Statistics Indonesia 2015). Dairy cooperatives market farmers' milk to dairy processors, provide access to dairy inputs and extension services.

[11] Data collected by personal communication with the Indonesian Dairy Cooperatives Union (GKSI) in November 2016.

drinking water (Hernandez et al. 2018; Maleko, D et al. 2018; Reiber et al. 2010). We consider these effects in interpreting our data and presenting our results. The data collection entailed interviewing household heads using a structured questionnaire in the mobile-based application, CommCare version 2.36.1 (Dimagi, Cambridge, MA).

Table 3.1 Distribution of respondents by districts

Districts	Respondents	%
Bandung	253	48.84
Garut	118	22.78
Cianjur	80	15.44
Bogor	67	12.93
Total	**518**	**100.00**

The questionnaire was designed to collect information about smallholder dairy farmers' socioeconomic status, household, farm production characteristics, and decision-making regarding the adoption of multiple technologies. The questionnaire was revised several times after focus groups with key stakeholders in the dairy sector and extensive pre-testing with smallholder dairy farmers. The questionnaire was translated into Bahasa Indonesia, the official language of Indonesia. Trained local enumerators with extensive experience conducting household surveys implemented the survey.

3.4.1 Dairy feed technology options

Eleven different technology options (including non-adoption) from the four dairy feed technologies considered in this study (Table A6-2 in the Appendix), were adopted by dairy farm households in the sample. This range of technology bundles adopted confirms the heterogeneity of adoption decisions made by smallholder dairy farmers. Specifically, this study analyses five technology options that were frequently adopted by dairy farm households (Table 3.2).

Table 3.2 Adoption rates of single technology and technology bundles (n=518)

Adoption	Description	%
0	Did not adopt any technologies	13.71
1	High-quality grass varieties only	10.62
2	Fertiliser only	9.65
3	Bundle A: high-quality grass varieties and fertiliser	33.59
4	Bundle B: Bundle A plus unrestricted access to drinking water	23.17
5	Bundle C: High protein concentrates (16% or higher) with any other technologies	9.27

3.4.2 Variables included in the regression and exclusion restrictions

The technology bundles in Table 3.2 are the dependent variables in the MNL model used to estimate the determinants of the probability of adopting different technology bundles (Equation 3). In the outcome equation (Equation 4), the dependent variable is the average milk production per cow per day, based on the number of lactating cows managed by each household. Most farmers receive notes from the cooperatives on the total volume of milk they supply per day (morning and afternoon supply), making this a relatively accurate measure of milk yield.

The independent variables (X and Z) included in the estimation of Equations 3 and 4 should influence the adoption decisions and potential outcomes simultaneously (Li & Graham 2016). Detailed descriptive statistics of the variables included in the estimation are available in Table 3.3. They include: individual characteristics, such as age and education; household characteristics, such as the number of household members; asset ownership, such as non-production assets[12]; non-dairy livestock ownership[13]; institutional factors, such as access to credit (Doss 2003, 2006; Feder, Just & Zilberman 1985; Kassie et al. 2013; Pannell et al. 2006); dairy farm characteristics, such as total dairy cow numbers; ownership of dairy farming

[12] We estimated principal component analysis (PCA) based indices for non-production and dairy farming equipment assets following Filmer and Pritchett (2001) and McKenzie (2005). Detail on the lists of assets and PCA loadings can be found in the Appendix Table A6-3 and Table A6-4.

[13] We estimated the number of tropical livestock units, excluding dairy cows based on weights from FAO (2011).

equipment[12]; land to grow grass; farm altitude (Eastham et al. 2018; Freeman, Ehui & Jabbar 1998; Moran & Chamberlain 2017; Negri & Brooks 1990; Rahelizatovo & Gillespie 2004; Sultana, Uddin & Peters 2016; Weersink & Tauer 1991; Yeamkong et al. 2010); and herd characteristics, such as the average age of lactating cows, first calving age and calving intervals (Cheng'ole, Kimenye & Mbogoh 2003; Eastham et al. 2018; Lush & Shrode 1950).

Herd characteristics may influence the adoption decision because farmers with older lactating cows are less likely to adopt good dairy feed technologies. Milk production decreases as cows age, and a common practice for commercially orientated farms is to cull older cows to maximise feed resources for more productive cows (Bell et al. 2010; Moran & Chamberlain 2017). Farm altitude reflects the climatic conditions of the dairy farm's location. Climate may have effects on the choice of technology adopted by farmers (Negri & Brooks 1990) and on milk production (Moran & Chamberlain 2017).

Dairy cooperatives play a number of important roles in the dairy value chain, including provision of inputs, services and collection, and distribution of milk to processors. Cooperatives offer their members different services, therefore the estimation includes district dummies to account for differences between cooperatives. There were two cooperatives located in the same district (Bogor). These two cooperatives sell 80% of their fresh milk production to the same processing company. They face similar price and quality requirements and provide the same information to cooperative members.

While the independent variables in the selection equation (X in Equation 3) and outcome equation (Z in Equation 4) may overlap in the MESR, the estimation requires the inclusion of exclusion restrictions or instruments in the selection equation to obtain unbiased estimates (Di Falco, Veronesi & Yesuf 2011; Marenya, Gebremariam & Jaleta 2020; Vigani & Kathage 2019). Two exclusion restrictions were included: dairy farm households which received information about feed technologies in the last twelve months and participation in off-farm employment of dairy farm households. It is assumed that receiving the information increases the probability of technology adoption (Doss 2006; Feder, Just & Zilberman 1985). Farmers may have information about the technologies, but they may lack the human and physical assets necessary to adopt them. Therefore, access to information alone does not affect milk production.

It is expected participation in off-farm employment will influence adoption decisions but will not directly affect milk yield. Off-farm participation implies additional sources of capital that could facilitate adoption (Feder, Just & Zilberman 1985; Hailu, Abrha & Weldegiorgis 2014) or implies less available time to implement technologies, which could reduce the likelihood of adopting technologies (Suvedi, Ghimire & Kaplowitz 2017; Wozniak 1993), especially for labour-intensive technologies like the dairy feed technologies. Participation in off-farm activities will not necessarily be associated with milk yield because farmers engaging in off-farm employment will have less available time on the farm to intensify their farm production; this is important, given the fact that milk production in the smallholder farming contexts is labour-intensive (Ngeno 2018). Another factor may be that farmers with off-farm employment are less likely to depend on dairy farming as their main source of household income, and increasing milk production may not be their primary goal.

To test the validity of these exclusion restrictions, a simple falsification test was performed using the Wald test. Exclusion restrictions are valid if they jointly affect the adoption decisions but do not affect milk production. The results in Table A6-5 (Appendix) show that receiving information and off-farm participation jointly affect farmers' decisions to adopt dairy feed technologies but not milk production.

Table 3.3 Individual, household and farm characteristics of smallholder dairy farm in West Java, Indonesia (n=518)

Variables	Mean	SD	Min	Max
Milk production				
Milk production per cow (litres/day)	14.74	3.87	2.00	26.25
Farmer characteristics				
Age of farmer (years)	46.25	11.43	21.00	84.00
Education of farmer (years)	6.45	3.11	0.00	18.00
Household (HH) characteristics and assets				
Number of family members	3.99	1.45	1.00	11.00
Non-production asset ownership index[12]	0.06	1.43	-3.09	5.93
Tropical livestock units (non-dairy)[13]	0.37	4.63	0.00	104.20
Dairy farm characteristics				
Farm altitude (kilometres)	1.27	0.31	0.26	2.56
Total dairy cows managed	5.66	4.87	1.00	39.00
Dairy farming equipment ownership index[12]	0.00	1.68	-3.60	10.10
Own land for growing grass (1 = Yes)	0.20	0.40	0.00	1.00
Hired labour (1=Yes)	0.21	0.41	0.00	1.00
Herd characteristics (lactating cow managed)				
Average age (years)	4.97	1.53	1.50	13.00
Average age when first calving (years)	2.26	0.36	1.50	7.22
Average calving interval in ideal range 12-13 months (1=Yes)	0.44	0.50	0.00	1.00
Institutional characteristics				
Had credit in the last 12 months (1=Yes)	0.56	0.50	0.00	1.00
Exclusion restrictions				
Farmers received information about feed technology in the last 12 months (1=Yes)	0.58	0.49	0.00	1.00
Off-farm income (1=Yes)	0.70	0.46	0.00	1.00
Districts				
Bandung (1=Yes)	0.49	0.50	0.00	1.00
Garut (1=Yes)	0.15	0.36	0.00	1.00
Cianjur (1=Yes)	0.23	0.42	0.00	1.00
Bogor (1=Yes), base category	0.13	0.34	0.00	1.00

3.5 Results and discussion

3.5.1 Factors affecting the adoption of technology bundles

The overall results show that the key determinant of the adoption of technology bundles is investment in productive assets, including dairy farming equipment, land to grow grass, and non-dairy livestock (Table 3.4).[14] This is consistent with the literature, which suggests that the adoption of technologies in a bundle requires farmers to have better access to capital (Kpadonou et al. 2017; Prakash et al. 2018; Teklewold, Kassie & Shiferaw 2013). Other significant variables include farmer age and receiving information about feed technology. These results refer to the determinants of adopting additional technology to be (a) technology bundle. This includes adding fertiliser to the adoption of high-quality grass varieties (Bundle A); adding unresctricted access to drinking water technology to the adoption of Bundle A (Bundle B); and adoption of high protein concentrates combined with any other feed technologies (Bundle C) relative to the adoption of high-quality grass varieties only, Bundle A and Bundle B (5 vs 1, 5 vs 3, and 5 vs 4 respectively).

Ownership of appropriate farming equipment facilitates the adoption of agricultural technologies (Moremedi, Hulela & Maruatona 2018; Myeni et al. 2019). In dairy farming, the ownership of equipment, such as water pumps and hoses, facilitates the adoption of improving cows' access to drinking water. Mattocks and metal forks are tools that facilitate growing high-quality grass varieties, and spraying pumps aid growth by spraying fertiliser. All of these assets were included in the dairy farm equipment index and had relatively high weights.

The adoption of Bundle A relative to the adoption of high-quality grass varieties only is negatively associated with ownership of non-dairy livestock, suggesting that farmers rely on their dairy farming business as the primary source of household income. Keeping greater

[14] To conserve space, only variables that are higly significant (at least at 5% level) are presented in Table 3.4. The complete table is available in Table A6-7 in the Appendix.

numbers of non-dairy stock would incur more costs for farmers, especially related to feeding costs. On the other hand, positive associations are found in the adoption of Bundle B and Bundle C relative to Bundle A. The positive association implies the financial capacity of farmers to invest in water infrastructure and procure high protein concentrates, which are capital intensive technologies.

Adding fertiliser to the adoption of high-quality grass varieties (Bundle A) is positively associated with ownership of land. Farmers who manage their land are more likely to make a long-term investment in improving soil (Abdulai, Owusu & Goetz 2011), such as applying fertiliser to improve land fertility and increase forage production (Martínez-García, Dorward & Rehman 2016). A similar association is found with the adoption of Bundle C relative to high-quality grass varieties. Ownership of land reflects farmers' access to productive resources and wealth, which can ease liquidity constraints which can limit adoption of agricultural technologies (Doss 2003; Jones-Garcia & Krishna 2021; Teklewold et al. 2017).

The results also suggest that younger farmers are more likely to adopt Bundle C. This is in opposition to the adoption of other bundles, such as Bundle A and Bundle B, which are more likely to be adopted by older farmers (Table A6-6 in the Appendix). Most concentrates available in Indonesia have protein contents of less than 13% protein (Bamualim, Kusmartono & Kuswandi 2009); therefore, the adoption of high protein concentrates is considered a new practice among smallholder dairy farm households. The literature suggests that younger farmers are more likely to experiment with new technologies (Kassie et al. 2015; Rahelizatovo & Gillespie 2004).

Receiving information about feed technology is negatively associated with the adoption of Bundle B relative to Bundle A. While this is surprising, a plausible explanation is that drinking water infrastructure availability could be less related to information availability but more capital intensive, as explained above. This means that the intensity of information provision about this infrastructure is not an influential factor in promoting adoption and that the cost of installation is a more important barrier to adoption. On the other hand, the variable is positively associated with the adoption of Bundle C relative to Bundle B. Adding high protein concentrates to the adoption of the bundle requires farmers to have awareness about the correct implementation of the technology, including the right proportion of concentrates to forages and timing them with cows' lactation periods to balance with other feed sources (Moran 2005). These factors may require farmers to have more access to information.

Table 3.4 Multinomial logit (odds ratio) estimation of the probability of the adoption of technology bundles relative to different base categories of bundles (n=518)

Variables	3 vs 1	4 vs 3	5 vs 1	5 vs 3	5 vs 4
Age (years)	-0.03	0.00	-0.07***	-0.04**	-0.05**
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)
Tropical livestock unit (non-dairy)	-0.59**	0.42*	-0.01	0.58**	0.16
	(0.25)	(0.24)	(0.05)	(0.25)	(0.16)
Dairy farming equipment index	0.43***	0.15	0.84***	0.41***	0.26*
	(0.16)	(0.11)	(0.19)	(0.14)	(0.14)
Own land for growing grass (1 = Yes)	2.02**	0.34	2.59***	0.57	0.23
	(0.79)	(0.31)	(0.87)	(0.47)	(0.47)
Received information of feed technology (1=Yes)	-0.19	-0.61**	0.04	0.23	0.84**
	(0.35)	(0.27)	(0.47)	(0.40)	(0.40)

Standard errors in parentheses
Levels of significance: *** p<0.01, ** p<0.05, * p<0.10
0 = Do not adopt any technologies
1 = High-quality grass varieties only
2 = Fertiliser only
3 = Bundle A: High-quality grass varieties and fertiliser
4 = Bundle B: Bundle A plus unrestricted access to drinking water
5 = Bundle C: High protein concentrates with any other technologies

The other results that compare the adoption of single technologies and technology bundles relative to non-adoption are also available in Table A6-6 in the Appendix. The results of this analysis (non-adoption as the base category) are consistent with the established adoption literature and suggest that the heterogeneity of farmers' adoption decisions is explained by their socioeconomic characteristics and ownership of assets, including farmers' age, education, access to credit, and ownership of non-production assets, land, and dairy farming equipment.

3.5.2 Effects of adopting technology bundles on milk production

Significant positive and robust effects on milk production are realised if farmers adopt technologies in bundles rather than adopting the technologies individually, especially if the technology bundle includes high protein concentrates (Table 3.5). These results are in line with the literature (Khonje et al. 2018; Manda et al. 2016; Marenya, Gebremariam & Jaleta 2020), suggesting synergistic benefits are present from the adoption of complementary technologies in bundles.

The adoption of high-quality grass varieties (as a single technology) has a significant and positive effect on milk production; 1.3 litres (per cow/day) higher for adopters than for non-adopters. Farmers who adopted high-quality grass varieties (as a single technology) are somewhat less likely to have land to grow grass (Table A6-6 in the Appendix), suggesting that they may rent land to grow grasses. Farmers are usually looking to rent the best land available (Byiringiro & Reardon 1996); for example, land with high fertility that can support the growth of high-quality grass varieties, hence improving availability, which are positively associated with higher milk production. Another plausible explanation is rent conditions make it risky to fertilise rented land if the payoff is over several years of less secure tenure of forages. This is in line with the findings from a recent study by Maina et al. (2020), who showed that the adoption of Brachiaria grasses (an improved grass variety) has positive effects on smallholder dairy farms' milk production in Kenya.

Farms that adopted high-quality grass varieties and fertiliser together (Bundle A) produced significantly more milk (1.1 units more) than the non-adopters. Additionally, the adoption of fertiliser only, which may be applied to grow unimproved varieties of grass, resulted in milk production that was 1.1 units higher than that produced by farms that only adopted high-quality grass varieties. This suggests positive complementary effects from the adoption of fertiliser to stimulate the growth of the grass. In most case, the land managed by smallholder farmers has reduced fertility due to the cut and carry feeding system, (Mannetje 1993; Stur & Horne 2001), requiring farmers to apply fertiliser to enrich the soil with nutrients.

Milk production increased with adoption of the bundle of high-quality grass varieties, fertiliser, and unrestricted access to drinking water (Bundle B) by 1.2 and 1.4 units compared to non-adoption and the adoption of high-quality grass varieties only, respectively. However, there was no significant difference between the adoption of Bundle B and Bundle A. This is surprising given that drinking water is important for dairy cows and positively affects milk production when ad-libitum drinking water is provided. A plausible explanation is that water in the study regions was actually limited to a point that hindered production.

Farmers obtain the highest gain in milk production when they adopt high protein concentrates bundled with any other feed technologies (Bundle C). The coefficients for the adoption of Bundle C are positive and statistically significant, resulting in milk production that is 2.5 units higher than non-adoption, 1.9 units higher than the adoption of high-quality grass varieties only, 0.9 units higher than Bundle A and 1.2 units higher than Bundle B.

The adoption of high protein concentrates is a complementary technology to the adoption of other technologies. Tropical forages do not normally contain sufficient protein content (Preston 1982), which can only support low levels of milk production (6-8 kg/cow/day) (Moran & Chamberlain 2017; Stur & Horne 2001). Thus high protein concentrates complement low protein tropical forages. Previous studies found that dairy cows produce more milk with supplementation of protein-rich concentrates (Muraguri, McLeod & Taylor 2004; van Schaik et al. 1996).

Despite the benefits of adopting high protein concentrates, the uptake rate for this technology was relatively low - only 9.27% of farmers adopted high protein concentrates. About 58.30% of farmers were not aware of the benefits of the high protein concentrates (Figure A6-1 in the Appendix). Approximately 70% of farmers did not adopt high protein concentrates due to limited affordability and 18 to 23% did not adopt because of limited availability (Figure A6-2 in the Appendix).

Table 3.5 Milk production differences as the effects of the adoption of feed technologies relative to non-adoption and adoption of technology bundles

Adoption of technologies	Base categories				
	0	**1**	**2**	**3**	**4**
1 = High-quality grass varieties only	1.34*** (0.45)				
2 = Fertiliser only	0.90 (0.54)	1.14** (0.54)			
3 = Bundle A: High-quality grass varieties and fertiliser	1.13*** (0.22)	0.18 (0.22)	-0.22 (0.25)		
4 = Bundle B: Bundle A plus unrestricted access to drinking water	1.23*** (0.25)	1.42** (0.30)	0.47 (0.47)	0.17 (0.19)	
5 = Bundle C: High protein concentrates with any other technologies	2.53*** (0.60)	1.92** (0.53)	-0.19 (0.90)	0.91** (0.39)	1.24** (0.44)

Numbers correspond to the estimated average treatment effects on the treated (ATET) coefficients. These are the differences in milk production (litres/cow/day) of farmers who adopt particular technology or bundles (column: Adoption of technologies) and the production of farmers who do not adopt any technologies (column 0) and those who adopt other technology or bundles (column 1 to 4).
0 = Do not adopt any technologies
Bootstrapped standard errors in the parentheses
Levels of significance: *** $p<0.01$, ** $p<0.05$, * $p<0.10$

Low adoption of high protein concentrates may limit the observability of the benefits of the technology. In a social system, farmers interact with other actors, including other dairy farmers, and this facilitates their access to knowledge, information and ideas, which shape their decisions to adopt technologies (Ramirez 2013; Weyori et al. 2018). When a technology is adopted at a low frequency, farmers may find it difficult to learn about the benefits from peers. Understanding the relative benefits of adopting different forms (qualities/costs) of concentrates would not be easy, and farmers may opt for lower cost rather than highest yield. In addition, dairy cooperatives are not incentivised to produce and supply high protein concentrates when demand is low, with a potential negative feedback on availability and price, and a suppressive effect on farmers' trialling the technology.

3.5.3 Robustness check

The results from the IPWRA estimation are quite robust (Table A6-8 in the Appendix), with most of the estimated coefficients having the same signs for each comparison. The significance level of the coefficients from the IPWRA estimation are slightly different from those estimated using the MESR[15], however, the results are still significant in economic terms (Wooldridge 2012). Both estimations consistently report that the adoption of technologies has positive effects on milk production. As this study relies on a cross-sectional dataset, we cannot claim that the results are completely free of endogeneity. The availability of panel data may address this issue and demonstrate causation on the effects of the adoption technologies rather than mere association.

3.6 Conclusions

This study demonstrates that achieving the full benefits of adoption requires promotion and uptake of complementary technology bundles. Improving farmers' awareness of technologies and the benefits of adopting complementary technologies is needed. This could be done through farmer-to-farmer (F2F) extension approaches that have been effective in increasing farmers' awareness (familiarity) of agricultural technologies (Fisher et al. 2018; Shikuku 2019). In addition, introducing technologies through demonstration farm may be helpful to increase farmers awareness of the benefits of technologies by allowing them to experiment with the new technology, observe yield improvement and recall technology implementation details on the farm (Maertens, Michelson & Nourani 2021). However, awareness of technologies and their benefits alone may not incentivise farmers to adopt them.

[15] Table A6-8 in Appendix shows that the standard errors from the comparison of milk production estimated using the MESR are smaller than the standard errors from the IPWRA, indicating that the estimation using the IPWRA is less precise. We also performed heterogeneity analysis on the effects of the adoption of technology bundles by the terciles of herd size managed by the dairy farm households. However, we did not find any interesting results from our estimation. Results are presented in Table A6-9 in the Appendix.

Access to productive assets and the availability of inputs, such as fertiliser, high-quality grass varieties, and unrestricted access to drinking water is required. Awareness, availability and affordability of high protein concentrates are influential factors in farmer adoption. Dairy cooperatives may need to alter credit conditions for farmers to be incentivised to purchase high protein concentrates. Increased uptake of technology bundles will allow smallholder dairy farm households to take advantage of emerging market opportunities and enhance household incomes and livelihoods.

For optimal policy development, targeting and implementation, it is imperative for future research to extend the analysis by considering full impact evaluation on the effects of the adoption of technologies on asset accumulation and agricultural income-related outcomes. Providing additional information on the welfare-related effects of adoption on dairy farming households would better shape the design of technology dissemination programs by signalling possible multiple effects from technology adoption.

3.7 References

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By signing the statement of authorship, each author certifies that:

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Chapter 4: Institutional failures hindering continuous adoption of agricultural technologies: The case of smallholder dairy farmers in Indonesia

Abstract

Extensive efforts have been undertaken to increase the technology adoption rates of smallholder dairy farmers in Indonesia to improve their milk productivity and quality. However, some critical technologies are dis-adopted by farmers and the reasons for dis-adoption are not well understood. Studies have focused on understanding adoption constraints at the farm level, but there has been less discussion of the role of institutions in fostering the continuous adoption of agricultural technologies. This study examines the role of institutions in smallholder dairy farmers' continuous adoption of key dairy technologies. Using a case study of smallholder dairy farmers in West Java Province, Indonesia, this study employs a mixed-method approach, combining quantitative information gained through surveys of dairy farm households and qualitative information from semi-structured interviews with village-level dairy cooperative board members. The main findings are that the current institutional arrangements (or lack thereof) related to the assessment of milk quality and farm input quality and the provision of dairy farm inputs and services are contributing to dis-adoption of some key technologies at the farm-level. The institutional environment in the smallholder dairy value chain has contributed to farmers having fewer incentives to adopt technologies and with farmers having limited access to complementary technology inputs and information, which discourages them from continuously adopting technologies.

Keywords: Dis-adoption, Indonesia, institutions, mixed-methods, smallholder farmers, dairy

4.1 Introduction

Extension efforts, policies and technology dissemination programs actively promote various agricultural technologies to improve farm productivity and incomes, especially to smallholder farmers because they are the world's dominant agricultural producers (Lowder, Skoet & Singh 2014). Technologies are successfully adopted by some farmers when their socioeconomic characteristics and access to essential resources facilitate adoption decisions (Ruzzante, Labarta & Bilton 2021). However, getting farmers to adopt technologies successfully is not a "once and for all" victory of the extension and technology dissemination programs. There is a possibility that farmers will drop the technologies after using them, as shown by the evidence in the field and literature (Chinseu, Dougill & Stringer 2019; Gedikoglu 2020; Lwiza et al. 2017; Razafimahatratra et al. 2021).

The literature has discussed the determinants of technology adoption at length (for a review see e.g., Feder, Just & Zilberman 1985; Liu, Bruins & Heberling 2018; Pannell et al. 2006; Ruzzante, Labarta & Bilton 2021) but less attention has been directed to understanding why farmers dis-adopt the technologies that are expected to improve their incomes and the welfare of their families (Beissinger et al. 2017; Chinseu, Dougill & Stringer 2019). However, the literature on dis-adoption of agricultural technologies by smallholder farmers is growing. Previous studies suggest that the determinants of farmers dis-adoption of technologies are generally similar to those of adoption but typically have the opposite signs (Kanyamuka et al. 2020; Mantey, Mburu & Chumo 2020; Marenya & Barrett 2007; Wakeyo & Gardebroek 2015).[16]

The literature identified the following reasons for dis-adoption: (i) discontinuation of support or assistance from development projects (Pannell & Claassen 2020; Pedzisa et al.

[16] Factors that increase probability of farmers adopting technologies, also decrease the probability of farmers dis-adopting the technologies (Marenya & Barrett 2007).

2015); (ii) the benefits of adoption are not what were originally expected (Chinseu, Dougill & Stringer 2019; Lwiza et al. 2017; Mantey, Mburu & Chumo 2020); (iii) limited access (affordability and availability) to agricultural inputs (Grabowski et al. 2016; Moser & Barrett 2006; Oladele & Adekoya 2006); and (iv) limited knowledge of and insufficiently improved skills by farmers to properly implement the technologies (Chinseu, Dougill & Stringer 2019; Kiptot et al. 2007).

While the findings of previous research are interesting, dis-adoption studies have failed to address the institutional factors that may lead to dis-adoption at the farm level (Chinseu, Stringer & Dougill 2019). Yet, the institutional environment has been shown to be critical to smallholders' success in technology adoption, particularly to compete in modern agricultural and food value chains (Abate et al. 2016; Doss 2006; Gebremedhin, Jaleta & Hoekstra 2009).

This study aims to expand our understanding of the issues faced by smallholder farmers, which lead to dis-adoption of agricultural technologies. Specifically, it seeks to explain why smallholder farmers decide to dis-adopt some dairy technologies that have the potential to improve their productivity by exploring the institutional environment in which they operate, focusing on smallholder dairy farming in West Java, Indonesia. This study uses a new institutional economics lens, using the work of North (1990) and Gabre-Madhin (2009), to develop our conceptual framework. We use this framework to analyse the role of institutions in promoting adoption or discouraging dis-adoption, focusing on the institutions, or links, between smallholder dairy farmers and dairy cooperatives in Indonesia.

This study utilises a mixed-method approach by combining quantitative and qualitative information. Quantitative data were collected from a survey of dairy farm households in dairy producing districts in West Java Province, Indonesia. The qualitative information was obtained from semi-structured interviews with board members from the village dairy cooperative. The data analysis uses information about the perceptions of farmers and cooperative board members to capture the institutional issues at the intermediary and the farm level. This study focuses on four technologies that were frequently dis-adopted by smallholder farmers in the study sample. They comprise two dairy feed technologies: high crude protein concentrates and forage conservation, and two herd-health enhancing technologies (teat dipping after milking and mastitis testing). The adoption of dairy feed technologies aims to improve dairy cows' nutritional intakes, while the health-enhancing technologies aim to prevent mastitis among dairy cows. This can both improve dairy cow productivity and milk quality.

Our findings suggest that dis-adoption of dairy technologies is rooted in the current institutional arrangements regarding the assessment of milk and farm input quality and the provision of dairy farm inputs and services. The poor quality of institutions in smallholders' input and output markets leads to value chain issues such as buyer and seller information asymmetry (related to milk quality and feed quality) and high transaction costs in input markets. Consequently, these issues discourage farmers from continuous technology adoption. This study suggests that the focus of efforts to encourage adoption at the farm level are not sufficient. Instead, reforms to institutional arrangements to guarantee the availability, consistency, and affordability of complementary inputs, and continuous capacity building for farmers, are required to facilitate sustained adoption.

The remainder of this paper is structured as follows. The next section describes the study setting, followed by a section on the conceptual framework, description of the data and the methodology are outlined in sections 4.2, 4.3, 4.4, and 4.5, respectively. Section 4.6 presents the characteristics of technologies analysed in this study. Section 4.7 reports the analysis based on the quantitative and qualitative data, followed by the discussion in section 4.8. Lastly, section 4.9 concludes the study.

4.2 Study setting

The Indonesian dairy farming sector is challenged by its low productivity, despite an emerging market for fresh milk and dairy products in the country. In fact, 77% of Indonesia's fresh milk production is supplied by smallholder dairy farmers with inefficient scale and business operations (USDA 2019). The Government and the private sector advocate the adoption of improved dairy farming technologies and management practices to improve milk yield and quality and thereby increase the incomes of smallholder dairy farmers. Anecdotal evidence suggests that different development agencies, including the government, NGOs, and universities, have introduced and disseminated various types of productivity-enhancing dairy technologies and management practices to smallholder dairy farmers. While some technologies are widely adopted (e.g., using detergents for washing milking equipment, growing improved varieties of grasses, and applying fertilisers to grow grasses), some other technologies are less adopted and are then dis-adopted by farmers after they have used them. However, there is limited understanding of why smallholder dairy farmers dis-adopt the technologies that have potential to improve milk productivity and quality.

Dairy cooperatives play an essential role in the Indonesian smallholder dairy supply chain.[17] Cooperatives collect milk supplied by farmers and distribute it to processing companies. Dairy cooperatives were first established in 1962 in East Java, and were initiated by farmers and supported by the government to improve farm-gate milk prices, milk production, and access to improved dairy cow breeds. The establishment of dairy cooperatives was followed in other regions, such as in West Java, Central Java and Special Region of Yogyakarta between 1969 and 1979 (Nurtini & Muzayyanah 2014). With the on-going development of the dairy industry in Indonesia, dairy cooperatives have served as an

[17] The dairy value chain map in West Java Indonesia is available in the Appendix, Figure A7-1.

institutional innovation to reduce farmers' transaction costs in supplying their milk to processing companies. They give smallholders access to critical dairy farming inputs and services (such as artificial insemination), concentrates, milking/production equipment, herd health, and cow reproduction services, and they provide access to development programs and credit programs (Tawaf, Murti & Saptati 2009). Through the Indonesian Association of Dairy Cooperatives (*GKSI*), the cooperatives also played the role of conveying the goals of farmers to the government regarding the development of dairy cattle agribusinesses (Tawaf, Murti & Saptati 2009).

4.3 Conceptual framework

Smallholder farmers adopt agricultural technologies to maximise their expected benefits given their various agricultural production constraints. Farmers adopt technologies with the hope that these will improve their welfare by improving farm production and/or product quality, increasing farm incomes, and/or reducing production costs. However, smallholder farmers face different constraints to adoption at the individual, farm, market, and institutional levels. These constraints reduce farmers' access to capital and information, lowering their probability of adopting technologies with capital[18] or knowledge-intensive[19] properties. The literature on technology adoption discusses individual and farm-level constraints to adoption at length (Feder, Just & Zilberman 1985; Liu, Bruins & Heberling 2018; Pannell et al. 2006). However, less attention has been paid to understanding institutional and market-level failures as causes of non-adoption or dis-adoption. For example, initial subsidies accompanying

[18] Adoption of knowledge or information-intensive technologies (or soft technologies) requires precise implementation, and expects farmers to have high exposure to information sources, improved skills and abilities to implement the technologies (Barnes et al. 2019; Kathage et al. 2016; Wheeler et al. 2017)
[19] Adoption of capital-intensive technologies requires farmers to purchase external inputs or equipment and the highest single cost to implement them are capital costs, rather than management costs as is the case with knowledge-intensive technologies (El-Osta & Morehart 1999; Lydia 1990).

adoption are offered, but then fall away after a period of time, disincentivising late-adopters or encouraging technology dis-adoption by early adopters (Duflo, Kremer & Robinson 2011).

This study is based on the conceptual framework of institutions which are defined as the "rules of the game" by North (1990). Institutions govern the relations between actors (or players of the game) in a value chain for market exchange, including formal and informal contracts, trading practices, codes of conduct, social norms, formal and informal laws, and regulations (Gabre-Madhin 2009). Institutions are designed to reduce transaction costs and correct market failures (De Janvry & Sadoulet 2016).

Building on the work of Gabre-Madhin (2009) on market institutions, which describes the institutions between actors in the value chain from producers/firms to consumers, the environment enabling technology adoption conceptualised in this study is also administered by institutions linking actors to facilitate smallholder farmers adopting agricultural technologies. In this case, the enabling environment for adoption includes three main actors: the state, intermediary organisation, and the farmer (Figure 4.1). A recent study by Chinseu, Stringer and Dougill (2019) also depicts a conceptual framework of the drivers of the dis-adoption of agricultural conservation practices in Malawi at three different levels: higher; intermediary; and lower levels. The state plays the role of developing new technologies and improved practices that can help farmers improve their farm's performance (A, as depicted in Figure 4.1).

In developing countries, where market institutions may typically be less advanced, governments use intermediate organisations, such as farmers' cooperatives or farmers' organisations, to "correct" the market failures that can impede technology adoption. Specifically, an intermediary plays the role of facilitating farmers' adoption of agricultural technologies through extension programs (knowledge and/or technology transfer), financial assistance, and/or the provision of technology inputs (e.g., new chemical products) (B in Figure in 4.1). The intermediary-level could also be composed of buyers of farmers' products. In most cases, cooperatives help farmers market their products by purchasing products from farmers and aggregating them to sell to traders or private companies.

Different institutions govern the relations between actors in the environment to facilitate adoption of technologies at the farm level. The state and intermediary levels are governed by institutions that include production standard regulations, agricultural policies (e.g., subsidies), agricultural credit provision, and policies aimed at developing, adapting, and disseminating technologies (C in Figure 4.1). On the other hand, relationships between the intermediary and farm levels may also be governed by institutions such as goods and services exchanges practices (product selling and input buying practices) and regulatory and extension program approaches (D in Figure 4.1).

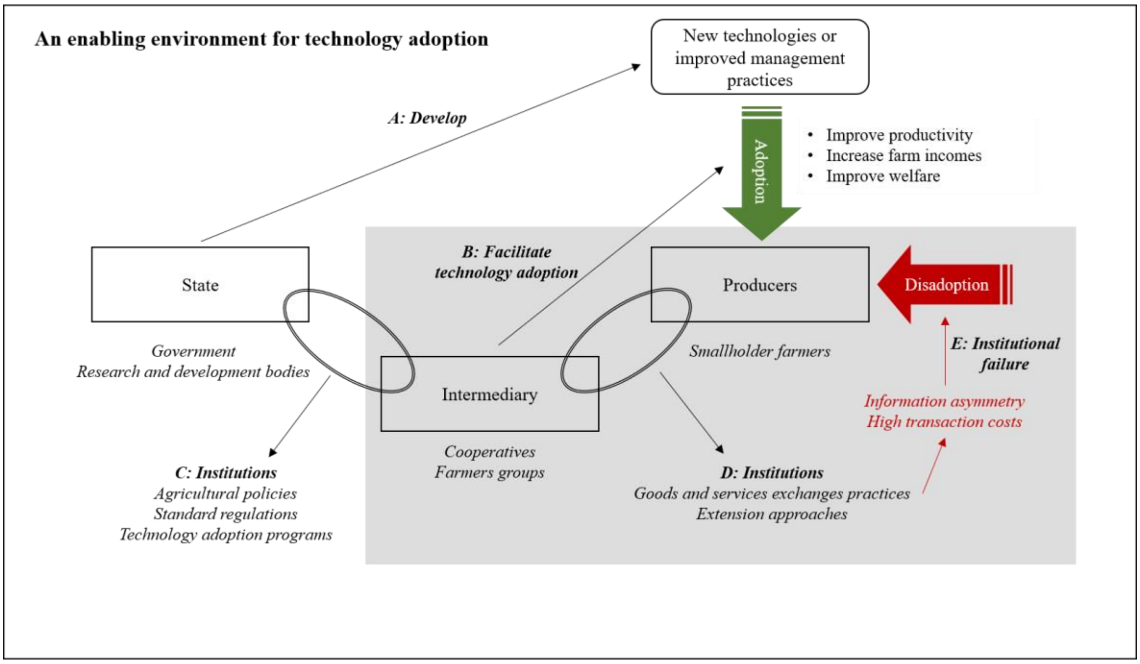

Figure 4.1 Conceptual framework for the dis-adoption of agricultural technologies

The adoption of technologies by smallholder farmers will generally be successful if the institutions shown in Figure 4.1. that connect all of the actors in the relevant context work properly. However, many institutions fail to provide the environment necessary to enable farmers to adopt technologies. Institutional failures could arise between the state and intermediary levels or between the intermediary and farm level. This study focuses on the latter, by discussing institutional failures between the intermediary and farm levels, leading farmers to dis-adopt agricultural technologies (the shaded area in Figure 4.1).

Related to the discussion above, the broader economic literature informs us about institutional failures, which lead to information asymmetry and high transaction costs, and can discourage continuous adoption (dis-adoption) of farm technologies (E in Figure 4.1). Information asymmetry is one type of market failure where one party has better access to information, or has more complete information, than the other party involved in a transaction or exchange. The presence of asymmetric information between the intermediary and farmer levels suggests that the institutions that govern both parties are not working correctly. This asymmetric information can create a disincentive for parties to improve their actions; for example, asymmetric information between buyers and producers (farmers) about product quality could provide fewer incentives for farmers to improve their farming practices through technology adoption (de Janvry, Sadoulet & Trachtman 2019).

High transaction costs in the exchange of goods and services between an intermediary and a farmer may also indicate that institutions, at single or multiple levels, are not working properly. Farmers' poor access to key assets, such as information and physical assets, such as infrastructure, have an impact on transaction costs (De Janvry & Sadoulet 2016; Gabre-Madhin 2009). For example, high transaction costs for farmers in accessing technology inputs, due to poorly developed infrastructure, such as roads, transportation, and long distances to input markets, could increase the overall cost of using the technologies, reducing profitability from their adoption (Kebebe 2019; Minten, Koru & Stifel 2013; Suri 2011). Asymmetric information about product grades and standards may increase transactions costs for producers related to compliance (e.g., search costs for information to comply with the standard) and increase monitoring costs for buyers to ensure producers are meeting standards.

In such cases, the institution of extension programs, which disseminate technologies to farmers, by intermediaries, can be ineffective, hampering farmers' access to information. Extension programs in developing countries commonly have characteristics, such as top-down approaches, which fail to account for the heterogeneity of farmers' characteristics, needs, and constraints and the specific characteristics of the technologies (Birner et al. 2009; Hammond et al. 2020; Norton & Alwang 2020; World Bank 1994). Further, the approach of targeting likely adopters who are resource-endowed (Diagne 2006; Haug 1999; Muneer 2014) means that more poorly endowed farmers have less access to information. In addition, infrastructure bottlenecks, such as the limited number of extension staff, in tandem with poor rural infrastructure, also hinder extension staff from visiting farmers located in dispersed locations (Amede et al. 2017; Baig & Aldosari 2013). These infrastructure bottlenecks could increase transaction costs for extension staff in delivering extension services to farmers and for farmers in accessing that information as well as the critical technologies and complementary inputs.

4.4 Data

This study utilised a combination of quantitative and qualitative data to address the research questions: what are the main reasons farmers dis-adopt some dairy technologies that have the potential to improve milk production? How do prevailing institutional arrangements prevent continuous adoption of agricultural technologies?

The data captures information about the perceptions of farmers and cooperative board members to understand the institutional issues at the intermediary and the farm level. The quantitative data involved a farm household survey conducted with 600 dairy farm households in four dairy-producing districts in West Java, Indonesia. A purposive proportional random sampling method was utilised to identify the sample. As most smallholder dairy farmers in Indonesia are members of dairy cooperatives (Statistics Indonesia 2015), the households in the study sample are dairy cooperative members.[20] A detailed structured questionnaire was developed in a mobile-based application, CommCare version 2.36.1 (Dimagi, Cambridge, MA), compiling cross-sectional information, such as farmers' socioeconomic and household statuses, dairy farm production characteristics, and decision-making processes about adopting multiple technologies.

Specific questions were asked to collect information for this study (Table 4.1). Farmers indicated which technologies they have used (Question A) and technologies they have dis-adopted (Question B). Farmers who have used the technologies were further asked from whom they learnt about the technologies (Question C), the type of assistance they received to adopt the technologies (Question D) and who provided the assistance (Question E). Lastly, farmers were asked about their reasons for dis-adoption of the technologies if they indicated they dis-adopted the technologies (Question F).

The qualitative data involved semi-structured interviews with the dairy cooperative board members, conducted between December 2017 and January 2018. Dairy cooperatives involved in the interviews were the cooperatives whose members participated in the household survey. Nine cooperative leaders and board secretaries drawn from five cooperatives, were involved in the interviews. The interviews were recorded and guided by an interview instrument (available in Appendix 4 of the thesis) designed to focus on the themes of the provision of inputs and services to cooperative members, issues at the farm and cooperative levels, and challenges in technology adoption by dairy farmers.

[20] More detailed information on the sampling technique is provided in the Appendix 7.

Table 4.1 Questions in the household survey to collect information for this study

Codes	Questions	Responses	
A	Have you used/done [technology]?	YES/NO	
B	*If the response for Question A is YES,* Are you still using/doing [technology] now?	YES/NO *Farmers responded NO in this question are categorised as discontinuous adopters of the [technology]*	
C	Who introduced [technology] for the first time?	*Choose one of the options:* • Dairy cooperatives • Other dairy farmers • Local government staff • Non-dairy farmer neighbour • Milk trader • Veterinary doctor • Village leader • University	 • Media (newspaper, TV, radio) • Internet • Input seller • NGO • Farmers groups • Family members • Self-observation • Others
D	What type of assistance or help have you received to adopt [technology]?	*Choose a maximum of two from the options below:* • Information (flyer, books, advise) • Training/seminar/workshop • Physical inputs	 • Credit access • Nothing
E	Who provided the support to adopt [technology]	Choose one of the options in Question C	
F	What are the two main reasons you stopped using/adopting [technology]?	*Choose a maximum of two from the options below:* • Lack of information • High costs • Too complicated • Satisfied with the current practice • Limited availability of inputs • Excessive labour requirements • Milk yields lower than expected • Benefits too far in the future • Other farmers recommend stopping	 • Lack of government support • Price paid for the milk is too low • Too much risk involved • The existing practice is better • Unsuitable for the local area conditions • No further assistance • Others

4.5 Methods

The quantitative data are presented descriptively to summarise responses to the questions outlined in Table 4.1. To put dis-adoption into context, percentages[21] are compared between continuous adopters and discontinuous adopters using t-tests for the agents or people who introduced the technology to farmers, the assistance farmers received, and who provided the assistance to adopt each of the technologies. Analysis of the differences between continuous adopters and discontinuous adopters was also conducted using t-tests for each of the technologies with respect to their socioeconomic and dairy farm characteristics and their access

[21] Percentages or ratios are the frequency of responses divided by the number discontinuous adopters or continuous adopters.

to institutional services. Logistic regression models were also employed to explore the determinants of dis-adoption for each of the technologies. The aim of including this analysis was to observe whether the determinants of dis-adoption are similar to the determinants of adoption, but with the opposing signs that were found in the literature. When considering the reasons for the dis-adoption of technologies, percentages were compared to explore common themes and patterns from the discontinuous adopters' responses to understand issues underpinning the dis-adoption of technologies.

For the qualitative data, the audio recordings of the semi-structured interviews were transcribed and translated from Bahasa Indonesia into English. The transcription was analysed through categorisation to explore common themes raised in the interviews, following Morris, Henley and Dowell (2017) and Tobin, Glenna and Devaux (2016). From the identified themes, we picked out patterns exhibited across the interviews. Verbatim quotes were used to support and complement the key findings from the quantitative analysis, enriching discussion on the external issues that discourage continuous adoption by smallholder dairy farmers.

4.6 Dairy technologies and characteristics of technologies

This section outlines the characteristics of technologies frequently dis-adopted by farmers in the sample, including forage conservation, high protein concentrates, teat dipping after milking, and mastitis testing (Table 4.2). From these technologies, 36.5% (219 out of 600) of farmers dis-adopted at least one technology, and 29.8% (179 out of 600 farmers) continued the adoption of at least one technology. The information presented in the quantitative results is based on the responses from the subsample of continuous adopters and discontinuous adopters. Agricultural science literature, especially on tropical livestock production, helps in understanding the characteristics of each of the technologies (Table 4.3). The complete explanation of the characteristics of technologies is available in Appendix 7.

Table 4.2 Dis-adoption rates of dairy technologies

Technologies	Number of farmers that have used (a)	Number of farmers that dis-adopted (b)	Percentage of farmers dis-adopted (c = b/a*100)
Forage conservation	75	67	89%
High protein concentrates	118	70	59%
Teat dipping after milking	214	99	46%
Mastitis testing	121	51	42%

Table 4.3 Characteristics of technologies

Technologies	Characteristics
Forage conservation	The implementation requires complementary inputs and intensive knowledge
High protein concentrates	It is more expensive than standard concentrates with less than 13% protein content. Its implementation is knowledge intensive
Teat dipping after milking	The implementation requires complementary inputs, but its implementation is considered simple and easy
Mastitis testing	The implementation requires complementary inputs and intensive knowledge

4.7 Results

4.7.1 Quantitative analysis results

Who introduced the technology?

Farmers were asked who first introduced each technology to them. Their response to this question suggested that dairy cooperatives played a dominant role in introducing the technologies to farmers (Table 4.4). The government also played an important role in introducing forage conservation to farmers, and veterinarians also were important in introducing mastitis testing to smallholder farmers.

Table 4.4 Agents/people who initially introduced the technologies to discontinuous adopters (%)

Technologies	Cooperative	Dairy farmer	Local government	Veterinarian	University
Forage conservation	34.33	4.48	13.43	0.00	39.22
High protein concentrates	52.86	4.29	5.71	0.00	1.96
Teat dipping after milking	61.62	0.00	4.04	4.04	0.00
Mastitis testing	39.22	1.96	1.96	19.61	0.00

This table only presents information for discontinuous adopters because there are no significant differences between continuous adopters and discontinuous adopters for most of the options. Table including figures for continuous adopters is available in the Appendix (Table A7-3).

Assistance received to adopt technologies

The typical assistance received by farmers in adopting technologies is seminars or training (Table 4.5) and this was provided mainly by the cooperatives (Table 4.6). Physical input is also the typical assistance received by farmers in adopting teat dipping after milking, and mastitis testing. It is interesting to observe that a significantly higher proportion of continuous adopters than discontinuous adopters received training on how to use high protein concentrates, teat dipping, and mastitis testing and credit assistance for the adoption of high protein concentrates. On the other hand, a significantly higher proportion of discontinuous adopters than continuous adopters received information (e.g., flyer, book, advise) and physical inputs to implement forage conservation and high protein concentrates, respectively.

Table 4.5 Types of assistance received by continuous and discontinuous adopters (%)

Assistance received	**Forage conservation**			**High protein concentrates**		
	Continuous adopters	Discontinuous adopters	Sig.	Continuous adopters	Discontinuous adopters	Sig.
n	8	67		48	70	
Information	0.00	28.36	*	8.33	5.71	
Seminar/Training	50.00	44.78		64.58	44.92	**
Physical inputs	0.00	14.94		12.50	30.00	**
Credit access	0.00	0.00		10.42	2.86	*
Assistance received	**Teat dipping after milking**			**Mastitis testing**		
	Continuous adopters	Discontinuous adopters	Sig.	Continuous adopters	Discontinuous adopters	Sig.
n	99	115		70	51	
Information	19.13	11.11		14.29	9.80	
Seminar/Training	70.43	40.40	***	64.29	43.14	**
Physical inputs	70.43	77.78		54.29	43.14	
Credit access	3.48	5.05		0.00	0.00	

Sig. = Significance level from t-tests; * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ indicate significance at the 10%, 5% and 1% levels respectively.

Table 4.6 Who provided the assistance to discontinuous adopters (%)

Technologies	Cooperative	Dairy farmer	Non-dairy farmer neighbour	Veterinarian	University
Forage conservation	29.85	5.97	10.45	0.00	5.97
High protein concentrates	30.00	5.71	5.71	0.00	1.43
Teat dipping after milking	61.62	0.00	4.04	4.04	0.00
Mastitis testing	35.29	1.96	1.96	19.61	0.00

This table only presents information for discontinuous adopters because there are no significant differences were found between continuous adopters and discontinuous adopters for most of the options. Table including figures for continuous adopters is available in the Appendix (Table A7-4).

Comparison of the characteristics of continuous adopters and discontinuous adopters

We compared the characteristics of continuous adopters and discontinuous adopters (Table A7-5 and A7-6 in the Appendix). In general, discontinuous adopters have fewer physical assets (non-production and production assets) and human assets (family members and hired labour) than continuous adopters. With respect to institutional variables, discontinuous adopters live further away from dairy cooperative offices (meaning more travel time), have a fewer number of contacts with the cooperative extension staff and are less likely to receive assistance to adopt technologies compared to continuous adopters. These results are consistent with the literature on dis-adoption, which suggests farmers with fewer assets and who are less engaged with extension activities or programs are more likely to dis-adopt technologies (Kanyamuka et al. 2020; Marenya & Barrett 2007; Wendland & Sills 2008). Table A7-7 in the Appendix also presents the determinants of dis-adoption of each technology calculated using logistic regressions.

4.7.2 Qualitative analysis results

There are five common themes arising from the semi-structured interviews: input and service provision by cooperatives, farm-level issues; cooperative level issues; the adoption behaviour of farmers; and support from milk processing companies as buyers of milk from smallholder farmers (Table 4.7).

Table 4.7 Identified themes and patterns from the semi-structured interviews

Identified themes	Identified patterns
Input and services provision by dairy cooperatives	Dairy cooperatives supply most general dairy farming inputs, including feed concentrates, medicine, vitamins, milking equipment (e.g., milk cans, filters, and rubber floors for cow barns). The cooperatives also provide different services, including artificial insemination, extension services and technology dissemination, herd health, and credit supports. Farmers do not have to pay for the inputs upfront, payments will be deducted from farmers' milk payment, received fortnightly or monthly.
Farm-level issues	The main issue at the farm level is the low level of cow ownership by farmers. Most farmers manage less than five cows, with an average of 2-3 cows per farm. Low milk quality is also an issue. Many farmers are still not adopting practices to improve milk hygiene. The capacity of farmers is still low, causing sub-optimal management of dairy farms (e.g., feed management, herd health care, business management).
Adoption behaviour of farmers	Dairy cooperatives deliver extension programs which also include introducing improved technologies and practices to farmers. However, the adoption of technologies by smallholder farmers remains low. Participants reported some reasons for this, including no attractive reward (incentives), and farmers favouring traditional practices over innovation.
Dairy cooperative level issues	Dairy cooperatives are constrained by a limited supply of milk from dairy farmers, which does not balance with the handling costs of the cooperative. This is related to the low level of cow ownership by farmers. The dairy cow population decreased due to increased beef prices in 2012, tempting farmers to sell their dairy cows. Another issue is the distant location of farmers and poor road infrastructure, which increases milk collection costs and impedes cooperatives' access to farmers for extension services. The distant location of farmers also reduces the quality of milk collected by cooperatives. Dairy cooperatives also have an issue with their limited numbers of extension staff, where the ratio of active farmers to extension worker is high. Some cooperatives do not even have staff dedicated to delivering extension activities; they ended up being delivered by the veterinary team and/or the cooperative board members. Most of the cooperatives do not have the capacity and infrastructure to individually test farm's milk quality. As a result, milk prices at the farm level are determined based on the aggregate or average quality of farmers in the same or similar groups. One exception is a cooperative that has upgraded some of their milk collection points (MCPs) to be able to do individual milk quality testing. However, the MCPs are still not able to serve all members of the cooperative.

Table 4.7 (Continued) Identified themes and patterns from the semi-structured interviews

Identified themes	Identified patterns
Milk processing companies support and milk pricing systems	Milk processing companies provide support to cooperatives and dairy farmers, mainly to assist in improving milk quality. Some companies directly target the farmers by visiting farms and providing direct extension services to farmers. Other companies provide technical extension at the cooperative level, such as milk quality control and extension for the cooperative staff, expecting the staff will share their knowledge with farmers. Milk processing companies determine the milk price based on the quality of milk delivered by the cooperatives.

4.7.3 Challenges encountered leading to dis-adoption of dairy technologies

In this section, we elaborate on the challenges faced by farmers in continuing to adopt forage conservation, high protein concentrates, teat dipping after milking, and mastitis tests. We complement the analysis of farmers' perspectives with cooperative board members' interview responses. This combined analysis provides information from the perspectives of the farmers and the intermediary institution, in this case, the cooperative. The five main reasons expressed by farmers who dis-adopting each of the technologies are presented in Figure 4.2. The complete list of farmers' reasons for dis-adoption of technologies is available in the Appendix (Table A7-8 to A7-11).

Challenges with forage conservation

Farmers mentioned various reasons for the dis-adoption of forage conservation. Limited availability of inputs, too complicated, and satisfaction with the current practice were the main inhibiting factors expressed by them. The response "limited availability of inputs" may be related to the inability of farmers to find the equipment and complementary materials required, such as inoculants, to conserve forages. As this practice is knowledge-intensive, it is not surprising that farmers considered it too complicated. Farmers explained that they did not implement the practice because they had adequate access to forages (i.e., satisfied with their current practices), therefore, they felt that they did not have a need to conserve forages for the dry season.

One of the participants from the semi-structured interviews provided interesting insight reporting that farmers did not continue adopting forage conservation because they could not afford to buy a forage chopper:

> *"We have given farmers equipment to make silage, but after it gets damaged they stop using it. Actually, for silage making, they do not need expensive tools, for example, the forage chopper machine. It could be done using a simple tool such as sickle to chop the forages. It was because they see the demonstration used forage chopper machine, and they constrained with the machine because they have to buy it, and it is expensive. Therefore, even though now I keep communicating to make silage, it would be difficult for them"* (Participant 6, Cooperative 4).

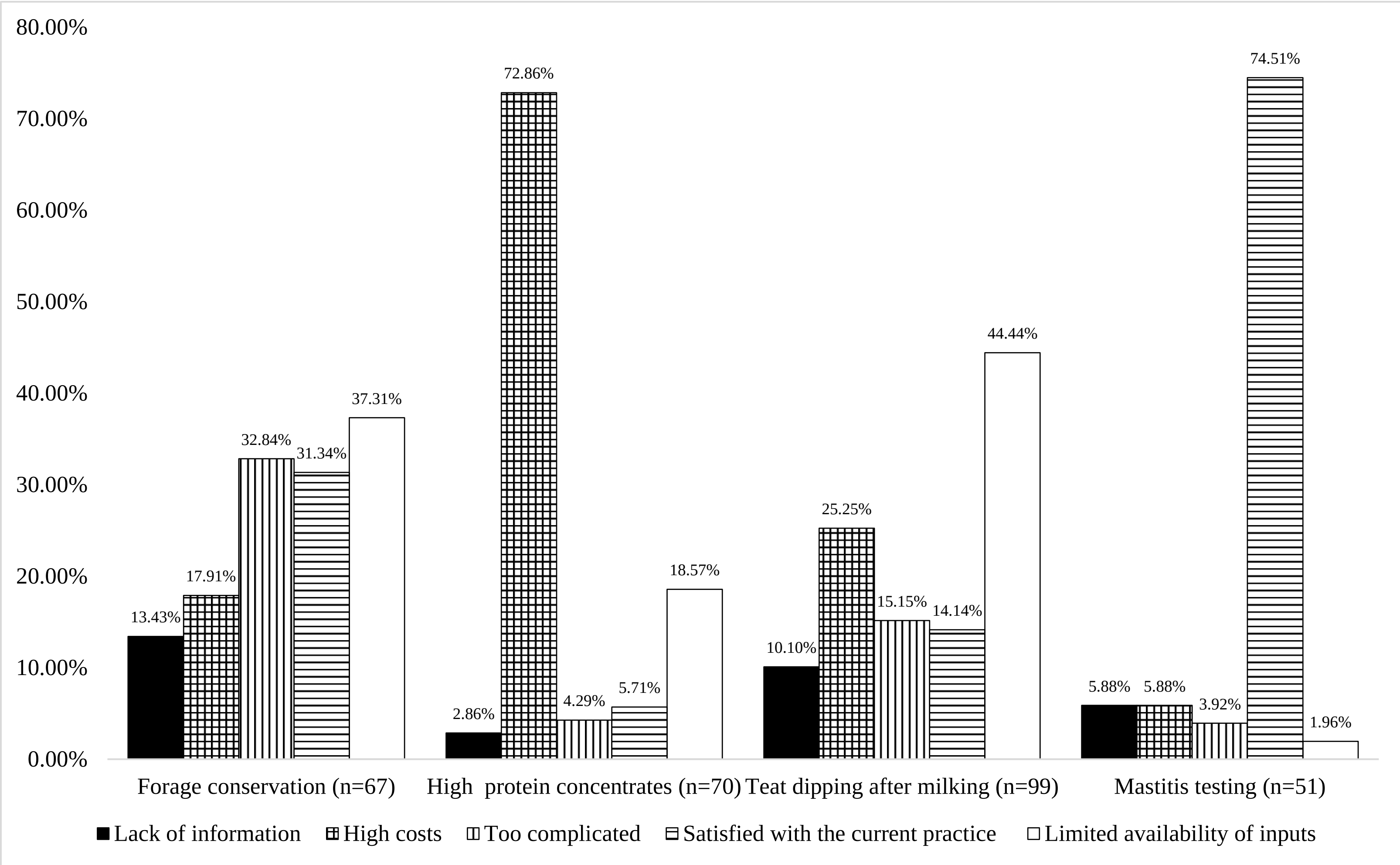

Figure 4.2 Main reasons for dis-adoption of dairy technologies

Numbers in the parentheses are total discontinuous adopters

Challenges with high protein concentrates

The main reason for farmers dis-adopting high protein concentrates was the high cost of adoption. The semi-structured interviews revealed that although high protein concentrates are more expensive, their use will generate higher profit margins than standard concentrates.

> *"We offer two [concentrate] choices [the standard and high protein concentrates]. The good quality one is not adopted by farmers, even though it has a positive impact on the quality and price of milk. They [farmers] are just not sure, although we have tested it. A testimony from farmers who have used [high protein concentrates] saying that the result is good. Even with the price of IDR 3,900 per kg [high protein concentrates] ... it has increased profits. It looks like it is expensive, but if farmers used [concentrates] with price IDR 3,900 per kg, the amount given to the dairy cows will not be as much as [concentrates] with price IDR 2,600 per kg [the standard concentrates]"* (Participant 6, Cooperative 4).

Most cooperatives use their feed mill to produce, or to mix, the concentrates using raw materials purchased from feed suppliers. The semi-structured interviews identified some issues faced by the cooperatives, particularly centred on high transactional costs in producing quality concentrates. These include increasing prices, decreasing quality, and continuity of supply of raw materials, resulting in high protein concentrates being costly for farmers. As one respondent said,

> "*On the one hand, we have to make concentrates with adequate protein content for the needs of cows. On the other hand, the price is high, and it is not affordable for farmers. The problem is the price of raw materials continue to increase"* (Participant 3, Cooperative 3).

Additionally, the quality of raw materials is decreasing*:*

> *"In the past, we produced a lot of concentrates [high protein concentrates]. We bought the [raw] materials from outside [suppliers], but there were many obstacles. First, shrinkage and second, the quality of the materials was originally good, but it is bad after that"* (Participant 5, Cooperative 3).

Another issue is the continuity of the raw materials from cooperatives' suppliers:

> *"The supply of raw materials is not always available all the time, and we have not yet entered into contracts with suppliers. For wheat pollard [material with high protein content], we have a quota from the supplier [not through written contract]. For example, we get a quota of 90 tons a month, and we have paid it to the supplier. Because of the high demand, the price has also increased a lot, and we only get 20 tons"* (Participant 6, Cooperative 4).

Besides the high cost of adoption, the limited availability of high protein concentrates hinders farmers from using this technology. Farmers must buy high protein concentrates directly from the manufacturers because cooperatives only supply the standard concentrate. For example, one participant explained:

> *"We let farmers decide which concentrates they want to use. If the farmers want to use concentrates with better quality, they need to buy it by themselves [from manufacturers]"* (Participant 2, Cooperative 2).

Challenges with teat dipping after milking and mastitis testing

Teat dipping after milking and mastitis tests aim to improve the hygiene of dairy cows' teats and udders, reducing the probability of them developing mastitis. The main issue faced by farmers who dis-adopted teat dipping is that they could not get the complementary inputs; that is, the disinfectant solution. Another common reason farmers dis-adopted mastitis tests is that they are satisfied with their current practice. Farmers said that they do not have to do mastitis tests because the cows seem to be healthy and therefore do not need to be tested.

4.8 Discussion

The results suggest that farmers discontinue the dairy technologies for a mix of reasons. For example, farmers discontinued the adoption of forage conservation and teat dipping after milking due to limited availability of inputs; high protein concentrates were dis-adopted mainly because of high costs; and mastitis testing was discontinued mainly due to farmers were satisfied with their current practices. Responses from members of the cooperative boards identified that farmers lacked adequate knowledge about the technologies and their benefits. Also, the lack of price incentives for improved milk quality was a barrier that caused farmers to discontinue adoption of technologies.

The results provide insights into how the current institutional arrangements (or lack thereof) governing the relationship between farmers and intermediary actors have resulted in dis-adoption. This primarily includes the institutions shaping practices related to exchanging goods and services between the players (D in Figure 4.1), including the assessment of milk quality and farm input quality and the provision of dairy farm inputs and services (extension programs). These institutional failures are discussed through the lenses of asymmetric information and/or issues associated with transaction costs. Further, links are established between the institutional issues and the main reasons farmers mentioned for their dis-adoption of technologies.

4.8.1 Institutional arrangements for milk and farm input quality assessment

One important incentive for smallholder farmers that cooperatives may offer to trigger technology adoption at the farm level is to incentivise the milk price based on individual milk quality (Saenger, Torero & Qaim 2014). However, the current arrangement in milk quality assessment is suffered from asymmetric information. Milk supplied by farmers is pooled into one tank at the milk collection points organised by dairy cooperatives, and this combines good quality milk with poor quality milk from farmers from the same group. Farmers receive milk prices based on the average quality of the aggregated milk supplied by farmers in their group. One cooperative even implements a flat-price system for members, meaning farmers are less willing to improve the quality of their milk. The high cost of monitoring (a transaction cost) each farmer’s activities could explain the absence of the procedures to individually assess milk quality.

A recent study by Treurniet (2021) of one of the dairy cooperatives in Indonesia highlights the positive impact of public private partnerships (PPP) in improving milk quality through individual price incentives. The cooperative was supported to upgrade some of their milk collection points to be able to do individual quality testing, and farmers were given physical inputs and training to improve milk hygiene. However, as the provision of physical inputs and training by the intervention diminished, the milk quality also decreased. This points to the need for continuous monitoring to maintain farmers’ behaviours. However, ongoing monitoring will be costly.

Another underlying issue is information asymmetry in that milk quality of farmers is measured by the buyers (the milk processing companies), it means that knowledge of the milk quality is observable to buyers but not to the sellers (cooperatives/farmers). In Indonesia, there is no independent body that is trusted to measure the milk quality. This situation has the potential to keep the price of milk paid to farmers/cooperatives low by possibly underestimating the quality of milk and discouraging farmers from adopting technologies and practices that lead to improved milk quality (Saenger, Torero & Qaim 2014; Treurniet 2021). An experimental study by Saenger, Torero and Qaim (2014) tested the impact of the provision of third-party assessment on the quality of milk quality produced by dairy farmers in Vietnam as a way of alleviating asymmetric information by verifying the milk testing results provided by the milk buyers. The experiment found that the provision of independent quality assessment increased farmers' use of quality inputs (purchased concentrates), which translated into higher milk quality and revenue.

Asymmetric information is also found in relation to the quality of inputs supplied to farmers, especially high protein concentrates. This issue was explored by the project team in a nutrition study that found the concentrates used by farmers were labelled as 16% crude protein content on the package. However, laboratory tests found that the actual quality was only around 14% protein (Puastuti et al. 2021). As with the milk quality assessment (explained above), there is no independent body that tests the quality of agricultural inputs in Indonesia. Poor or highly variable quality inputs disincentivise farmers to use the inputs, because the results of the adoption will not bring the promised benefits (e.g., high productivity or profitability) (Ashour et al. 2017).

Asymmetric information problems with milk quality and the value of improved milk quality to processors lead to farmers not having clear incentives to adopt technologies; this helps to explain why the adoption rate of technologies is low (Ullah et al. 2020). Consequently, low adoption rates provide fewer incentives for the cooperatives and other agricultural input providers to supply the inputs due to the thin market for these technologies. This is comparable with the case of low farmer demand for hybrid seed varieties due to their subsistence orientation, which is not an attractive business proposition for input suppliers to supply improved seed varieties (Mutambara 2016). This phenomenon is a plausible explanation for the shortage of supply of complementary inputs, which constrains farmers from continuing to adopt technologies such as teat dipping, high protein concentrates, and forage conservation.

4.8.2 Provision of dairy farm inputs and services institutional arrangements

Supply of high protein concentrates

Dairy farmers depend heavily on their cooperative for farm input supplies. This is because there are few other inputs suppliers located near their farms. Cooperatives aim to reduce farmers' transactions costs in accessing essential dairy farm inputs by allowing them to purchase the inputs without paying for them upfront (or "pay later"). Payment is deducted from the fortnightly, or monthly milk payment farmers receive from their cooperative. The cooperatives also provide inputs in smaller quantities, meaning that farmers do not have to buy in bulk. If the cooperatives do not have an adequate supply of the inputs, farmers need to find alternative suppliers to get their required inputs. For example, as explained (in the previous section) by a participant in the semi-structured interviews, farmers need to buy high protein concentrates directly from the manufacturers because the cooperative does not supply higher protein versions. Having to source this input on their own could increase farmers' transaction costs (e.g., search and transportation costs) in acquiring the input, which could reduce the potential benefits of using the technology (Kebebe 2019). The transaction costs may be even higher because farmers may not get the "pay later" option as they would have if they had purchased the inputs from the cooperatives. The manufacturers also do not allow farmers to buy the concentrates in smaller quantities.

The high production costs of cooperatives in mixing or producing concentrates is another factor adding to the high adoption costs of high-quality concentrates by farmers. Information from the qualitative analysis sheds light on the high prices of raw materials used to produce high protein concentrates, increasing the costs of producing concentrates for the cooperatives. As a result, the cooperatives charge higher prices for the concentrates to recover their production costs and compensate for all the variability they face in the input markets for the raw materials. As a consequence, adopting high protein concentrates is not an affordable technology for farmers. The high price of raw materials was also linked to the high demand for these materials, because the poultry industry also uses them.

Extension approaches and technology dissemination programs

Agricultural extension programs are designed to facilitate knowledge and information transfer about technology to farmers (Anderson & Feder 2007). Farmers' perceptions about the complexity of technology implementation and their satisfaction with their current practices have led to dis-adoption of technologies. This may reflect farmers lacking the level of skills needed to implement them. For example, while the typical assistance received by farmers to adopt technologies is training, fewer discontinuous adopters than continuous adopters received training to adopt technologies that are characterised by their knowledge intensiveness.

Farmers dis-adopted the practice of mastitis tests because they are satisfied with their current practices, suggesting a lack of understanding about the benefits of regularly implementing the practice to prevent cows from developing mastitis. Veterinary technologies, like mastitis tests, are only adopted by farmers when problems are visible (Nell & Schwalbach 2002), suggesting that farmers are more likely to treat diseases instead of taking preventive action. In fact, most of the mastitis cases in Asia and Sub-Saharan Africa are subclinical mastitis, which is not visible to farmers (FAO 2014).

The adoption of high protein concentrates is also knowledge-intensive; to increase adoption of this technology, farmers need to know the right proportion of concentrates to the forages and timing of use during the lactation period in which to balance concentrates with feed sources (Moran 2005). The high cost of adoption perceived by farmers may be related to the provision of incorrect quantities of concentrates to cows and at the wrong time during the lactation period. This may be related to the lack of farmers' knowledge in implementing the technology.

It could be argued that the high cost of adoption of concentrates is not about whether farmers have access to credit, because the cooperatives have credit programs for farmers. The cooperatives also provide “pay later” option for farmers, as discussed above. The most plausible explanation for the dis-adoption of high protein concentrates is related to the inability of farmers to translate the adoption into profitability. In other words, the adoption of high protein concentrates is likely perceived as income loss by farmers. This is in line with Foster and Rosenzweig (2010), who suggest that the adoption of technologies depends only on the net return if all farmers are not constrained with access to credit.

The ineffective institutional arrangements in the extension programs that lead to farmers having limited access to information are related to the high transaction costs for the cooperatives in providing their services to dairy farmers. This would be related to the size of the cooperatives measured by the number of active members they serve and the availability of extension staff which could determine the effectiveness of the knowledge transfer programs. The average ratio of extension staff to the number of farmers that needs to be served is 1:160 farmers. The biggest cooperative in this study serves 3,500 active members with only ten extension staff, suggesting the ratio is 1:350 farmers. Some cooperatives do not even have specific extensions staff, and the extension activities are delivered by veterinary staff and/or the cooperative boards. The ratio may not be enough to cover all the complexity in the dairy farming system. This issue is compounded by the fact that most farmers have low educational attainment, and still adhere to conventional farming practices. Furthermore, the dispersed locations of farmers, who have less developed infrastructure, challenges the extension staff in reaching farmers and providing extension services, increasing the transaction costs in delivering extension.

This may justify the standard extension approaches taken, targeting the likely adopters who have the characteristics that can facilitate adoption, such as higher education, greater wealth, and closer proximity to the primary source of information (Haug 1999; Muneer 2014; Takam-Fongang, Kamdem & Kane 2019). This is in line with previous studies in Indonesia suggesting that dairy extension programs are usually targeted at cooperative board members and farm group leaders (Mulatmi et al. 2016; Roessali, Eddy & Marzuki 2013). The ineffectiveness of the extension system explained above is also common in other developing countries, where the extension is perceived to be under-resourced, costly, overloaded, and often complicated due to bureaucratic processes (Mapiye et al. 2021).

4.9 Conclusions

The results of farmers' reasons for discontinuous adoption of key technologies suggest that the current institutional arrangements in the smallholder dairy value chain fail to provide an enabling environment for sustained technology adoption. Similar to other studies in the literature, our research suggests that institutions have a critical role in promoting sustainable and long-term adoption of agricultural technologies (Chinseu, Stringer & Dougill 2019; Kebebe 2019; Makate 2020; Schut et al. 2016). The role of institutional arrangements in this case study of smallholder Indonesian dairy farmers has shed light on important issues beyond the farm gate. These include institutional arrangements for the assessment of output quality, sustained provision of dairy farm inputs and extension services.

Interventions that focus on addressing adoption constraints at the farm level are not enough to incentivise continuous adoption. However, dairy cooperatives as the intermediary institutions are unlikely to be able to overcome institutional barriers on their own. Adequate milk quality standards and its effective enforcement to reduce information asymmetry, investments in infrastructure to reduce transaction costs in input markets, building the capacity of extension workers with up-to-date information, and the design and implementation of effective dissemination programs are all beyond what cooperatives can do by themselves. Therefore, it is imperative to enhance value chain collaboration for effective technology transfer by inviting milk processing companies to be involved in reforming the institutions at the intermediary level. For example, companies could invest their resources (knowledge and capital) in capacity building programs for farmers and extension staff and assist the cooperatives in overcoming milk quality assessment and supply of quality and affordable dairy farm inputs to farmers. Cooperatives and processors can work together in the design and implementation of price incentives aimed at improving the milk quality of farmers, which will incentivise the adoption of dairy technologies by farmers.

The institutional reforms at the intermediary level can only be successfully implemented if the state-level institutions are supportive. Therefore, future study is needed to examine the state-level institutions that may be related to the ineffectiveness of institutions at lower levels which could hinder the adoption of technologies by smallholder dairy farmers. Besides, it is also pivotal for future study to complement the analysis by not only looking at institutions at different levels but also contrasting the roles of formal institutions (rules, contract, policy, and rights) and informal institutions (norms, values, beliefs, and culture) for each level. This would provide significant inputs to improve the design of policies and extension approaches to facilitate technology adoption by smallholder dairy farmers.

4.10 References

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Chapter 5: Summary, policy implications, study limitations and recommendation for future research

5.1 Summary of key findings

Smallholder dairy farmers in Indonesia continue to struggle to meet the rapid growth in domestic demand for dairy products. Smallholder dairy farmers, as the primary fresh milk producers in the country, are encouraged to increase their milk productivity and quality to benefit from this market opportunity. Adopting improved dairy farming technologies and practices is identified as one of the priority strategies for improving smallholder dairy farmers' milk productivity and quality. Despite ongoing investments in technology dissemination programs, there has been limited information on the status of the adoption of technologies, barriers to their adoption and the effects on milk productivity from their adoption. By understanding this topic, practical and workable strategies can be designed to encourage smallholder farmers to adopt technologies and allow them to benefit from the increased market demand through increased milk productivity and improved quality.

The overall aim of this study was to understand the heterogeneity of technology adoption decisions, multilevel barriers (at the farm and institutional levels) to initial and continual adoption, and to examine the effects of adoption on milk production, in the context of smallholder dairy farms in Indonesia. The study utilised a primary cross-sectional dataset from a survey of 600 dairy farm households in West Java, Indonesia. Chapter 4 also included qualitative information from semi-structured interviews with dairy cooperative board members to enrich the quantitative data and to provide additional insight into the issues addressed by this study. A combination of descriptive analysis, cluster analysis, and econometric methods were employed to address the research questions. This chapter provides a general discussion to integrate insights, and lessons learnt from the three analytical chapters presented in this thesis. This chapter also proposes workable strategies and policies based on the implications of the study’s results. Finally, this chapter concludes by outlining some study limitations, and by providing recommendations for future research.

The overall results of this PhD research support the notion that smallholder dairy farmers’ awareness of technologies and the stages they reach in the adoption of technologies are heterogeneous, and that farmers are faced with multiple constraints at both the farm and institutional levels. These constraints limit farmers’ adoption of technologies to varying degrees.

In the process of adopting multiple technologies, farmers are faced with different constraints at different stages of adoption. These constraints are namely, lack of individual awareness, lack of access to information, capital, and improved skills to properly adopt technologies. Farm-level constraints limit farmers’ awareness of technologies and farmers’ ability to adopt technologies, even if they are aware of them. Additionally, Indonesian smallholder farmers are challenged by ineffective institutional arrangements regarding milk and input quality assessment and the provision of dairy farm inputs and services. Poorly functioning institutions result in an environment where farmers lack incentives (e.g., price incentives for high quality milk) to adopt technologies that provide benefits to the entire dairy value chain and limit farmers’ access to affordable technology inputs and information. These institutional constraints are a main crux of problems that cause farmers to dis-adopt some productivity-enhancing technologies (e.g., mastitis testing, feeding high protein concentrate). The study also concludes that the adoption of multiple dairy farming technologies can significantly increase milk production, especially when high protein concentrate technology is included in the technology bundle. This indicates the importance of this technology as complementary to forages in supporting good milk production.

Chapter 2 profiles the heterogeneity of dairy farmers' awareness of and decisions regarding the adoption of multiple technologies. The chapter addresses the following research questions: are there any unique patterns of adoption categories, or subgroups of farmers, based on stages of technology adoption? How are the characteristics of subgroups of farmers associated with their patterns of technology adoption?

The adoption categories in the adoption stages include lack of awareness; aware but not adopted; dis-adoption; and continued adoption. Using Latent Class cluster analysis, unique subgroups of farmers are identified based on their adoption patterns for multiple technologies. Additionally, farmers' unique characteristics, related to their socioeconomic and farm characteristics, and their access to credit, information, and farming services are identified and help to explain the heterogeneity in the patterns. The results reveal two distinct clusters of farmers that are mainly differentiated by their awareness of technologies and the extent of their adoption of them. A considerable number (56.7%) of farmers are categorised as Low awareness/low adoption. Farmers in this cluster tend to live further from the primary information sources, and are less likely to utilise the farming services provided by dairy cooperatives (e.g., extension programs). By contrast, farmers in the second cluster (43.3%), the high awareness/adoption one**,** have higher levels of awareness of technologies, and have continued adoption of them. These farmers' characteristics include higher levels of education, being younger, living closer to primary information sources, which further explains their high exposure to technologies, leading to higher levels of awareness and adoption. Interestingly, some farmers in the second cluster still failed to adopt a few technologies, although they were aware of them. Other constraints to adopting these technologies, such as limited skills and capital, have challenged the capacity of farmers to adopt them, suggesting farmers are faced with different constraints in the stages of adoption.

In **Chapter 3**, the drivers of technology adoption and their effects on milk production of adopting feed technology bundles are examined. The research questions that are answered in the chapter are: what feed technology bundles are being adopted by smallholder dairy farmers in Indonesia? What factors affect farmers' adoption decisions? How does the adoption of the feed technology bundles affect smallholder dairy farms' milk production?

Data on farmers' adoption of four dairy feed technologies (taken from the data collected in the dairy farm household survey), either adopted as individual technologies or in bundles, are used in the analysis. Multinomial logit regression was employed to understand the drivers of the adoption of individual technologies and technology bundles. Farmers' age and education levels, and their access to credit and ownership of non-productive assets are the main drivers of the adoption of the majority of the technology options (whether adopted individually or in bundles). Interestingly, there are specific factors that predict only the adoption of technology bundles by farmers. These are variables related to productive asset ownership, especially dairy farming equipment and land on which to grow grasses, suggesting that the adoption of technology bundles is capital-intensive. To examine the effects of the adoption on milk production, a Multinomial Endogenous Switching Regression (MESR) was applied to correct for selection bias, based on observable and unobservable characteristics in adoption decisions and their effects on milk production. Additionally, the Inverse Probability of Weighted Regression Adjustment (IPWRA) was employed to check for the robustness of the results generated by the MESR. The results suggest that farmers who adopted technology bundles have higher milk production than those who adopted individual technologies, and those who did not adopt any of the technologies. The most positive and significant effects on milk production are realised if farmers include high crude protein concentrates in their technology bundle. While this is promising, only a few farmers have realised the higher milk production benefits of including high crude protein concentrate in their adoption portfolio. The high costs of adoption and the limited availability of high protein concentrate prevents other farmers from adopting this technology.

The final analytical chapter, **Chapter 4,** explores dis-adoption issues, addressing the following research questions: what are the main reasons farmers decide to dis-adopt some dairy technologies that have the potential to improve milk production? How do prevailing institutional arrangements prevent the continuous adoption of agricultural technologies?

A combination of quantitative data from the household survey and qualitative information from the semi-structured interviews with dairy cooperative board members are used to address these research questions. Using descriptive and qualitative analysis, it is found that the current institutional arrangements between dairy cooperatives and farmers fail to provide an environment that enables sustained technology adoption at the farm level. The milk and farm input quality assessments suffer the most from issues associated with asymmetric information that disincentivises farmers from adopting technologies. The institutions associated with the provision of dairy farm inputs and services by dairy cooperatives means they face high transactions costs in producing inputs (e.g., quality concentrates) and in delivering extension services to farmers. This consequently limits farmers' access to available and affordable technology inputs and access to information and knowledge to implement the technologies properly. All of these issues were found to be reasons related to farmers' decisions to dis-adopt dairy technologies.

5.2 General discussion, reflections on major findings and policy implications

Smallholder farmers are heterogeneous in many respects, including their socioeconomic characteristics, productive endowments and non-production assets, and access to and use of dairy farm services. These differences are all associated with farmers' heterogeneous adoption decisions in relation to different types of agricultural technologies. The following paragraphs elaborate on some lessons learnt and some implications of the analysis. They also emphasise some policy implications that might be considered as strategies to improve milk productivity, providing that smallholder farmers are encouraged to adopt these technologies and improved practices.

5.2.1 Multilevel barriers to adoption

In this thesis, multiple categories of technology adoption are considered: lack of awareness; aware but not adopted; dis-adoption; and continued adoption. Barriers to adoption found in the literature, such as limited access to capital, information, complementary inputs, and improved skills and lack of incentives from adoption (Grabowski et al. 2016; Kathage et al. 2016; Kebebe 2019; Lambrecht et al. 2014; Shiferaw et al. 2015) are relevant to each category of the adoption process **(Chapters 2 and 4)**.

Farmers' lack of awareness of dairy technologies may be related to less exposure to information about the technologies. Farmers in the Cluster with the lower level of awareness of most technologies have fewer resource endowments **(Chapter 2)**. As suggested in the literature (Diagne 2006; Haug 1999; Krishnan & Patnam 2014; Muneer 2014), it is likely that extension and technology dissemination programs tend to target farmers with better resource endowment, who are the likely adopters. Targeting these resource-rich farmers likely gives better results, from the perspective of extension providers, regarding farmers' adoption outcomes because of the higher probability of them adopting technologies. This is in line with previous studies in Indonesia suggesting that dairy extension programs are usually targeted to cooperative board members and farm group leaders (Mulatmi et al. 2016; Roessali, Eddy & Marzuki 2013), who are both more likely to have better resource endowments. Yet, this general approach misses on an opportunity to reach farmers who might adopt if their constraints could be overcome through appropriate extension programming and policies.

Farmers may be aware of technologies but decide not to adopt them because of constraints, such as the technology being perceived to be too costly and too complicated, as well as the lack of availability of complementary technology inputs **(Chapter 2)**, in agreement with the literature (Brown, Nuberg & Llewellyn 2018; Grabowski et al. 2016; Kebebe 2019; Shah, Grant & Stocklmayer 2014). This implies that being aware of the existence of the technologies may not necessarily make farmers adopt them straight away. Farmers are "rational thinkers" who would likely adopt agricultural technology if it works well in their farm context, and they can maximise the expected benefits of adoption, and if they also have enough access to the resources required for adoption (capital, knowledge, and inputs). These findings are in line with the cases of dis-adoption of technologies by farmers, where the primary reasons for dis-adoption are farmers' limited access to technology inputs, knowledge, and improved skills necessary for adoption **(Chapter 4)**. All these issues are linked to failures of institutional arrangements to provide an environment enabling farmers to adopt technologies (Brown, Nuberg & Llewellyn 2018; Chinseu, Stringer & Dougill 2019). This suggests that there are multiple constraints to adoption, and they exist at both the farm and institutional levels.

5.2.2 Farmers face different adoption constraints

Smallholder farmers are faced with different technology options, and they have unique responses in the adoption process of these different technologies. Consistent with the previous research findings (Bizimungu & Kabunga 2018; Floyd et al. 2003; Lambrecht et al. 2014), this heterogeneity can be explained by farmers' diverse socioeconomic characteristics, access to agricultural services, and the characteristics of the technologies **(Chapters 2 and 4)**. The results suggest that in order to design effective extension programs, these elements need to be properly considered. This raises the idea that agricultural extension programs and assistances need to be well-tailored, based on farmers' unique characteristics, needs, and constraints (Kaliba et al. 2020; Rolfe & Harvey 2017; Umberger et al. 2015) and in accordance with the characteristics of the technology being introduced (De Groote et al. 2016; Harris et al. 2013). For example, a technology that is perceived by farmers to be complex in its implementation should be addressed by extension programs that provide more assistance in the form of training and workshops and other forms of knowledge transfer programs to improve farmers' skills. The assistance should go beyond providing information that is limited to advice, flyers or books. Farmers need to be trained and to be given hands-on experience to help them adopt technologies and to realise the benefits of adoption.

5.2.3 Effects of the adoption of technology bundles

Although each agricultural technology has different expected outcomes, some technologies have complementary features to address issues faced by farmers (Canales, Bergtold & Williams 2020; Perry, Moschini & Hennessy 2016). For example, in the case of smallholder dairy farmers that are faced with limited availability of forages and their low quality can be addressed by adopting complementary technologies. These include growing improved varieties of grasses that have advantages, such as shorter growth time and yielding higher-quality forages. Also, applying fertilisers to grow grass can improve soil quality and support the growth of grasses. Similarly, high crude protein concentrates that are adopted as complementary to other feed technologies increase the nutrition of dairy cows' feed. Given the adoption of feed technology bundles results in higher milk production **(Chapter 3)**, supporting evidence from previous observations that the adoption of agricultural technologies bundles demonstrate additional benefits (Khonje et al. 2018; Kotu et al. 2017; Manda et al. 2016; Marenya, Gebremariam & Jaleta 2020; Tambo & Mockshell 2018), it would be ideal for farmers to adopt technologies that are bundled with complementary features. However, the adoption of technology bundles comes with costs for farmers because they are capital intensive, as suggested by previous studies (Kpadonou et al. 2017; Prakash et al. 2018; Teklewold, Kassie & Shiferaw 2013).

A lesson learnt from a study by Peralta, Swinton and Jin (2018) is that promoting technology packages can be done by targeting farmers, based on their level of asset ownership, given that access to capital is the main driver of the adoption of technology bundles. Targeting resource-poor farmers by encouraging the adoption of "asset light" technologies, requiring fewer resources, and which have a quicker payoff, can give farmers fast benefits at the time of adoption, allowing future investment in adopting technologies that require more resources.

5.2.4 Roles of dairy cooperatives and their struggles to source dairy inputs

This study emphasises the critical role of dairy cooperatives, especially in encouraging technology adoption at the farm level. Most farmers become aware of the technologies and receive support to initiate the adoption of them from dairy cooperatives **(Chapter 4)**. Farmers who had more contact with extension staff and utilised dairy farming services are more likely to have a higher level of awareness of technology, and are more likely to practice (continued) adoption **(Chapter 2)**, corroborating earlier findings in the adoption literature (Kathage et al. 2016; Lambrecht et al. 2014). Dairy cooperatives in Indonesia are the primary source of information for farmers. Many dairy development programs initiated by the local and national governments, NGOs, and international organisations are delivered through the cooperatives. Additionally, dairy cooperatives play the role of primary input suppliers to farmers. They provide basic dairy farming needs and services, such as artificial insemination, minerals, vitamins, feed concentrates, and milking equipment.

Because of the central role that cooperatives play as the input providers and knowledge hubs for farmers, it is essential to improve the capacity of dairy cooperatives to improve their capacity to provide their services to farmers. One possible strategy is to enhance the skills (e.g., communication and approach strategies) of extension staff who are the spearheads of dairy cooperatives in the field. Encouraging investment in extension is needed in increasing the quality of knowledge transfer programs to farmers (Antwi-Agyei & Stringer 2021; Mariano, Villano & Fleming 2012); this is particularly important, given a significant number of farmers are unaware of some of the important dairy technologies.

Additionally, complementary extension approaches should also be taken into account in introducing and disseminating technologies to increase farmers' awareness of them by improving farmer' access to information and knowledge, such as through farmer-to-farmer extension (F2FE), utilisation of information and communication technologies (ICT) such as text messages and mobile phone applications (Cole & Fernando 2021; Fisher et al. 2018; Kondo et al. 2020; Shikuku 2019; Voss et al. 2021). In addition, as highly emphasised in this thesis that being aware is not necessarily translate into practice changes, improving farmers' learning opportunity is needed. This could be through participatory extension approach such as farmers discussion groups, facilitated by extension staff, where farmers gather with their peers to discuss and learn particular technologies based on farmers' interests and needs (Hennessy & Heanue 2012; Prager & Creaney 2017).

The collaborative learning platform should be complemented with farmers access to direct experimentation with the technologies, for example, through demonstration farm to allow farmers to observe the on-farm implementation of the technologies in detail and recognise the benefits (i.e. yield improvement) (Maertens, Michelson & Nourani 2021). To trigger practice changes, improving farmers capacity to adopt technologies would not be enough. Therefore, it is essential to complement the efforts by improving farmers' access to input markets such as land, finance and complementary inputs (Foster & Rosenzweig 2010; Kebebe 2019; Shiferaw et al. 2015) and output markets by incentivising their practice changes, for example, through individual-quality-based pricing (Saenger, Torero & Qaim 2014).

The discussion in **Chapter 4** highlights that dairy cooperatives can struggle to source dairy farm inputs for their members, especially the provision of affordable, high protein feed concentrates. In addition, some technologies are not adopted by farmers due to the absence of the supply of complementary technology inputs **(Chapter 4)**, supporting findings in the literature (Grabowski et al. 2016; Mustapha, Salau & Ezra 2012). It is suggested that cooperatives need to implement strategies to increase their economies of scale in producing high protein concentrates and in supplying other technology inputs. When the demand for technology increases, the cooperatives will have incentives to produce and supply these inputs to farmers. This awareness might improve dairy cooperatives' economies of scale, lowering the costs of producing and supplying the inputs, ultimately making the input prices more affordable for farmers. This strategy should also be complemented by other strategies to ensure farmers have access to services to improve their skills and access to capital to facilitate adoption.

5.2.5 Value chain collaboration supports technology adoption

The adoption of technologies by smallholder dairy farmers will benefit farmers through increased milk productivity and quality and other actors at different stages in the value chain. For example, with an increase in milk productivity and quality by smallholder farmers, through technology adoption, dairy cooperatives receive greater quantities and higher quality milk from farmers, which means more income for the cooperatives due to increasing economies of scale in milk collection and distribution. In turn, milk processing companies are better able to meet growing demand, and end-consumers have better access to safe and affordable local dairy products.

Technology transfer can occur from the downstream to the upstream value chain (Kuijpers & Swinnen 2016; Swinnen & Kuijpers 2017). Milk processors as the downstream companies could have a key role in inducing technology adoption by smallholder dairy farmers. They have better information on the technologies required to improve milk productivity and quality, the products desired by consumers and also about government regulation. They also have better resources in the forms of capital, knowledge and technological know-how. Given these resources and potential benefits for the milk processing companies, there is a need for them to become involved in institutional reforms. For example, by investing their resources in training and extension programs for both farmers and dairy cooperative extension staff, as well as providing programs to help cooperatives be able to do individual milk quality testing and to solve issues in the supply of quality dairy farm inputs to farmers.

5.3 Limitations of this study and recommendations for future research

This study contributes to the literature on understanding heterogeneity in technology adoption among smallholder dairy farmers, barriers to the adoption of technologies, and the effects of adopting multiple technologies on agricultural production by using a unique case study of this rarely-investigated group. While its contribution is significant for additional knowledge in the adoption literature and the development of the dairy farming industry in Indonesia, this study is not without limitations.

Firstly, the use of cross-sectional data allows us to understand the patterns of adoption. However, the dynamics of adoption could be better explored if panel data were available. Likewise, the analysis of the effects of the adoption of technologies on milk production could move beyond establishing association and demonstrate causation if panel data were available. Despite this limitation, the results from this study still provide significant insight into the heterogeneity of adoption decisions, different adoption barriers and the positive outcomes of the adoption of multiple technologies.

Secondly, farmers adopt technologies if they can clearly see the potential returns of adoption. Therefore, it is important to extend the analysis in Chapter 3 to include measuring the effects of adopting multiple technologies on different key economic and livelihood measures, especially farm profitability. However, to do this, accurate data on production costs and revenues from dairy businesses would need to be available (Foster & Rosenzweig 2010). It has been a challenge for this study to collect such information, because smallholder farmers do not generally keep good records, as has been shown by the low adoption rates of record-keeping practices; only around 16% of farmers in the sample adopted these practices. For policymakers, further analysis is needed to determine the technology bundles that provide the best return for smallholder farmers' business conditions.

Thirdly, the scope of the study in Chapter 4, while revealing important issues underlying the dis-adoption of agricultural technologies, was limited to arrangements between the intermediary and farm levels. This study, however, has not touched on the institutional arrangements at the state level, which also may be related to the ineffectiveness of institutions at lower levels. Therefore, future study is needed to examine the state-level institutions that may hinder the adoption of technologies by smallholder dairy farmers. In addition to identifying possible institutional failures at different levels, further study is needed to understand the roles of different types of institutions at different levels, formal institutions (rules, contract, policy, and rights) and informal institutions (norms, values, beliefs, and culture), to provide more comprehensive insights on aspects beyond farm that may facilitate or impede technology adoption by smallholder farmers. This information would be needed to improve policy designs, especially for better extension approaches, by acknowledging the existence of formal and informal institutions and building on them to facilitate technology adoption.

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Appendices

Appendix 1. Low-risk human ethics approval

THE UNIVERSITY of ADELAIDE

RESEARCH SERVICES
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CRICOS Provider Number 00123M

18 April 2017

Professor W Umberger
Centre for Global Food and Resources

Dear Professor Umberger

ETHICS APPROVAL No: **H-2014-188**

PROJECT TITLE: **Improving milk supply, competitiveness and livelihoods in smallholder dairy chains in Indonesia**

Thank you for the Annual Report on Project Status dated 10.3.17, updated ethics application and supporting documents dated 10.3.17. and detailed response dated 13.4.17 to the matters raised following the review. The extension of ethics approval for an additional three years including changes to the investigators has been approved by the Low Risk Human Research Ethics Review Group (Faculty of Arts and Faculty of Professions).

The ethics expiry date for this project is: **30 September 2020**

Ethics approval is granted for three years and is subject to satisfactory annual reporting. The form titled *Project Status Report* is to be used when reporting annual progress and project completion and can be downloaded at http://www.adelaide.edu.au/ethics/human/guidelines/reporting. Prior to expiry, ethics approval may be extended for a further period.

Participants in the study are to be given a copy of the Information Sheet and the signed Consent Form to retain. It is also a condition of approval that you **immediately report** anything which might warrant review of ethical approval including:

- serious or unexpected adverse effects on participants,
- previously unforeseen events which might affect continued ethical acceptability of the project,
- proposed changes to the protocol; and
- the project is discontinued before the expected date of completion.

Yours sincerely

DR JOHN TIBBY

Co-Convenor
Low Risk Human Research Ethics Review Group
(Faculty of Arts and Faculty of the Professions)

DR ANNA OLIJNK

Co-Convenor
Low Risk Human Research Ethics Review Group
(Faculty of Arts and Faculty of the Professions)

Appendix 2. Participant consent form

A. HOUSEHOLD CHARACTERISTICS (REGISTRATION)

INDONESIAN DAIRY FARM HOUSEHOLD SURVEY 2019

Hello, my name is _________________. We are carrying out a survey of dairy farmers in West Java and North Sumatera. The survey is intended to understand the status of technology adoption and decision making in dairy farming business. Your household is one of the households that have been selected to participate. Remember, there are not right or wrong answers; ideally the answers should be as accurate as possible. The results are confidential and will only be used for research purposes. We would like about 2-3 hours of your time to interview you about your dairy business.

Objective

The main purpose of this survey is to improve our understanding about some of the key characteristics about dairy farmers in West Java and North Sumatera, particularly to address farm performance, technology adoption, and decision making.

Use of data

The data collected as part of this survey are for research purposes ONLY. Household-level data will not be shared with non-research organizations. Only summary results will be included in published report.

A. HOUSEHOLD CHARACTERISTICS (REGISTRATION)

Does the respondent consent to the interview?

The respondent should be the person that makes most of the decisions regarding the dairy farm, it may or may not be the head of the household

- ◯ Yes
- ◯ No

Appendix 3. Dairy farm household questionnaire

Indonesian Center for Agricultural Socio Economic and Policy Studies
Indonesian Agency for Agricultural Research and Development, Ministry of Agriculture

Indonesian Dairy Farm Household Survey 2017

THE UNIVERSITY of ADELAIDE

Objective: The main purpose of this survey is to improve our understanding about some of the key characteristics about dairy farmers in West Java particularly to address farm performance, technology adoption, and decision making.

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Household ID number				
Village code			Enumerator code	Household code

		Code in A2
Name of head of household		
Name of the respondent*		
Address of the house (NOT FARM)		
Name of farmer groups		
Name of KUD		
Phone		
Sub-district		
District		
Province		
GPS Coordinate		

Introduction
Hello, my name is _________________. We are carrying out a survey of dairy farmers in West Java. The survey is intended to understand the status of technology adoption and decision making in dairy farming business. Your household is one of the households that have been selected to participate. Remember, there are not right or wrong answers; ideally the answers should be as accurate as possible. The results are confidential and will only be used for research purposes. We would like about 2-3 hours of your time to interview you about your dairy business.

*The respondent should be the person that makes most of the decisions regarding the dairy farm, it may or may not be the head of the household

A. HOUSEHOLD CHARACTERISTICS*

	Name	What is the relationship between [name] and the head of household? Please use the CODES below to reply CODES: 1 Head of household 2 Spouse/partner 3 Son/daughter 4 Son/daughter in law 5 Grandchild 6 Parent or in-law 7 Other related 8 Other unrelated	**Gender**	**Age**	**Ask these questions only for members 6 years or older (A4>6)**		**Ask these questions only for members 10 years and older**		
			Is [name] a male or female? CODES: 1=Male 2=Female	How old is [name]? (age at last birthday) use 0 for members < 1 yr	What is the highest level of education completed (e.g. Year 8 = 8)	Which of this tertiary education has been completed by [...] ? 1 = No 2 = Undergraduate 3 = Post graduate 4 = Vocational training	What is the marital status of [name]? 1 Single 2 Married or de-facto 3. Divorced or separated 4 Widowed	*What are the **main activities in the last 12 months** of [name]? If there is no secondary activity, write 0 for A8 1. Dairy farming 2. Farmer or fishermen 3. Self-employed/employer 4. Wage/salary employee 5. Unpaid family/community worker 6. Student 7. Unemployed 8. Retired 9. Disabled 10. Other	
					Total number of years	**Choose one option**		Main	Secondary
	A1	**A2**	**A3**	**A4**	**A5a**	**A5b**	**A6**	**A7**	**A8**
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									

*NOTES: 1.The household is defined as a group of people who live and eat together most of the time under the same roof.

*NOTES: 2.Each member must live with others at least 6 months of the year unless a new member (baby, or new in-law living for at least a month in the HH)

*NOTES: 3.The head of the household is defined as the member (male or female) who makes most of the economic decisions.

*NOTES: **Questions A7 and A8**. 'main activities' are defined according to the time it takes, rather than the money it generates.

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B.HOUSING

What is the approximate area of your house in square metres? Do not include the farm land. <u>If don't know, please write DK</u>		B1
[If house owned] What is the approximate value of your house without farmland? [IDR] *if not owned write 0; don't know write (DK)*		B2a
[If house rented] What is the monthly rent that you pay for your house (without farmland)? [IDR] *if neither owned nor rented please write 0*		B2b
[If house] is neither own nor rented, what is the status? Select codes		B2c

Codes for **B2c**

1= borrowed from family 2= borrowed from non-family 3=other

What is the main source of water for your household for drinking? [ ] **B3a**

1 Bottled water	5 Outdoor shared tap	9 Collected rainwater
2 Refill water	6 Covered well	10 River, lake, or pond
3 Indoor tap	7 Uncovered well	11 Other
4 Outdoor private tap	8 Spring	

What is the main source of water for your household for cooking? [ ] **B3b**

1 Bottled water	5 Outdoor shared tap	9 Collected rainwater
2 Refill water	6 Covered well	10 River, lake, or pond
3 Indoor tap	7 Uncovered well	11 Other
4 Outdoor private tap	8 Spring	

What is the main source of water for your household for non-drinking and non-cooking activities? [ ] **B4**

1 Indoor tap	5 Uncovered well	9 other
2 Outdoor private tap	6 Spring	
3 Outdoor shared tap	7 Collected rainwater	
4 Covered well	8 River, lake, or pond	

What is the main type of toilet used by your household? [ ] **B5**

1 Flush toilet	4 Latrine over water
2 Latrine with pipe	5 Public toilet (all types)
3 Pit latrine	6 Other or none

What is the main type of lighting used by your household? [ ] **B6**

1 Electric lights	4 Candles
2 Generator	5 Solar
3 Oil lamps	6 Other or none

What type of fuel is used by your household for cooking? [ ] **B7**

1 Electricity	3. Biogas	5 Wood/charcoal
2 LPG	4. Kerosene	6. Other

Do you have public garbage collection? (1=Yes; 0=No) [ ] **B8**

C1. ASSETS AND GENERAL FARMING TOOLS

A. Household items	How many of each does your household <u>**CURRENTLY OWN**</u>? If none, please write 0 — Number		How many […] did your household own <u>**12 months ago**</u>? If none please write 0 if can't recall please write DK — Number		When did you buy the most recent […] e.g. 2016 If cannot recall please write DK		If you were to sell […] TODAY how much money would you get? [IDR] if more than one […] use an average	
a refrigerator		C1a		C1b		C1c		
a mobile phone?		C2a		C2b		C2c		
a television		C3a		C3b		C3c		
a parabola		C4a		C4b		C4c		
internet access?		C5a		C5b		C5c		
a washing machine?		C6a		C6b		C6c		
Transportation								
Bentor		C7a		C7b		C7c		C8d
a motorbike?		C8a		C8b		C8c		C8d
Three-wheeled motorcycle		C9a		C9b		C9c		C9d
Tricycle (becak)		C10a		C10b		C10c		C10d
a car?		C11a		C11b		C11c		C11d
a truck?		C12a		C12b		C12c		C12d
Others								
biogas?		C13a		C13b		C13c		
Genset		C14a		C14b		C14c		
manure/dung processing tool		C15a		C15b		C15c		

C2. ASSETS (LAND AND LIVESTOCK)

*The following table refers to land CURRENTLY managed or owned by the respondent, other than the house

Plot ID used in the last 12 months	Plot use (please use the codes below)	Size of the plot, please use the codes below for the units		Tenure system (use codes)	If C21=1,2; who owns the plot? (use codes)
		Area	Unit		
C16	C17	C18	C19	C20	C21
1					
2					
3					
5					
6					

Plot use codes C17	Codes for C19	Codes for C20	Codes for C21
1=crops	1 Hectare	1= owned	1=head of household
2=dairy cattle	2 Bau	2= rented	2=spouse
3=grow grass	3 Bata/Tumbak	3= share cropped	3=joint (household head and spouse)
4= livestock non-dairy	4 Are	4= pawned	4=father head of household
5 : horticulture	5 M2	5=borrowed	5=mother head of household
6 = idle	6 Patok	6=communal/public land	6=in-laws
7 others		7=other	7=other relatives
			8=other

How many of this ruminansia livestock [...] do you own?

Livestock Ownership	How many of […] does your household **CURRENTLY MANAGE**?	How many of […] does your household **CURRENTLY OWN**?	How many of […] did your household **12 months ago?**
C22	C23	C24	C25
Dairy cattle			
Beef cattle			
Buffalo			
Goat/lamb			

The following table records the herd structure of managed and owned DAIRY CATTLE

Herd category		How many of […] does your household **CURRENTLY MANAGE**?	How many of […] does your household **CURRENTLY OWN**?	How many of […] did your household **OWN I 12 months ago?**	If you were to sell ONE of the animals for each category, how much money would you get for it?
C26		C27	C28	C29	C30
		Number	Number	Number	[IDR]
1	Milking cows [lactation]				
2	Dry cows				
3	Pregnant heifers				
4	Heifers				
5	Calves				
6	Culling cow				
7	Bulls (dairy)				

Note: if don't know or can't remember please write DK

Have you sold stock (dairy) in the last 12 months? 1=Yes; 0=No ______ C31

If C31=1, how many stocks have you sold? [number] ______ C32

If C31=1, what is your reasons sold your stocks? use codes for C33 ______ C33

Codes for C33	
1 = for family party (e.g. wedding)	5 = for purchasing vehicle
2 = for children's education fee	6 = stocks are not productive anymore
3 = for renovating house	7 = others
4 = for medical fee	

*NOTE FOR 'C.ASSETS': If the respondent does not own or manage any land at all, please write a line vertically across all columns. It may be the case that the barn/cage is attached to the house and there is no land available for any other activity within the property.

C2. INDIVIDUAL ANIMAL INFORMATION									
The following table records the milking cows									
Milking Cows		Method of Breeding	Breeds	Age (in years and in months)	Farmer measurement (KG)	Parity (times)	Age of cows at the first calving (in years and months)	Calving interval (months)	Average Milk production (liter/day)
	C34	C35	C36	C37	C38	C39	C40	C41	C42
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

Note: if don't know or can't remember please write DK

Codes for C35	Codes for C36		
1. Artificial Insemination (AI)	1. Friesian Holstein (fh)	5. Red danish	9. Other
2. Natural	2. Shorthorn	6. Droughmaster	999. DK
	3. Jersey	7. Local	
	4. Brown Swiss	8. Crossbreed	

C3. CALVES MANAGEMENT

Do you feed colostrum to calves? (1=Yes, 0=No) [ ] C43

If C43=1, continue to next questions / If C43=0, continue C47

In what time did you feed colostrum to calves after birth (hours) ? use codes for C44 [ ] C44

Codes for C44		
1 = 0 - 1 hour	3 = 4 to 6 hours	6 = 13-24 hours
2 = 1 to 3 hours	4 = 7 to 12 hours	7 = more than 24 hours

How frequently colustrum is given to the calves (feeds/day)? Codes for C45 [ ] C45

Codes for C45			
1 = once a day	2 = twice a day	3 = three times a day	4 = Ad libitum

How much amount given each time (in liter)? Use codes for C46 [ ] C46

Codes for C46				
1 = <1 liter	2=1-2 liter	3 = 3-4 liter	4 = >= 5 liter	5 = ad libitum

Do you deworm the calves? (1=Yes; 0 = No) [ ] C47

IF C47= 0, continue to C49

IF C47=1, at what age do you deworm the calves? (Use codes for C48) [ ] C48

Codes for C48			
1 = 1-2 montl	2 = 3-4 months	3 = 5-6 montl	0 = Other

Do you practice dehorning? (1 = Yes; 0 = No) [ ] C49

IF C49= 0, continue to C51

If C49=1, in what age do you practice dehorning? (in years old) [ ] C50

At what age do you sell your male calves? (use codes for C51) [ ] C51

Codes for C51		
1 = 0 - 3mont	3 = 8 - 11 months	5 = >18 months
2 = 4-7 montl	4 = 12 -17 months	6 = not sold

How often [...] problem occur in your calves	C52 Use codes for C52
Diarrhoea	
Mange	
Indisgetion	
Other (......)	
Other (......)	

Codes for C52		
1 = never	2 = ocassionally	3 = often

D1. EXPERIENCE AND CAPITAL

Would you say the dairy business is for your household … Please use the codes below **D1**

Codes for **D1**
1=the main business activity
2= a secondary business
3= a third or fourth..

How many **years** in total have you been working in dairy business? **D2**

For the last 12 months what has been the **main** source of capital for your dairy cow business? Please use the codes below **D3**

Codes for D3
1=private (own/savings)
2=cash loan
3=partnership
4=government aid
5=heritage
6=cooperative input credit
7 = state owned bank (e.g. BPR)
8=other

If D3=2; what was the source of the loan? Please use the codes below

If D3=other than 2, skip to Q D6 **D4**

Credit sources codes for **D4**	
1=private commercial bank;	8=NGO
2= cooperative	9=employer
3=farmer's group	10=landlord/cow owners
4=government agency/bank	11=leasing
5=input supplier/SAPRODI	12=arisan
6=family member	13=pawn shop
7=money lender	14= buyer
	15= other

If D3=2; what is the interest rate of the loan? **D5**

Please use DK if you don't know or can't remember *[% per month]*

How much was the loan? (in IDR) D5a

How long was the payment period? (in months) D5b

How much was the monthly payment? (in IDR) D5c

What was the interest rate of the loan? (in % per month) D5d

D2 ACCESS TO CREDIT

Do you know of a place or person where you can go to borrow money? (1 = Yes, 0 = No) **D6**

If D6=0; Skip to Question E1

D7 From the following list of sources can you borrow money? Select from the following codes 1=Yes; 0=No; DK=Don't Know

1=private commercial bank;		9=employer	
2= cooperative		10=landlord/cows owner	
3=farmer's group		11=leasing	
4=government agency/bank		12=arisan	
5=input supplier/SAPRODI		13=pawn shop	
6=family member			
7=money lender			
8=NGO			

Have you ever borrowed money? D8

1 = yes, 0 = no

In the **past 12 months** have you tried to borrow money **except from** family/friend/neighbour? (1=Yes; 0=No) **D9**

IF F9=1, What was the purpose you borrow money? D10

Codes for D10	
1 = for dairy business	5 = for medical fee
2 = for family party (e.g. wed	6 = for purchasing vehicle
3 = for children's education f	7 = other
4 = for renovating house	

If D9=1; which source/s did you approach to lend you the money **D11a**

Select up to three sources from the codes in the D7 list above **D11b** **D11c**

If D9=1; Were you successful on the efforts of securing a loan? (1=Yes; 0=No) **D12**

If D12=0; Skip to Question D17

If D12=1; which source/s agreed to lend you the money **D13a**

Select up to three sources from the codes in the D7 list above **D13b** **D13c**

Was the amount of money borrowed that time enough for its main purpose? (1=Yes; 0=No) **D14**

What was the interest rate per month? (%/month) DK=don't know **D15** [%/month]

What was the payback time? (months) **D16** [months]

Do you currently hold a loan/credit? 1=Yes; 0=No **D17**

E1. FAMILY AND HIRE LABOUR

What is the main source of labour in your dairy business? **E1**

Codes for E1		
1=just myself	3=hired labour	5=collective action
2=my family and I	4= hired labor and I	0=other

Have you hired anyone to work in your dairy business in the last 12 months? (1=Yes;0=No) **E2**

If E2=1; How many people are you currently hiring? (number of people) **E3**
If E2=0; Skip to question E4

If you were to hire someone today to work at the dairy farm what would be the daily rate? (In IDR including meals) DK=Don't Know **E4**

What are the most common methods of payment when you hire someone to work in dairy farming? Select from the following codes: **E5**

Codes for E5		
1=only cash	3=cash and milk	0=other
2=cash and meals	4=cash, meals and milk	

In your local area, how easy is to find people to hire to work at your dairy farm? **E6**

Codes for E6		
1= easy	2=somewhat easy	3= difficult

Please complete the following details as per the labour allocation in hours per day**.** Think of the activities, how long does it take **every day** and how many hired workers (in case hired labour). If there is family and hired labour, please write both, don't know please write DK.

Daily Activities		Family labour (total working hours/day)			Hire Labour	
					Daily hours and # hired workers	
		Male	Female	*Children	Hours/day	# hired workers
E7		E8	E9	E10	E11	E12
1	Cut-and-carry grass					
2	Feeding					
3	Providing water					
4	Milking					
5	Washing barn/cage					
6	Washing cows					
7	Cleaning equipment					
8	Milk handling (filtering, packing)					
9	Milk delivery					

E2. COSTS AND EXPENSES IN THE DAIRY BUSINESS

Do you have reproduction and health package from coop? (1= Yes, 0=No) [ ] **E13**

If E13=0, continue to E15

If E13=1, what is covered in the pakckage? (choose min.1) - checkbox

E14a	E14b	E14c	E14....

Codes for E14			
1= AI	3 = Vitamin	5 = reproduction incentive	7 = other (specify)
2 = Medicine	4 = Veterinary fees	6 = other (specify)	8 = other (specify)

Code E15b
1= %
2 = Rp
3 = Other

Code E15c
1 = per liter
2 = per kg
3 = per total sales
4 = Other

How much is the package?

Fill E15a-E15c, if the options cannot cover the package details, type in other option E15d

Value	E15a
Unit	E15b
Per	E15c
Other	E15d

Operational costs

	Inputs and items [checkbox]	Do you use [..]? 1= Yes, 0=No. If no, skip to next row	How often do you use [...] 1=daily; 2=weekly; 3 = fortnightly; 4 =monthly; 5 = quarterly ; 6 = six months; 7=yearly 8=others	What is the package type? 1 = sack ; 2 = bottle ; 3 = straw ; 4 = pack ; 5 = pikul ; 6 = pick up cars 7 =dose	Package size Numbers	Unit of input 1 = kg ; 2 = Gr ; 3 = L ; 4 = mL ; 5 = straw	How many units of input used? Number	Price of input/unit IDR	Source Use codes for E24
	E16	E17	E18	E19	E20	E21	E22	E23	E24
1	Artificial Insemination (non-packet)								
2a	Medicines (non-packet) (…)								
2b	Medicines (non-packet) (…)								
2c	Medicines (non-packet) (…)								
3a	Vitamins (non packet) (…)								
3b	Vitamins (non packet) (…)								
3c	Vitamins (non packet) (…)								
4a	Concentrates (……………..)								
4b	Concentrates (……………..)								
4c	Concentrates (……………..)								
5a	Forage/grass								
5b	Leguminosa								
6	Mineral mix								
7	Tofu waste								
8	Cassava waste								
9	fermented soybean waste								
10	Soybean meal								
11	Palm kernel cake								
12	Crop straws (rice, corn,								
13	Vegetable waste								
14	Other feed (.....)								

Codes for question E24

1=I grow my own forages

2=Cut and carry from
3=cooperative
4=inputs supplier
5=self-mix it
6=other farmers
7=NGO
8=farmer's group
9 = Government
10 = others

Other expenses

	E25	Do you pay [..]? 1= Yes, 0=No. If no, skip to next row	[IDR]	Time period 1=daily; 2=weekly; 3=monthly; 4=yearly	Do these costs exclusively belong to the dairy business? 1=Yes; 0=No E29
		E26	E27	E28	
1	Land rent				
2	Taxes				
3	Water costs				
4	Milk delivery costs				
5	Feed delivery costs (concentrates, forages)				
6	Costs electricity				
7	KUD membership				
8	Veterinary Doctor fees				
9	Recorder fees				
10	Other memberships				

E3. EQUIPMENT USED OF DAIRY FARM PURPOSES			
E30		Do you own this equipment [...]? 1 = Yes, 0= No, If 0, skip to next question	How long have you been using [...] for? 1 = last 12 months ; 2 = last three years ; 3 = more than three years
		E31	E32
	Around animal house		
1	hand tractor		
2	cow barn		
3	warehouse		
4	a water pump		
5	spraying pump		
6	recording facilities		
7	floor insulation (rubber) for cage		
	Tools		
8	chaff cutter		
9	aluminium milking cans		
10	stainless steel milking buckets		
11	plastic buckets		
12	milking machinery		
13	drum Can		
14	litre measurement tool		
15	milk filter		
16	teat dipper		
17	scale		
18	brush		
19	broom		
20	mattock		
21	metal fork tool		
22	hose		
23	plastic boots		
	Milk processing		
24	milk processing tool (pasteurization, yoghurt, UHT)		

F. MILK PRODUCTION, QUALITY, CONSUMPTION AND NUTRITION

How many times do you milk your cows per day? (times/day) — F1

In the last 6 months, in average, how many litres of milk in TOTAL do you produce from all your cows? **(litres/day)**	morning	afternoon
	F2	F3

Is there any difference in milk production in dry and rainy seasons? (1=Yes; 0 = No; DK=Don't know) — F4

IF F4=1, in average how many litres are produced in TOTAL per day	dry season	rainy season
	F5	F6

IF F4=0, How many litres milk do you produce **last** month? (litres) — F7

Do you filter the milk or cool it down before delivery? Select one of the codes below for **F8** — F8

Codes for F8	
1=Yes, filter	3=Yes, filter AND cool it down
2=Yes, cool it down	4=do nothing

Do you know about **Total Solid (TS)** ? (1 = Yes ; 0 = No) — F9

If F9=1, Do you know the Total Solids (TS) of the milk at the collection point? (1=Yes; 0=No) — F10

If F9=0, continue to F12

If F10=1; What is the average percentage of TS? (%) — F11

If F10=0, why dont you know? Use codes for F12, — F12

Codes for F12, F16, F20, F24, F28
1 = I cannot measure
2 = I have not been told the result of measurement
3 = not measured by cooperative

Do you know about **Fat Content** ? (1 = Yes ; 0 = No) — F13

If F13=0, continue to F17

If F13=1, Do you know the fat content (%) of the milk sold at your KUD? (1=Yes; 0=No) — F14

If F14=1; What is the average fat content? (%) — F15

If F14 = 0, why dont you know? use codes for F16 — F16

Do you know about Somatic Cell Count ? (1 = Yes ; 0 = No) — F17

If F17=0, continue to F17

If F17=1, Do you know the SCC (somatic cell count) of the milk sold at your KUD?(1=Yes; 0=No) — F18

If F18=1; What is the average SCC? (cells per milliliter) — F19

If F18 = 0, why dont you know? use codes for F20 — F20

Do you know about **Total Plate Count (TPC)** ? (1 = Yes ; 0 = No) — F21

If F21=0, continue to F25

If F21=1, Do you know the Total Plate Count (TPC) of the milk sold at your KUD? (1=Yes; 0 = No) — F22

If F22=1; What is the average TPC? (cfu/ml) — F23

If F22 = 0, why dont you know? use codes for F24 — F24

Do you know about **milk density ?** (1 = Yes ; 0 = No) — F25

If F25=0, continue to F29

If F26=1, Do you know the milk density of the milk sold at your KUD? (1=Yes; 0 = No) — F26

If F26=1; What is the average milk density? (g/ml) — F27

If F26 = 0, why dont you know? use codes for F28 — F28

Do you get paid more (per litre) if you improve the quality of the milk? (1=Yes; 0=No, DK) — F29

Has the farmers ever experiece their milk get rejected by buyers (cooperative)? (1= Yes or 0=No) — F30a

If F30a =1, what is the reason? Use codes for F30b — F30b

Kode F30b		
1 = don't meet standard (TPC, TS, fat conten	3 = chemical contaminatio	5 = tidak tahu
2 = antibiotic residue	4 = others	

Do you get paid less (per litre) if the quality of the milk you deliver drops? (1=Yes; 0=No, DK) — F30c

How do you deliver the milk ? Choose one of the following codes: — F31

Codes for F31			
1=delivered to end-buyer location;	2=delivered to cooperative/milk collection point	3=picked up by coop	4= picked up by buyer

F. MILK PRODUCTION, QUALITY, CONSUMPTION AND NUTRITION (cont)

Do you or your family consume milk? (1= Yes; 0=No) **F32**

If F32 is 1, ask how frequently do you or your family consume milk? Select one of the codes below for F32a: **F32a**

Codes for F32a		
1=every day	3= twice or three times a week	5=a few times a year
2=once a week	4=once a month	6=never

If F32a is not 6 ; Do you boil the milk before consumption? (1=Yes; 0=No) **F33**

In average for the last 1 month, what percentage of the milk you produce is consumed at the household? (liter/month) **F34**

Do you use concentrates to feed **milking cows**? (1=Yes; 0=No) **F35**

Do you know the protein content of the concentrate? (1=Yes; 0 = No) **F36**

If F36=0; Skip to question F39

If F36=1; what is the percentage? (%) **F37**

Who do you generally get/buy the concentrate from? Select one of the following options: **F38**

Codes for F38		
1=cooperative	4=other farmers	7=farmer's group
2=inputs supplier	5=NGO	8=other
3=government agency	6=self-mix it	

In average, how many kg of concentrate do you feed **per milking cow** [kg/day]? **F39**

Do you feed mineral mix to your **milking cows**? (1=Yes; 0= No, DK) **F40**

Do milking cows have access to water all day long? (1=Yes; 0=No) **F41**

If F41= 0; how many times a day do you offer water? **F42**

If F41=1; Skip to question F43

Approximately, how many kg of grass do you feed per adult cow? **F43**

How do you use the waste (what for) ? **F44**

Codes for F44		
1 = Fertiliser	2 = Dung cakes for energy sources	5 = other
3 = Both	4 = not utilsed	

G. SALES AND MARKETING OF PRODUCTS FROM THE DAIRY FARM

	Products from the dairy farm	Over the last 12 months, have you sold any […]?	Over the last 12 months how many different buyers have you sold [...] to?	*Who is your main buyer and your secondary buyer for […]? See codes below G4		On the last 12 months what has been the AVERAGE unitary price you get for […] from your main buyer? See codes below for units G6u		Over the last 12months What has been the highest price you get for […] from your main buyer?		Which **month** has been **the highest price** you get for […] from your main buyer?	Over the last 12 months What has been the lowest price you get for […] from your main buyer?		Which **month** has been **the lowest price** you get for […] from your main buyer?	What year did you start selling […] to your Main buyer?	Do you have a verbal or written contract with your main buyer?	**If G10= 1 or 2** What are the **most important** clauses in the contract with the buyer? *(please select up to three options below)*			Who made the decision on the price	Can you negotiate the price of […] with your main buyer?	Do you get paid based on the quality of […] ?	**If G14=1,** What are **the most important** quality factors for the buyer? *(please select up to three options below)*			What are the main reasons you sell […] to your **main buyer**? (please select the three **most important** options below)		
		1=Yes; 0=No>> skip to next row	number of buyers, e.g. '3'	Main (code)	Second (code)	IDR	See codes G6u	**IDR**	**Unit**	**Month 1=Jan; 2=Feb;…; 12=Dec ; 13 = price not vary**	**IDR**	**UNit**	**Month 1=Jan; 2=Feb;…;12=Dec ; 13 = price not vary**	**year [e.g. 2014]**	1=Yes written; 2= Yes verbal; 0= None>> skip to G13	See codes below G11a-G11c			See codes below G12	See codes below **G13**	1=Yes; 0=No>> skip to G17	See codes below **G15a-G15c**			See codes below **G16a-G16c**		
G1		G2	G3	G4	G5	G6	G6u	G7	G7u	G7a	G8	G8u	G8a	G9	G10	G11a	G11b	G11c	G12	G13	G14	G15a	G15b	G15c	G16a	G16b	G16c
1	Raw milk																										
2	Pasteurised milk																										
3	Flavoured milk																										
4	Yogurt																										
5	Sweet condensed milk																										
6	Meat from butchered dairy cattle																										
7	skin and hides																										
8	Live heifers																										
9	Live calves																										
10	Adult female dairy cattle																										
11	Adult male dairy cattle																										
12	Culling cows for slaughter																										
13	Feed																										
14	bull services																										
15	Cow dung/manure																										
16	Urine																										

Codes for G4 and G5
1. KPGS Cikajang
2. KUD Giri Tani
3. KPS Cianjur Utara
4. KPBS Pengalengan
5. KPS Bogor
6. Other KUD/KPS
7. Processor
8. Dairy farmers
9. Trader
10. Multiple individual consume
11. Family members
12. Community group
13. School
14. Hotel
15. Restauran/café
16 Nongraded buyers/low graded milk buyer
17. Other

Codes G6u, G7u,
1. Kilogram
2. Litre
3. 50 litre can
4. Gram
5. 20 kg bag
6. 40 kg bag
7. 50 kg bag
8. 250ml bottle
9. 500ml bottle
10. cow
11. Pack
12. Other

Codes for G11a-G11c
1. Price
2. Quantity
3. Quality
4. Frequency of collection
5. Time of payment
6. Inputs provided on credit (feed, medicines, vitamins, supplements)
7. Exclusivity of supply
8. Duration of contract
9. Fluctuation of price policies
10. Management process
11. Other

Codes for G12
1 Buyers
2 Sellers (producer/dairy farmers/farmers group)
3 Buyers and sellers

Codes for G13
1. No, I always accept the price the buyer offers
2. Yes, I sometimes negotiate the price with the buyer
3. Yes, I always negotiate the price with the buyer
4. I generally set the price that I want to get

Codes for G15a-G15c
1. Total Solids (TS)
2. Total plate count (TPC)
3. % of fat
4. % protein
5. Milk density
6. Absence of adulterants
7. Body condition
8. Genetic quality
9. Liquid content of milk/watery
10. Other

Codes for G16a-G16c
1. The only buyer in the area
2. I trust this buyer
3. Buyer always pays on time
4. Buyer provides inputs on credit
5. Buyer provides training
6. Buyers provides credit when needed
7. Buyer helps the community
8. Buyer is respected in the area
9. Neighbours sell to this buyer
10. I've been selling to buyer long time
11. Higher price
12. Membership obligations
13. Buyer picks up […] from the farm
14. Buyer pays cash straight away
15. Other

NOTE: *Main Buyer refers to the person/organisation that purchases the largest amount of […], and from whom you obtain the largest amount of income in average for every particular product.

H. DISTANCE TO PLACES				
What is the distance in minutes using the transport method that is most utilised to go from your dwelling to the nearest […] *If don't know, please write DK.*				
Please indicate the approximate distance in kilometres IF KNOWN; if don't know please write=DK				
	Location	Means	**[Minutes]**	**[kilometres]**
	H1	**H2**	**H3**	**H4**
1	…non-asphalted road			
2	…asphalt road			
3	…traditional market			
4	…urban centre			
5	…milk collection point			
6	…KUD/Dairy co-operatives			
7	…extension office			
8	…dairy inputs and supplies			
9	…milk processing centre?			
10	…potential raw milk buyer?			
11	…free grass to cut and carry?			
12	…neighbour dairy farmer?			
13	…dairy farmer leader?			
14	…big dairy farm >15 milking cows?			
15	… your agricultural plots? (If any)			
16	… Research centre for agricultural development (Balitbangtan)			
17	… Local livestock services offices (dinas peternakan)			
18	… House of Inseminator			
19	… Livestock clinic/veterinary doctor			
20	… Veterinary technician			
21	… Middlemen/buyer			

Codes H2

1. walking	3. Bicycle	5. owned car	7. minibus	9. other
2. horse	4. motorcycle	6. bus	8. truck	

I1. ADOPTION OF TECHNOLOGY AND MANAGEMENT PRACTICES

How do you manage your cows? (use code for I1) ______ I1

Codes for I1		
1 = not offered shade	3=offered shade all day	5 = other ________
2= offered shade for part of the d	4=continously housed	

How do you restrain your cows? (use code for I2) ______ I2

Codes for I2		
1 = continously tied	2 = tied for part of day	3 = not tied

What method of heat detection do you use? (use codes for I3) ______ I3

Codes for I3		
1 = visual	2= bull/teaser	3 = none

What method do you use for the induction of oestrus? (use codes for I4) ______ I4

Codes for I4
1 = One shot of prostaglandin
2 = Two shots of prostaglandin
3 = None
4 = Other ______

How often do the following reproductive problems [....] occur on your farm?	**I5** Use codes for I5	**Use codes for I5** 1 = never 2 = ocassionally 3 = often
Anoestrus animals		
Uterine infection		
Prolapse		
Dystocia		
Repeat breeder		
Mastitis		

I2. ADOPTION OF TECHNOLOGY AND MANAGEMENT PRACTICES

					Answer these questions ONLY if I7b=1									If I7b=0 ; I8=0 and I10=0	
New technologies, management practices and business models		Are you familiar with or have you heard of […]?	Have you ever used/done […]?	Have you used/done […] since 2014	What year did you used/do [...] for the first time?	Are you still using/doing [...]?	Who introduced [...] for the first time to you or your farm?	What type of assistance or help have you received to adopt […]? IF I12=17 skip to I15	Is the person or organisation that introduced you to […] the same that provided support in I12?	If I13=0, Who provided this support?	What are the main two reasons you decided to adopt [...]?		If I10=0, What year did you stop doing [...]?	What are the 2 main reasons you have not used/adopted or stopped using [...]?	
		1= Yes, 0= No>> skip to the next row	1= Yes; 0= No>> skip to question I17	1= Yes; 0= No	[e.g. 2013]	1=Yes; 0=No	**See codes below for I11 & I14**	See codes below for I12	0=No; 1=Yes>> skip to quesiton I15	**See codes below for I11 & I14**	**See codes below for I15**		[e.g. 2013]	**See codes below for I17**	
I6		**I7a**	I7b	**I8**	**I9**	**I10**	**I11**	**I12**	**I13**	**I14**	**I15a**	**I15b**	**I16**	**I17a**	**I17b**
1	Artificial Insemination (AI)														
2	Mastitis test														
3	High protein concentrates (16% or higher)														
4	Feed legume forages (e.g. Leucaena)														
5	Use of high quality grasses														
6	Grow animal feed crops														
7	Use of fertiliser to grow grass														
8	Rubber/Plastic floor for the barn/cage														

Codes for I11 & I14	Codes for I12	Codes for I15 'Reasons for adoption'	Codes for I17 'Reasons for not adopting'
1 Dairy farmer	1 Training/Seminar/Workshop	1 To reduce costs of production	1 Lack of information about the new
2 Non-dairy farmer neighbour	2 Information (flyer, books, advice)	2 To reduce risks	2 Costs of adoption or implementation
3 Technical officer from KUD/KPS	3 Semen for AI	3 To increase milk yields	3 Too complicated to adopt
4 Milk Trader	4 Seeds	4 To earn higher profits	4 Excessive labour requirements
5 Government extension officer DINAS	5 Raw feeding materials	5 Increase quality of milk	5 I am satisfied with the current practice
6 BPTP	6 Mixers and feeding equipment	6 To reduce labour use	6 Milk yields lower than expected
7 Veterinary doctor	7 Filters	7 Saw neighbours adopting with good results	7 Benefits too far in the future
8 Village leader	8 Vaccines	8 To increase yield grass	8 Limited availability of inputs
9 University	9 Fertilisers	9 To improve health and wellbeing of the animals	9 Other farmers recommend stopping
10 Media (Newspaper, TV, radio)	10 Vitamins	10 To prepare better feed (hay, silage) for the dry season	10 Extension agent recommends stopping
11 Internet	11 Medicines	11 A new technology that becomes available	11 Other government officials recommend stopping
12 Inputs seller	12 Access to credit	12 To have access to new buyers	12 Lack of financial support or credit
13 NGO	13 Milk quality testing	13 To take advantage of promotions by chemical vendors	13 Lack of government support
14 Farmer's group	14 Mastitis tests	14 To benefit from assistance programs	14 Complaints from neighbours
15 Family member	15 Other inputs	15 Learned and implement after training	15 Price paid for the milk is too low
16 Self-observation	16 Equipment	16 Recommended by other farmers	16 Too much Risk involved
17 Other	17 Nothing	17 Recommended by extension agent	17 The existing practice is better
	18 Other	18 Recommended by a trader	18 Unsuitable for the local area conditions
		19 Recommended by other government officials	19 Other
		20 More practical	
		21 to be enviromentally friendly	
		22 to improve the breed	Page 15
		23 other	

I3. ADOPTION OF TECHNOLOGY AND MANAGEMENT PRACTICES

New technologies, management practices and business models		Are you familiar with or have you heard of […]?	Have you ever used/done […]?	Have you used/done […] since 2014	Answer these questions ONLY if I7b=1: What year did you used/do […] for the first time?	Are you still using/doing […]?	Who introduced […] for the first time to you or your farm?	What type of assistance or help have you received to adopt […]? IF I12=17 skip to I15	Is the person or organisation that introduced you to […] the same that provided support in I12?	If I13=0, Who provided this support?	What are the main two reasons you decided to adopt […]?		If I10=0, What year did you stop doing […]?	If I7b=0 ; I8=0 and I10=0: What are the 2 main reasons you have not used/adopted or stopped using […]?	
		1= Yes; 0= No>> skip to the next row	1= Yes; 0= No>> skip to question I17	1= Yes; 0= No	[e.g. 2013]	1=Yes; 0=No	**See codes below for I11 & I14**	See codes below for I12	0=No; 1=Yes>> skip to quesiton I15	**See codes below for I11 & I14**	**See codes below for I15**		[e.g. 2013]	**See codes below for I17**	
I6		**I7a**	I7b	**I8**	**I9**	**I10**	**I11**	**I12**	**I13**	**I14**	**I15a**	**I15b**	**I16**	**I17a**	**I17b**
9	Teat dipping after milking														
10	Improving drinking water availability 24/7														
11	Conserving forages for the dry seasons (hay, silage)														
12	Record keeping														
13	Using detergents for milking equipment														
14	Improved milking hygiene to reduce TPC														
15	Automatic milking machines														

Codes for I11 & I14	Codes for I12	Codes for I15 'Reasons for adoption'	Codes for I17 'Reasons for not adopting'
1 Dairy farmer	1 Training/Seminar/Workshop	1 To reduce costs of production	1 Lack of information about the new technology
2 Non-dairy farmer neighbour	2 Information (flyer, books, advice)	2 To reduce risks	2 Costs of adoption or implementation are too high
3 Technical officer from KUD/KPS	3 Semen for AI	3 To increase milk yields	3 Too complicated to adopt
4 Milk Trader	4 Seeds	4 To earn higher profits	4 Excessive labour requirements
5 Government extension officer DINAS	5 Raw feeding materials	5 Increase quality of milk	5 I am satisfied with the current practice
6 BPTP	6 Mixers and feeding equipment	6 To reduce labour use	6 Milk yields lower than expected
7 Veterinary doctor	7 Filters	7 Saw neighbours adopting with good results	7 Benefits too far in the future
8 Village leader	8 Vaccines	8 To increase yield grass	8 Limited availability of inputs
9 University	9 Fertilisers	9 To improve health and wellbeing of the animals	9 Other farmers recommend stopping
10 Media (Newspaper, TV, radio)	10 Vitamins	10 To prepare better feed (hay, silage) for the dry season	10 Extension agent recommends stopping
11 Internet	11 Medicines	11 A new technology that becomes available	11 Other government officials recommend stopping
12 Inputs seller	12 Access to credit	12 To have access to new buyers	12 Lack of financial support or credit
13 NGO	13 Milk quality testing	13 To take advantage of promotions by chemical vendors	13 Lack of government support
14 Farmer's group	14 Mastitis tests	14 To benefit from assistance programs	14 Complaints from neighbours
15 Family member	15 Other inputs	15 Learned and implement after training	15 Price paid for the milk is too low
16 Self-observation	16 Equipment	16 Recommended by other farmers	16 Too much Risk involved
17 Other	17 Nothing	17 Recommended by extension agent	17 The existing practice is better
	18 Other	18 Recommended by a trader	18 Unsuitable for the local area conditions
		19 Recommended by other government officials	19 Other
		20 More practical	
		21 to be enviromentally friendly	
		22 to improve the breed	Page 16
		23 other	

I4. ADOPTION OF TECHNOLOGY AND MANAGEMENT PRACTICES															
					Answer these questions ONLY if I7b=1									If I7b=0 ; I8=0 and I10=0	
New technologies, management practices and business models		Are you familiar with or have you heard of [...]?	Have you ever used/done [...]?	Have you used/done [...] since 2014	What year did you used/do [...] for the first time?	Are you still using/doing [...]?	Who introduced [...] for the first time to you or your farm?	What type of assistance or help have you received to adopt [...]? IF I12=17 skip to I15	Is the person or organisation that introduced you to [...] the same that provided support in I12?	If I13=0, Who provided this support?	What are the main two reasons you decided to adopt [...]?		If I10=0, What year did you stop doing [...]?	What are the 2 main reasons you have not used/adopted or stopped using [...]?	
		1= Yes; 0= No>> skip to the next row	1= Yes; 0= No>> skip to question I17	1= Yes; 0= No	[e.g. 2013]	1=Yes; 0=No	See codes below for I11 & I14	See codes below for I12	0=No; 1=Yes>> skip to quesiton I15	See codes below for I11 & I14	See codes below for I15		[e.g. 2013]	See codes below for I17	
I6		I7a	I7b	I8	I9	I10	I11	I12	I13	I14	I15a	I15b	I16	I17a	I17b
16	Nutrient feed blocks														
17	Cooling milk in water tanks														
18	Stainless steel milking equipment														
19	Biogas units														
20	Milk pasteurisation														
21	Milk processing (make yogurt)														

Codes for I11 & I14	Codes for I12	Codes for I15 'Reasons for adoption'	Codes for I17 'Reasons for not adopting'
1 Dairy farmer	1 Training/Seminar/Workshop	1 To reduce costs of production	1 Lack of information about the new technology
2 Non-dairy farmer neighbour	2 Information (flyer, books, advice)	2 To reduce risks	2 Costs of adoption or implementation are too high
3 Technical officer from KUD/KPS	3 Semen for AI	3 To increase milk yields	3 Too complicated to adopt
4 Milk Trader	4 Seeds	4 To earn higher profits	4 Excessive labour requirements
5 Government extension officer DINA	5 Raw feeding materials	5 Increase quality of milk	5 I am satisfied with the current practice
6 BPTP	6 Mixers and feeding equipment	6 To reduce labour use	6 Milk yields lower than expected
7 Veterinary doctor	7 Filters	7 Saw neighbours adopting with good results	7 Benefits too far in the future
8 Village leader	8 Vaccines	8 To increase yield grass	8 Limited availability of inputs
9 University	9 Fertilisers	9 To improve health and wellbeing of the animals	9 Other farmers recommend stopping
10 Media (Newspaper, TV, radio)	10 Vitamins	10 To prepare better feed (hay, silage) for the dry season	10 Extension agent recommends stopping
11 Internet	11 Medicines	11 A new technology that becomes available	11 Other government officials recommend stopping
12 Inputs seller	12 Access to credit	12 To have access to new buyers	12 Lack of financial support or credit
13 NGO	13 Milk quality testing	13 To take advantage of promotions by chemical vendors	13 Lack of government support
14 Farmer's group	14 Mastitis tests	14 To benefit from assistance programs	14 Complaints from neighbours
15 Family member	15 Other inputs	15 Learned and implement after training	15 Price paid for the milk is too low
16 Self-observation	16 Equipment	16 Recommended by other farmers	16 Too much Risk involved
17 Other	17 Nothing	17 Recommended by extension agent	17 The existing practice is better
	18 Other	18 Recommended by a trader	18 Unsuitable for the local area conditions
		19 Recommended by other government officials	19 Other
		20 More practical	
		21 to be enviromentally friendly	
		22 to improve the breed	Page 17
		23 other	

I5. ADOPTION OF TECHNOLOGY AND MANAGEMENT PRACTICES

New technologies, management practices and business models		Are you familiar with or have you heard of […]?	Have you ever used/done […]?	Have you used/done […] since 2014	Answer these questions ONLY if I7b=1: What year did you used/do [...] for the first time?	Are you still using/doing […]?	Who introduced […] for the first time to you or your farm?	What type of assistance or help have you received to adopt […]? IF I12=17 skip to I15	Is the person or organisation that introduced you to […] the same that provided support in I12?	If I13=0, Who provided this support?	What are the main two reasons you decided to adopt […]?		If I10=0, What year did you stop doing […]?	If I7b=0 ; I8=0 and I10=0: What are the 2 main reasons you have not used/adopted or stopped using […]?	
		1= Yes; 0= No>> skip to the next row	1= Yes; 0= No>> skip to question	1= Yes; 0= No	[e.g. 2013]	1=Yes; 0=No	**See codes below for I11 & I14**	See codes below for I12	0=No; 1=Yes>> skip to quesiton I15	**See codes below for I11 & I14**	**See codes below for I15**		[e.g. 2013]	**See codes below for I17**	
I6		**I7a**	I7b	**I8**	**I9**	**I10**	**I11**	**I12**	**I13**	**I14**	**I15a**	**I15b**	**I16**	**I17a**	**I17b**
22	Milk quality test														
23	UHT (Ultra High Temperature)														
24	Breeding plan applied														
25	Synchronization estrus														
26	Manure processing / manure re-use														

Codes for I11 & I14	Codes for I12	Codes for I15 'Reasons for adoption'	Codes for I17 'Reasons for not adopting'
1 Dairy farmer	1 Training/Seminar/Workshop	1 To reduce costs of production	1 Lack of information about the new technology
2 Non-dairy farmer neighbour	2 Information (flyer, books, advice)	2 To reduce risks	2 Costs of adoption or implementation are too high
3 Technical officer from KUD/KPS	3 Semen for AI	3 To increase milk yields	3 Too complicated to adopt
4 Milk Trader	4 Seeds	4 To earn higher profits	4 Excessive labour requirements
5 Government extension officer DINAS	5 Raw feeding materials	5 Increase quality of milk	5 I am satisfied with the current practice
6 BPTP	6 Mixers and feeding equipment	6 To reduce labour use	6 Milk yields lower than expected
7 Veterinary doctor	7 Filters	7 Saw neighbours adopting with good results	7 Benefits too far in the future
8 Village leader	8 Vaccines	8 To increase yield grass	8 Limited availability of inputs
9 University	9 Fertilisers	9 To improve health and wellbeing of the animals	9 Other farmers recommend stopping
10 Media (Newspaper, TV, radio)	10 Vitamins	10 To prepare better feed (hay, silage) for the dry season	10 Extension agent recommends stopping
11 Internet	11 Medicines	11 A new technology that becomes available	11 Other government officials recommend stopping
12 Inputs seller	12 Access to credit	12 To have access to new buyers	12 Lack of financial support or credit
13 NGO	13 Milk quality testing	13 To take advantage of promotions by chemical vendors	13 Lack of government support
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15 Family member	15 Other inputs	15 Learned and implement after training	15 Price paid for the milk is too low
16 Self-observation	16 Equipment	16 Recommended by other farmers	16 Too much Risk involved
17 Other	17 Nothing	17 Recommended by extension agent	17 The existing practice is better
	18 Other	18 Recommended by a trader	18 Unsuitable for the local area conditions
		19 Recommended by other government officials	19 Other
		20 More practical	
		21 to be enviromentally friendly	
		22 to improve the breed	Page 18
		23 other	

J. INFORMATION SOURCES

	Type of information	In the last 12 months, have you received information about [...] 1= Yes, 0=No. if Yes continue next question, if No skip to next row	In the last 12 months, what have been your main sources of information about [...]? (ask for up to 2 sources) If J3a or J3b=22 skip to the next row. see codes for **J3**		If sources=[1 to 15] in average, what has been the total number of visits or contact in the last 12 months? If sources [16 to 21] N/A, continue to next row		[For these 2 sources] How would you rate the quality of the information? 1=useful; 2= somewhat useful; 3 =poor	
			1st	2nd	visits in the last 12 months		1st	2nd
	J1	**J2**	**J3a**	**J3b**	**J4a**	**J4b**	**J5a**	**J5b**
1	Dairy cow nutrition							
2	Reproduction and AI							
3	Milk sales (buyers, prices)							
4	Increase milk quality							
5	Increase milk yields							
6	Forage and grasses							
7	Cow's health							
8	Applied of breeding plan/progeny testing							
9	Rearing heifer for replacement cow							
10	Provision of new credit							
11	Information on new technology							
12	New management practices							
13	Concentrates							
14	Access to new markets							
15	Government programs							
16	Knowledge sharing							
17	Value adding of milk							
18	Feed supplements							
19	Mastitis test							

Codes for J3a, J3b

1. Balitbangtan	12. Inputs seller
2. DINAS	13. farmers' field school
3. Government extension officer	14.Friend
4. University	15. NGO
5. Veterinary doctor	16.TV
6. Technical officer from the KUD	17. Radio
7. Non-dairy farmer neighbour	18. Newspaper
8.Dairy farmer	19. Internet
9. Farmer group	20. flyer & brochure
10. Trader	21. books and magazines
11. Processor	22. None

K. MEMBERSHIP

Membership groups		Have you ever been a member of [...]? (1=Yes, 0 =No)	Have you or any of the household members ever joined […] since 2014? 1=Yes; 0=No, If Yes continue next question, if No skip to next row	From the household members (including yourself) who is **currently** a member of […]? select from the codes **above for K3**	**IF K3 other than=8;** Do you/ your household members attend the regular meetings of […]? **IF K3=8 skip to the next row** 1=Yes always; 2 = Yes, often, 3=Yes sometimes; 4=never	Has this group provided with support in any of the follow fields? 1=Yes, utilised ; 2 = Yes, not utilised, 3 = Tidak , 4 = DK: Dairy cow nutrition	Reproduction and AI	Milk sales (buyers, prices)	Increase milk quality	Increase milk yields	Forages and grasses	Cow's health	Applied of breeding plan/progeny testing	Rearing heifer for replacement cow	provision of credit	information on new technologies	new management practices	concentrates	access to new markets	government programs	knowledge sharing	value adding of milk	feed supplements	mastitis tests	**How satisfied are you / your family members with […]?** 1.Satisfied; Satisfied; 3.Not Satisfied	**Do you receive dividends from […]?** 1=Yes; 0=No
K1		K2a	**K2b**	**K3**	**K4**	**K5**	**K6**	**K7**	**K8**	**K9**	**K10**	**K11**	**K12**	**K13**	**K14**	**K15**	**K16**	**K17**	**K18**	**K19**	**K20**	**K21**	**K22**	**K23**	**K24**	**K25**
1	KUD/Dairy Co-operatives																									
2	Farmer's group																									
3	Women association																									
4	Farmer's field school																									
5	Colony farming																									
6	Science technopark																									
7	Other (specify)																									

Codes for question K3	
1=head of household	6=in-laws
2=spouse	7=other relatives
3=joint (household head and spouse)	8=nobody
4=father head of household	9=other
5=mother head of household	

L. RISK
Please select the statement below that best describes your attitude towards new technologies, new management practices and new production methods. Select only one of the following: [ ] **L1** [1,2,3,4, or 5] 1. I am **always the first** to try new technologies new management practices and new production methods. 2. I am **one of the first** to try new technologies new management practices and new production methods. 3. I normally **wait to see other's success** with new technologies new management practices and new production methods **before I try them.** 4. I am **one of the last** to try new technologies new management practices and new production methods. 5. I **never** try new technologies new management practices and new production methods. Page 21

M. PERCEPTIONS OF CHANGE

M1		How would you rate each of the following [...] as of today? (M2)	Compare to **2014**, Do you think each of the following [...] has (M3)	What would the reason? (M4)
		1. Good 2. Fair 3. Poor 4. N/A	1. Improved 2. No change 3. become worse 4. DK	See codes below
M1		**M2**	**M3**	**M4**
1	Price of milk			
2	Price of concentrates			
3	Quality of the grass and forages			
4	Availability of land to purchase			
5	Availability of grass and forages to feed dairy cattle			
6	Availability of concentrates to feed dairy cattle			
7	Availability on dairy nutritional information			
8	Availability of technologies to improve milk yields			
9	Availability of marketing information			
10	Availability of credit			
11	Availability of veterinary services			
12	Availability of veterinary medicines			
13	Availability of extension services			
14	Number of milk buyers			
15	Roads in your district			

Facts at the dairy household level		How has [..] changed since in the last 12 months?	[If M6= 1 or 3] What is **the main reason** for this change [...]?
		see codes below	**see codes below**
M5		**M6**	**M7**
1	The total number of dairy cattle		
2	The total number of milking cows [lactation]		
3	The total average milk produced per day		
4	The total income received for milk sales		
5	Total household family labour in dairy business (male)		
6	Total household family labour in dairy business (female)		
7	Total household family labour in dairy business		

Codes for M6

1. Increased
2. No change
3. Decreased
4. N/A

NOTE: Link numbers 1 and 2 from Question **M4** back to the section C. ASSETS Cont… The answer has to make sense with the original questions in section C. In the same way with number 3, to check this go to section F. Milk Production.

Codes for M4 and M7

1. Change in milk quality
2 change in buyers/coop product development
3 change in scale of production of coop
4 Change in milk price
5 Change in the price of inputs
6 Change in dairy cattle price
7 Change in availability of credit
8 Change in services offered by buyer/cooperati
9 Change in knowledge
10 Change in milk buyers
11 Change in quantity of inputs used
12 Change in technologies
13 Change in management practice
14 Change in ownership of equipment
15 Breeding reasons
16 change labour availability
17 household event
18 change in information availability
19 other

How has the financial situation in your household changed since **2014**? Use codes below for question **M8** [ ] **M8**

Codes for **M8**	
1. Much better	4. Somewhat worse
2. Somewhat better	5. Much worse
3. No different /not change	6. No opinion or N/A (>> skip to the next section 'N')

[If change in financial situation M8=1, 2, 4, or 5] What is the **main reason** for the change in financial situation of your household? Use codes below for question M9 [ ] **M9**

Codes for M9

1 Change in milk prices
2 Change in milk yield
3 Change in milk buyer
4 Change in dairy cattle price
5 Change in livestock (non-dairy) income
6 Change in non-farm income
7 Change in health of family members
8 Change in level of crime in area
9 Change in family size
10 household member found a new job
11 household member lost job
12 natural disaster
13 expenses associated with illness
14 expenses associated with newborn
15 expenses associated with education
16 Inheritance
17 member of the household passed away
18 other

N. CASH INCOME ACTIVITIES

	Income Activities	Have members of your household been involved in [activity] at ...?		If N2=YES, ask questions N4-N7 if not draw a horizontal line across							If N2=1 & N3=1
				In the last 12 months who in the household was mainly responsible for this activity?	In the last 12 months how many [units] did the household member receive income from [...]?		For each of these income activities that your household was involved in, please answer the following				
							How much gross revenue did the household member make from this activity?		How much does your household spend in BUSINESS expenses related to this activity?		Has [income source] become less important or more important as a percentage of total income since 2014?
		2017	2014	1. Head 2. Spouse of head 3. Both 4. Other		Units		[IDR] Units		[IDR] Units	
		1=Yes 0=No	1=Yes 0=No		Number	1. days 2.weeks 3. months 4. year 5. tasks 6.harvests	[IDR]	[IDR]1. days [IDR]2.weeks [IDR]3. months [IDR]4. year [IDR]5. tasks [IDR]6.harvests	[IDR]	[IDR]1. days [IDR]2.weeks [IDR]3. months [IDR]4. year [IDR]5. tasks [IDR]6.harvests	1. More 2. Same 3. Less
	N1	N2	N3	N4	N5	N5u	N6	N6u	N7	N7u	N8
1	Agricultural wage employment										
2	Non-agricultural wage employment										
3	Pension										
4	Remittances from family members										
5	Milk sales										
6	Milk processing business										
7	Horticultural products sales										
8	Crop farming										
9	Live dairy cattle sales										
10	Agricultural trading										
11	Aquaculture										
12	Other livestock products										
13	Non-agricultural trading										
14	Non-agricultural self employment										
15	other non-labour sources of income										
16	Expertise fee (veterinarian, insemination)										

O. CONSUMPTION PATTERN

Type of Food		Did your household in the past week consume [...]?	If O2 =1, how frequent?	Source of food
		1 = Yes ; 0 = No . If 0, continue to next row	Number of days (1-7)	Use code for O4
O1		O2	O3	O4
1	Rice			
2	Corn			
3	Cassava			
4	Sweet potato			
5	Flour and its processed products			
6	Other kinds of tuber			
7	Tofu			
8	Tempe			
9	Nuts/beans (kacang-kacangan)			
10	Fresh fish			
11	Presevered fish			
12	Chicken			
13	Red meat (beef, buffalo, lamb)			
14	Organ meat			
15	Egg			
16	Milk			
17	Green leafy vegetables			
18	Tuber vegetables			
19	Vegetable flowers			
20	Fruit vegatables			
21	Fruits			
22	Sugar or sweetener			

Dairy Products		Do your household consume in the past week[…]?	if O6=1, how frequent?
		1 = Yes ; 0 = No . If 0, continue to next row	Number of days (1-7)
O5		O6	O7
1	Fresh milk		
2	Pasteurisation milk		
3	UHT milk		
4	Powdered milk		
5	Sweet condensed milk		
6	Yoghurt		
7	Kefir		
8	Cheese		
9	Butter		

Codes for O4
1. From Own production(e.g. own garden or farm)
2. Purchased by the family member
3. Borrowed from friends/relatives
4. Gifts from friends/relatives
5. Food assistance (e.g. from government organizations or NGOs)

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P. HOUSEHOLD FOOD INSECURITY ACCESS SCALE (HFIAS)

Now, I am going to ask you about the food eaten in your household in the past 4 weeks.
I am going to read you several statements. Please tell me either yes or no, and if yes, how often does it happen.

P1	In the past 4 weeks, did you worry that your household would not have enough food?	[ ]	0. no (go to P4) 1. yes
P2	If 『yes』 was it ..? 1. … rarely (1-2 times) 2. … sometimes (3-10 times) 3. ... often (> 10 times)	[ ]	P2
P3	If P2 is 2 or 3, what is the main coping strategy?	[ ]	P3
P4	In the past 4 weeks, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	[ ]	0. no (go to P7) 1. yes
P5	If 『yes』 was it ..? 1. … rarely (1-2 times) 2. … sometimes (3-10 times) 3. ... often (> 10 times)	[ ]	P5
P6	If P5 is 2 or 3, what is the main coping strategy?	[ ]	P6
P7	In the past 4 weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?	[ ]	0. no (go to P10) 1. yes
P8	If 『yes』 was it ..? 1. … rarely (1-2 times) 2. … sometimes (3-10 times) 3. ... often (> 10 times)	[ ]	P8
P9	If P8 is 2 or 3, what is the main coping strategy?	[ ]	P9
P10	In the past 4 weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	[ ]	0. no (go to P13) 1. yes
P11	If 『yes』 was it ..? 1. … rarely (1-2 times) 2. … sometimes (3-10 times) 3. ... often (> 10 times)	[ ]	P11
P12	If P11 is 2 or 3, what is the main coping strategy?	[ ]	P12

Codes for Coping Strategy P3, P6 P9, P12, P15, P18, P21, P24, P27
1 = Reducing eating frequency
2 = Reducing the meal portion
3 = Consuming alternative cheaper food
4 = Selling livestock
5 = Selling/pawning other assets
6 = Take first, pay later (kas bon)

P13	In the past 4 weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	[ ]	0. no (go to P16) 1. yes
P14	If 『yes』 was it ..? 1. … rarely (1-2 times) 2. … sometimes (3-10 times) 3. ... often (> 10 times)	[ ]	P14
P15	If P14 is 2 or 3, what is the main coping strategy?	[ ]	P15
P16	In the past 4 weeks, did you or any household member have to eat fewer meals in a day because there was not enough food?	[ ]	0. no (go to P19) 1. yes
P17	If 『yes』 was it ..? 1. … rarely (1-2 times) 2. … sometimes (3-10 times) 3. ... often (> 10 times)	[ ]	P17
P18	If P17 is 2 or 3, what is the main coping strategy?	[ ]	P18
P19	In the past 4 weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?	[ ]	0. no (go to P22) 1. yes
P20	If 『yes』 was it ..? 1. … rarely (1-2 times) 2. … sometimes (3-10 times) 3. ... often (> 10 times)	[ ]	P20
P21	If P20 is 2 or 3, what is the main coping strategy?	[ ]	P21
P22	In the past 4 weeks, did you or any household member go to sleep at night hungry because there was not enough food?	[ ]	0. no (go to P25) 1. yes
P23	If 『yes』 was it ..? 1. … rarely (1-2 times) 2. … sometimes (3-10 times) 3. ... often (> 10 times)	[ ]	P23
P24	If P23 is 2 or 3, what is the main coping strategy?	[ ]	P24
P25	In the past 4 weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?	[ ]	0. no (go to next section) 1. yes
P26	If 『yes』 was it ..? 1. … rarely (1-2 times) 2. … sometimes (3-10 times) 3. ... often (> 10 times)	[ ]	P26
P27	If P2 is 2 or 3, what is the main coping strategy?	[ ]	P27

Q. FARMERS' EXPECTATION

What is your future intention with respect to dairy? (Use codes for Q1) [ ] Q1

Codes for Q1				
1 = Remain the same	2 = Expand	3 = Undecided	4 = Quit	5 = Other (.....)

If Q1 = 2, to what size of operation do you want to expand? (number of cows) [ ] Q2

Would you be happy to take part in a year long survey with us and keep records on milk production? (1 = Yes; 0=No) [ ] Q3

If Q3=1, what is the production unit you want to do? (1 = per animal ; 2 = total on farm) [ ] Q4

If Q3=1, what is the frequency your records? (1 =daily ; 2 = weekly ; 3 = monthly) [ ] Q5

Who is capable of maintaining these records? (use codes for Q6) [ ] Q6

Codes for Q6				
1 = No one	2 = household head	3 = spouse	4 = children	0 = other (....)

If we were to organize a farmer training day/workshop in your village would you likely to attend? (1=Yes ; 0=No) [ ] Q7

If we were to organize a farmer training day/workshop in your village for **women** would **female members** of your family be able to attend? (1=Yes ; 0=No) [ ] Q8

What kind of training would you prefer? [ ] Q9

Codes for Q9	
1 = Seminar	3 = Field practice
2 = Theory/ written materials	4 = Farm visit

Which of these would like training in the most? (List up to three topics, use codes for Q10)

	Q9a
	Q9b
	Q9c

Codes for Q10	
1 = Nutrition/feeding management	4 = Milking practice
2 = Animal husbandry	5 = Farm business management
3 = Reproduction	6 = Other

In your opinion, what are the most significant constraints to the dairy industry in your current situation? (tick only, can choose more than one)

	Q11
Knowledge	
Training	
Quality animals	
Feed resources	
Availability of vet services	
Marketing	
Nutrition	
Labour	
Reproduction	
Calf rearing	
Other	

R. ABBREVIATED-WOMEN'S EMPOWERMENT ON AGRICULTURE INDEX (A-WEAI)

At this stage, I would like to interview the (1) **primary*** and (2) **secondary* decision-makers SEPARATELY. (See notes below)**
One should be male and the other female *(Place 88888 if not applicable, meaning there is no appropriate secondary decision-maker).*

D.P. PRIMARY/SECONDARY:_______
(Refer to A1).

1. Role in Household Decision-making around Production and Income Generation [checkbox]

Now, I would like to ask you some questions about your participation in certain types of work activities and on making decisions on various aspects of household life.	Did you yourself participate in [ACTIVITY] **<u>in the past 12 months</u>**?	When decisions are made regarding [ACTIVITY], who is it that normally makes the decision? [Tick all that applies] ***If response is SELF***	How much input did you have in making decisions about [ACTIVITY]?	To what extent do you feel you can make your own personal decisions regarding [ACTIVITY] if you want(ed) to? Select one.	How much input did you have in decisions on the **<u>use of income generated from</u>** [ACTIVITY]?
Activity description	0. no ***(go to the next activity)*** 1. yes	1. self 2. spouse 3. other HH member 4. other non-HH member	1. input in few decisions 2. input into some 3. input into most or all decisions	1. not at all 2. small extent 3. medium extent 4. to a high extent	1. input in few decisions 2. input into some 3. input into most or all decisions
	R1	R2	R3	R4	R5
A. Food crop farming: These are crops that are grown primarily for household food consumption.					
B. Cash crop farming: These are crops that are grown for sale in the market.					
C. livestock raising (cattle, buffalo, horse, etc.)					
D. Dairy Production scale (population) : selling and buying cows Kinds and quantity of forages Kinds and quantity of concentrates Herd health Milk marketing					

Provide this note at the beginning of this section
The primary and secondary member are usually the husband and wife; however, they can also be another member as long as there is **<u>one male and one female aged 18 years old and over</u>**
In general, the primary decision-maker is also the head of the household but this may not always be the case (i.e. elderly parent living with adult son/daughter and the adult son/daughter may be

It may also be the case that there is only a primary female respondent and there is no adult male present in the household. In cases whereby the primary male adult is absent from the house due

2. Access to Productive Capital [checkbox]

Now, I would like to ask you about your household's assets to and ownership of a number of items that could be used to generate income.	Does anyone in your household currently have any [item]?	Do you own any of the item? Choose all applicable.
Productive capital	0. no ***(go to the next item)*** 1. yes	0. no 1. yes, solely 2. yes, jointly
	R6	R7
A. Agricultural land (pieces/plots)		
B. Large livestock (cattle, buffalo, horse, etc.)		
C. Small livestock (goats, pigs, etc.)		
D. Chickens, ducks, turkeys, pigeons		
E. Fish pond or fishing equipment		
F. Farm equipment (non-mechanized; hand tools, animal-drawn plough,		
G. Farm equipment (mechanized: tractor-plough, power tiller, treadle		
H. Nonfarm business equipment		
I. House or other structures		
J. Large consumer durables (refrigerator, TV, sofa, etc.)		
K. Small consumer durables (radio, cookware, etc.)		
L. Mobile phones		
M. Other land not used for agricultural purposes (pieces/plots, residential		
N. Means of transportation (bicycle, motorcycle, car, etc.)		

R. ABBREVIATED-WOMEN'S EMPOWERMENT ON AGRICULTURE INDEX (A-WEAI) (cont.)

3. Access to Credit

Next, I would like to ask about your household's experience with borrowing money or other items in the past 12 months.	Has anyone in your household taken any loans or borrowed cash/in-kind from [SOURCE] in the past 12 months?	Form(s) of loan	Who makes the decision to borrow from [SOURCE] most of the time? [Choose all that applies]	Who makes the decision about what to do with the money/item borrowed from [SOURCE] most of the time? [Choose all that applies]
Lending source	0. no ***(go to the next*** 1. yes	1. cash 2. in-kind 3. cash and in-kind	1. self 2. spouse 3. other HH member 4. other non-HH member	1. self 2. spouse 3. other HH member 4. other non-HH member
	R8	R9	R10	R11
A Dairy cooperative				
B Formal lender (bank/financial institution)				
C Informal lender (private moneylenders and traders and friends charging				
D Friends/relatives (charging zero interest)				
E Union (Farmers'/Women's Union, People's Credit Funds)				
F Informal savings and credit groups (SCGs)				
G.NGO				

4. Group Membership

Now I am going to ask you about groups in the community. These can be either formal or informal and customary groups.	Is there a [GROUP] in your community (village/commune)?	Are you an active member of this
Group	0. no ***(go to next group)*** 1. yes 999 don't know	0. no 1. yes
	R12	R13
A Agricultural/Livestock/Fisheries producer's group (including marketing group)		
B Youth Union		
C Forest user's group		
D Credit or microfinance group, insurance group		
E Trade and business association group		
F Civic groups (improving community) or charitable group		
G Religious group		
H Women's Union		
I Other (specify)		

Appendix 4. Planned questions of semi-structured interviews with dairy cooperative board members (part of a value chain study)

Business Type:	
Address:	
Phone:	
Contact Person:	
Email:	

1. Dairy Business/Sector Perception

1.1. Overall, how do you feel about the future of your dairy business?
- Very positive
- Fairly positive
- Fairly negative
- Very negative
- Neutral
- Unsure

1.2. Can you list some reasons why you feel this?

1.3. Overall, how do you feel about the future of the dairy industry in Indonesia?
- Very positive
- Fairly positive
- Fairly negative
- Very negative
- Neutral
- Unsure

1.4. Can you list some reasons why you feel this?

2. Members/Suppliers and Location

2.1. How many dairy farms/cows supply you with milk?

2.2. Has this number increased or decreased over the last five years? What has been the magnitude of this change*? If they could tell you the % that would be helpful. Otherwise you could use a likert scale?*

2.3. What has been the driver of this change?

2.4. Where are they mainly located (what regency)?

2.5. What is the average farm size (no. of cows) and range of farm sizes of your members/suppliers? Or is it quite variable?

2.6. How many farms and what percentage of your milk is produced from herds with:
- Less than 3 cows;
- Between 3-8 cows
- More than 20 cows

3. **Local Milk Supplies**
   3.1. What volume of milk do you receive/produce/collect (per day/month)?
   3.2. How does this change throughout the year?

If possible, try using the table below to document the amount of milk they collect each month. Otherwise, try to get an understanding of how much the production changes throughout the year.

Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**

   3.3. How is milk transported from the farm to the KUD? Does KUD pick up or do farmers drop off? If both, then what % is each?
   3.4. How many local collection points do you operate?
   3.5. Name the factories you deliver to and what is the proportion? Does this change throughout the year?
   3.6. Have your buyers changed in the past 5 years? How? Why do you think that is? (NOTE the how and why part is really important- must probe a bit)
   3.7. How is the milk sent to the customer/buyer (refrigeration?)?
   3.8. Do you know what products it is made into (e.g. fresh milk, cheese yogurt, powdered milk)? Do you know where the products end up (e.g. local market, Jakarta, Indonesian exported)?

4. **Product Quality and Prices**
   4.1. What is your relationship with your **<u>suppliers/farmers</u>**? (contract; milk quality standard; payment system: number of days to receive payment, price information?)
      4.1.1. Does this vary from farmer to farmer?
      4.1.2. What quality do you require?
      4.1.3. How is the price you pay farmers determined?
      4.1.4. When do farmers know the price they will receive (e.g. when milk is picked up or delivered etc.)?
      4.1.5. Who has the negotiating power in setting the price?
      4.1.6. What product specification do you require farmers to meet? (Fat, SNF, TS, TPC, Antibiotics, Other requirements?)
      4.1.7. In the last 12 months, what is the price range that you pay the farmers for the milk?
      4.1.8. How do prices change throughout the year? (determine seasonal high and seasonal low)
      4.1.9. What do you think is the main determinant of the price paid to farmers? determines the price (e.g. quality attributes?)
      4.1.10. What testing of the milk is done? Where and when? Individual farmers or batch testing? What happens to the results?

4.2. What is your relationship with your **buyers**? (contract; milk quality standard; payment system: number of days to receive payment, price information?)
   - 4.2.1. How is the price you receive for milk you sell determined?
   - 4.2.2. When do you know what price you will receive (e.g. when milk is picked up or delivered etc.)
   - 4.2.3. Who has the negotiating power in setting the price?
   - 4.2.4. What product specification are you required to meet? (Fat, SNF, TS, TPC, Antibiotics, Other requirements?)
   - 4.2.5. In the last 12 months, what is the price range that you have **received** for the milk?
   - 4.2.6. How do prices change throughout the year? *Determine seasonal high and seasonal low of price received for milk sold*?
   - 4.2.7. What do you think is the main determinant of the price you receive? (e.g. quality attributes?)
   - 4.2.8. How many days after selling milk do you receive payment?

5. Technical Services

5.1. Do you or your members/suppliers receive any technical services?
5.2. What kind of technical services and advice?
5.3. From whom do you receive the technical services?
5.4. How often do your farmers / you receive formal or informal training?
5.5. How much of this training is undertaken on farm?
5.6. Did you adopt these new methods? Why, why not?
5.7. How much technical advice do you receive from your AI technician?
5.8. Is there any support from govt or aid programs?

6. Capital investments

6.1. Did you make any on business capital investments in the **last 12 months** (machinery, facilities, land, etc)? What were they? Did you get a loan for this or was it from cash savings?
6.2. Are you planning any business capital investments in the **next 12 months**? What will they be? What will be the source of the investment (loan, cash)?

7. Challenges and barriers to sector growth

7.1. At each step of the dairy value chain, in your opinion, what is the biggest challenge affecting the dairy industry? For these challenges can you recommend priorities or strategies to overcome these and who should be responsible for driving the change (e.g government, industry, retailers, processors, farmers).

Use the table below to list out the issues and recommendations. Record a maximum of three issues per actor. Use the following list to prompt the respondent if needed:

- *Inputs*
- *Production*
- *Collection*
- *Processing*
- *Market and prices*
- *Transport*
- *Labour*
- *Communications channels*
- *Negotiations*
- *Policies*
- *Competing industries*
- *Weather/climate related issues*

Value chain	Challenge / issue	Priorities and recommendations
Input suppliers	1.	
	2.	
	3.	
Farmers	1.	
	2.	
	3.	
Cooperatives	1.	
	2.	
	3.	
Processor	1.	
	2.	
	3.	
Retailers	1.	
	2.	
	3.	

7.2. Is hygiene on farm impacting on milk quality e.g. mastitis? Are there any other milk quality issues you face from the milk you receive from the farmers? e.g. chemicals, antibiotics, adulterants?
7.3. Is your buyer in a position to buy more of your product? If yes, what is stopping you suppling more?
7.4. Does your buyer ever communicate ways that could add value to the product you sell? Do you ever discuss with your buyer what these options are?
7.5. What are the barriers stopping your business from growing? Is access to finance, labour, logistics?
7.6. Are there any products that compete with what you sell? If yes, what are they?
7.7. Do you get to hear information about what other fellow value chain actors pay for their product or sell their product for?
7.8. What kind of policies have been issued by local/national government to support dairy industry in North Sumatera / Java (on farm including new methods/technology, inputs, market access, pricing)?
7.9. Are there any existing policies (from local / national government) that might act as a barrier to dairy industry development in North Sumatera / Java?
7.10. What kind/type of policies (from local/national government) would support farmers to improve the dairy industry in North Sumatera / Java?

We have reached the end of the interview. Thanks for your assistance. The information you've given me will be pooled with information received from other dairy farmers, processors and retailers and will provide an in-depth picture of issues currently facing the dairy industry in Indonesia.

If you are interested, the report from this study will be made available on the project website. Also, if you would like to receive updates from the project or participate in future activities, such as studies, forums or training, we can inform you via email.

https://www.indodairy.net/

Appendix 5. Appendices for Chapter 2: A latent class analysis approach to understanding heterogeneity in technology adoption among Indonesian smallholder dairy farmers

Table A5-1 Parameter estimates

Technologies	**Wald**	***P*-value**	**R^2**
High protein concentrates (16% or higher)	85.66	0.00	0.12
High-quality grass varieties	13.96	0.00	0.04
Fertiliser to grow grass	11.06	0.01	0.03
Unrestricted access to drinking water	74.68	0.00	0.12
Forage conservation for the dry seasons (hay, silage)	86.86	0.00	0.16
Improved milking hygiene to reduce TPC	16.25	0.00	0.07
Stainless steel milking equipment	9.13	0.03	0.02
Teat dipping after milking	98.73	0.00	0.16
Mastitis testing	79.84	0.00	0.12
Rubber floor mat for the barn/cage	33.98	0.00	0.06
Record keeping	90.75	0.00	0.17

Table A5-2 Pairwise comparison of decisions categories by latent clusters

Profile	Cluster 1 (56.67%)	Cluster 2 (43.33%)	Anova *P* value	Sig.
High protein concentrates (16% or higher)				
Not aware	79.35%	32.98%	0.00	***
Aware, but not adopt	12.99%	31.99%	0.00	***
Dis-adoption	5.19%	19.94%	0.00	***
Continued adoption	2.46%	15.08%	0.00	***
High-quality grass varieties				
Not aware	23.12%	6.52%	0.00	***
Aware, but not adopt	10.48%	7.49%	0.10	
Dis-adoption	1.58%	1.78%	0.67	
Continued adoption	64.83%	84.21%	0.00	***
Fertiliser to grow grass				
Not aware	16.63%	3.80%	0.00	***
Aware, but not adopt	16.28%	11.84%	0.22	
Dis-adoption	4.79%	4.12%	0.91	
Continued adoption	62.30%	80.23%	0.00	***
Unrestricted drinking water				
Not aware	62.36%	18.24%	0.00	***
Aware, but not adopt	16.50%	27.51%	0.00	***
Dis-adoption	0.00%	1.52%	0.02	**
Continued adoption	21.14%	52.73%	0.00	***
Forage conservation for the dry season (hay, silage)				
Not aware	64.82%	14.34%	0.00	***
Aware, but not adopt	30.19%	63.56%	0.00	***
Dis-adoption	4.63%	19.52%	0.00	***
Continued adoption	0.36%	2.57%	0.01	**
Improved milk hygiene to reduce total plate count (TPC)				
Not aware	24.55%	0.88%	0.00	***
Aware, but not adopt	2.74%	6.00%	0.00	***
Dis-adoption	0.00%	1.90%	0.01	**
Continued adoption	72.71%	91.22%	0.00	***
Stainless steel milking equipment				
Not aware	28.02%	8.60%	0.00	***
Aware, but not adopt	32.66%	38.37%	0.14	
Dis-adoption	1.77%	4.58%	0.04	**
Continued adoption	37.55%	48.45%	0.01	**
Teat dipping after milking				
Not aware	67.00%	9.28%	0.00	***
Aware, but not adopt	18.37%	28.16%	0.00	***
Dis-adoption	9.52%	25.42%	0.00	***
Continued adoption	5.11%	37.15%	0.00	***
Mastitis testing				
Not aware	79.28%	34.97%	0.00	***
Aware, but not adopt	10.24%	32.48%	0.00	***
Dis-adoption	4.85%	13.17%	0.00	***
Continued adoption	5.63%	19.38%	0.00	***
Rubber floor mat for the barn/cage				
Not aware	7.74%	0.35%	0.00	***
Aware, but not adopt	42.98%	21.00%	0.00	***
Dis-adoption	3.96%	3.68%	0.68	
Continued adoption	45.32%	74.97%	0.00	***
Record keeping				
Not aware	77.62%	22.67%	0.00	***
Aware, but not adopt	14.09%	40.46%	0.00	***
Dis-adoption	0.95%	10.56%	0.00	***
Continued adoption	7.34%	26.31%	0.00	***

Sig. = Significance level from ANOVA tests; * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ indicate significance at the 10%, 5% and 1% levels respectively.

Table A5-3 Main reasons for farmer's non-adoption despite awareness of technologies (%)

Technologies	Lack of information		High costs		Too complicated		Satisfied with the current practice		Limited availability of input	
	C1	C2	C1	C2	C1	C2	C1	C2	C1	C2
High protein concentrates (16% or higher)	22.73	13.10	65.91	60.71	6.82	8.33	6.82	11.90	13.64	16.67
Unrestricted access to drinking water	7.02	2.82	52.63	53.52	31.58	53.52	22.81	21.13	12.28	7.04
Forage conservation for the dry seasons (hay, silage)	37.25	15.57	35.29	33.53	48.04	47.31	15.69	20.36	9.80	14.37
Stainless steel milking equipment	3.60	2.00	74.77	60.00	4.50	6.00	22.52	25.00	6.31	7.00
Teat dipping after milking	20.97	33.78	27.42	22.97	20.97	21.62	22.58	10.81	25.81	21.62
Mastitis testing	29.03	34.83	12.90	8.99	29.03	26.97	38.71	40.45	0.00	1.12
Rubber floor mat for the barn/cage	5.48	1.85	82.88	79.63	6.16	3.70	17.12	25.93	0.68	3.70
Record keeping	6.38	5.56	0.00	0.00	57.45	62.96	36.17	15.74	0.00	0.00

Percentages: the proportion of farmers in the cluster who responded with reasons
Technologies that are highly adopted by both clusters are not presented
C = Cluster

Table A5-4 Main reasons for farmers' dis-adoption of technologies (%)

Technologies	Lack of information		High costs		Too complicated		Satisfied with the current practice		Limited availability of input	
	C1	C2	C1	C2	C1	C2	C1	C2	C1	C2
High protein concentrates (16% or higher)	6.25	1.85	62.50	75.93	0.00	5.56	6.25	5.56	18.75	18.52
Forage conservation for the dry seasons (hay, silage)	14.29	13.21	14.29	18.87	50.00	28.30	21.43	33.96	28.57	39.62
Teat dipping after milking	0.00	14.93	25.00	25.37	6.25	19.40	9.38	16.42	46.88	46.27
Mastitis testing	0.00	8.82	5.88	5.88	11.76	0.00	76.47	73.53	0.00	5.88
Record keeping	0.00	3.57	0.00	0.00	33.33	71.43	66.67	17.86	0.00	0.00

Percentages: the proportion of farmers in the cluster who responded with reasons
Technologies that are highly dis-adopted by both clusters are presented
C = Cluster

Table A5-5 Complete lists of significant variables that differentiate the latent classes

Variables	Definition	Cluster 1 (56.67%)	Cluster 2 (43.33%)	Total Mean	Total N	Sig.
Farmers characteristic						
Age	Age of the respondent (years)	47.15	45.06	46.24	600	**
Education	Education of the respondent (years)	5.69	7.42	6.44	600	***
Experience in dairy farming	Years of experience in dairy farming	18.10	20.37	19.08	600	**
Household characteristics						
Household size	Number of people in the household	3.85	4.07	3.95	600	*
Number of children	Members with age less than or equal to 18 years old	1.30	1.48	1.38	600	**
Have off-farm income	If HH has income from non-farming activity in the last 12 months (1=Yes, 0=Otherwise)	0.74	0.65	0.70	600	**
Household income						
Total income of all household	Total income of household from all their income activities (USD)†	2,095.51	4,495.31	3,132.89	600	***
Farm characteristics						
Total cows managed	Total dairy cows managed by the household	4.39	7.26	5.63	600	***
Total lactating cows managed	Total lactating cows	2.16	3.53	2.75	600	***
Farm milk production/day	Total farm milk production per day	30.56	50.10	39.02	600	***
Milk production per cow per day	Average milk production (litre/day))	14.42	15.19	14.75	600	**
Profitability						
Dairy farm profit	Dairy farm profit from all lactating cows managed in USD[1]	1,579.86	2,468.97	1,964.11	600	***
Capital and Credit						
Credit for dairy farming business	If farmer successfully access credit used for dairy farming business in the last 12 months	0.18	0.31	0.24	600	***
Labour						
Labour	Total hired labours in the farm	0.22	0.51	0.35	600	***
Male total hours	Total working hours of male family labour per day in dairy farming	6.92	7.51	7.18	600	**
Female total hours	Total working hours of female family labour per day in dairy farming	2.57	2.03	2.34	600	**
Total hired labour hours	Total working hours of hired labour per day in dairy farming	5.99	20.68	12.36	600	***

Sig. = Significance level from ANOVA tests; * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ indicate significance at the 10%, 5% and 1% levels respectively.
† Exchange rate 1 USD = 14,459.50 Indonesian Rupiah on 27 July 2018

Table A5-5 (Continued) Complete lists of significant variables that differentiate the latent classes

Variables	Definition	Cluster 1 (56.67%)	Cluster 2 (43.33%)	Total Mean	Total N	Sig.
Familiarity of the concept of milk quality indicators						
Familiarity about TPC	If farmers know about the concept of TPC (1=Yes, 0=Otherwise)	0.45	0.76	0.58	600	***
Familiarity about TS	If farmers know about the concept of Total solids (1=Yes, 0=Otherwise)	0.27	0.59	0.41	600	***
Familiarity about fat content	If farmers know about the concept of fat content (1=Yes, 0=Otherwise)	0.46	0.70	0.57	600	***
Familiarity about SCC	If farmers know about the concept of SCC (1=Yes, 0=Otherwise)	0.03	0.06	0.04	600	*
Familiarity about milk density	If farmers know about the concept of milk density (1=Yes, 0=Otherwise)	0.31	0.52	0.40	600	***
Marketing						
Number of milk buyers	Number of different buyers who farmers sell to	1.04	1.09	1.06	599	***
Number of type of products sold from dairy farms in the last 12 months	Number of types of products sold from dairy farm	1.79	2.14	1.94	600	***
Average milk price	Average milk price received in last 12 months in USD†	0.30	0.32	0.31	600	***
Distance to places in kilometres and minutes						
Distance to cooperative	in kilometres	0.37	0.25	9.09	588	**
Distance to farmer group leader	in kilometres	0.77	0.52	0.66	589	*
Distance to cooperative	in minutes	36.45	29.32	33.35	593	***
Distance to farmer group leader	in minutes	7.32	5.74	6.64	590	**
Meetings with cooperative and farm groups						
Always meet with cooperatives	If farmers always meet with the cooperative (1=Yes, 0=Otherwise)	0.50	0.62	0.55	600	***
Always meet with farmers group	If farmers always meet with the cooperative (1=Yes, 0=Otherwise)	0.42	0.54	0.48	600	***
Number of contacts in the last 12 months with veterinary doctor about […]						
Cow health	Number of contacts farmers made with vet doctor to access information about […] in the last 12 months	1.70	2.18	1.55	600	**
Number of contacts in the last 12 months with cooperative extensions about […]						
Increase milk quality	Number of contacts	1.48	2.18	1.79	600	**
Increase milk yield	Number of contacts	0.97	1.44	1.18	600	*
Information on new technology	Number of contacts	0.04	0.15	0.09	600	***
Value addition	Number of contacts	0.06	0.27	0.15	600	*
Feed supplement	Number of contacts	0.02	0.41	0.19	600	***
Mastitis test	Number of contacts	0.00	0.10	0.04	600	*

Sig. = Significance level from ANOVA tests; * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ indicate significance at the 10%, 5% and 1% levels respectively.

† Exchange rate 1 USD = 14,459.50 Indonesian Rupiah on 27 July 2018

Table A5-5 (Continued) Complete lists of significant variables that differentiate the latent classes

Variables	Definition	Cluster 1 (56.67%)	Cluster 2 (43.44%)	Total Mean	Total N	Sig.
Provision of support from cooperative about […..] (1 = Yes and utilised)						
Forages	If farmers utilised the support […] (1=Yes, 0=Otherwise)	0.24	0.32	0.28	600	**
Information on new technology	If farmers utilised the support […] (1=Yes, 0=Otherwise)	0.35	0.53	0.43	600	***
New management practices	If farmers utilised the support […] (1=Yes, 0=Otherwise)	0.20	0.34	0.26	600	***
Government program	If farmers utilised the support […] (1=Yes, 0=Otherwise)	0.21	0.36	0.28	600	***
Feed supplement	If farmers utilised the support […] (1=Yes, 0=Otherwise)	0.55	0.73	0.63	600	***
Mastitis test	If farmers utilised the support […] (1=Yes, 0=Otherwise)	0.16	0.43	0.28	600	***
Provision of support from farmers group about […..] (1 = Yes and utilised)						
Information on new technology	If farmers utilised the support […] (1=Yes, 0=Otherwise)	0.14	0.21	0.17	600	**
Government program	If farmers utilised the support […] (1=Yes, 0=Otherwise)	0.08	0.17	0.12	600	***
Value addition	If farmers utilised the support […] (1=Yes, 0=Otherwise)	0.02	0.05	0.04	600	**
Mastitis test	If farmers utilised the support […] (1=Yes, 0=Otherwise)	0.00	0.02	0.01	600	**
Adoption attitude						
Adoption attitude score	Higher score means farmers adopt more quickly than others	3.59	3.40	3.51	600	**

Sig. = Significance level from ANOVA tests; * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ indicate significance at the 10%, 5% and 1% levels respectively.

Table A5-6 Length of time of the continued used of the technologies (years)

Technologies	N	Mean	SD	Min	Max
Dairy feed					
High protein concentrates (16% or higher)	47	8.70	9.28	0	36
High-quality grass varieties	439	14.88	9.36	0	50
Fertiliser to grow grass	417	13.66	9.02	0	50
Unrestricted access to drinking water	210	16.71	10.59	0	50
Forage conservation for the dry seasons (hay, silage)	7	3.43	1.40	1	54
Milk quality-enhancing					
Detergents on milking equipment	501	14.90	10.28	0	50
Improved milking hygiene to reduce TPC	482	13.04	9.73	0	47
Stainless steel milking equipment	250	13.00	10.52	0	44
Animal health					
Teat dipping after milking	113	9.97	9.34	1	50
Mastitis testing	70	5.74	7.88	0	35
Rubber floor mat for the barn/cage	348	7.65	5.77	0	38
Farm management					
Record keeping	93	13.14	10.35	0	39

N = numbers of continuous adopters

The minimum of 0-year duration indicates that farmers just started to adopt the technology in 2017, which only account for a small number of farmers from the sample.

Table A5-7 Average characteristics of farmers who were aware but not adopted technologies

Variables	Mean
Individual, household and farm characteristics	
Age (years)	45.54
Education (years)	6.70
Experience (years)	19.27
Household size (members)	3.89
Herd size (cows)	5.33
Farm milk production (litres/day)	37.97
Cow productivity (litres/cow/day)	14.65
Dairy farm profit (USD/year)	2026.31
Credit (1 = Yes)	0.58
Labour (people)	0.31
Distance to cooperative (minutes)	32.93
Distance to farmer group leader house (minutes)	6.23
Marketing and familiarity with milk quality	
Milk buyers (number of buyers)	1.05
Milk price (USD/litre)	4457.15
Familiar with TPC (1=Yes)	0.62
Familiar with TS (1=Yes)	0.37
Familiar with fat content (1=Yes)	0.57
Familiar with milk density(1=Yes)	0.38
Group participation, contacts and use of dairy farming services	
Attend meetings with cooperatives (1=Yes)	0.53
Attend meetings with farmer’s group (1=Yes)	0.45
Number of times contacted (in the last 12 months) dairy cooperative extension to access information about […]	
Milk quality (contacts)	1.91
Milk yield (contacts)	1.32
Information on new technology (contacts)	0.10
Value addition (contacts)	0.18
Feed supplement (contacts)	0.25
Utilisation of support from the dairy cooperative about [….]	
Forages (1=Yes)	0.31
Information on new technology (1=Yes)	0.44
New management practices (1=Yes)	0.33
Government program (1=Yes)	0.32
Feed supplement (1=Yes)	0.68
Mastitis testing (1=Yes)	0.33

Means were calculated based on the average characteristics of farmers who were aware but not adopted for each of the technology.

Appendix 6. Appendices for Chapter 3: Adoption of technology bundles improves smallholder dairy farmers' milk production

Table A6-1 Comparisons between sample retained for analysis (n=518) and dropped sample due to missing values (n=82)

	Retained sample (n=518)	Dropped sample (n=82)	Diff.	Total sample (n=600)	P-value	Sig.
Milk production per cow (litres/day)	14.74	14.85	-0.11	14.75	0.81	
Age of farmer (years)	46.25	46.17	0.08	46.24	0.95	
Education of farmer (years)	6.45	6.35	0.10	6.44	0.79	
Number of family members	3.99	3.66	0.33	3.95	0.05	*
Non-production asset ownership index[12]	0.10	-0.11	0.20	0.06	0.24	
Tropical livestock units (non-dairy)[13]	0.37	0.22	0.15	0.35	0.77	
Farm altitude (kilometres)	1.27	1.37	-0.10	1.28	0.01	**
Total dairy cows managed	5.66	5.43	0.24	5.63	0.69	
Dairy farming equipment ownership index[12]	0.03	-0.13	0.15	0.00	0.45	
Own land for growing grass (1 = Yes)	0.20	0.16	0.04	0.19	0.41	
Hired labour (1=Yes)	0.21	0.23	-0.02	0.22	0.72	
Average age (years)	4.97	5.18	-0.21	5.00	0.27	
Average age when first calving (years)	2.26	2.29	-0.03	2.26	0.57	
Average calving interval in ideal range 12-13 months (1=Yes)	0.44	0.49	-0.05	0.45	0.44	
Had credit in the last 12 months (1=Yes)	0.56	0.57	-0.01	0.57	0.87	
Farmers received information about feed technology in the last 12 months (1=Yes)	0.58	0.51	0.07	0.57	0.27	
Off-farm income (1=Yes)	0.70	0.71	-0.01	0.70	0.85	

Diff: Differences between retained sample and dropped sample
P-value from t-tests
Sig: *** p<0.01, ** p<0.05, * p<0.1

Table A6-2 Heterogeneity of adoption of dairy feed technologies by smallholder dairy farmers (n=518)

High protein concentrates	High-quality grass varieties	Fertiliser to grow grass	Unrestricted access to drinking water	n	%
				71	12.57
	√			55	9.73
		√		50	8.85
	√	√		174	30.80
√	√			2	0.35
√		√		1	0.18
	√	√	√	120	21.24
√	√	√		15	2.65
√	√		√	4	0.71
√		√	√	2	0.35
√	√	√	√	24	4.25

Table A6-3 Non-production asset index deriving from Principal Component Analysis (PCA)

Asset variables	Obs	Mean	SD	Min	Max	Weights from PCA (first component)
Refrigerator	518	0.39	0.49	0	1	0.41
Mobile phone	518	0.87	0.34	0	1	0.32
Television	518	0.97	0.17	0	1	0.13
Parabola	518	0.25	0.43	0	1	-0.10
Internet	518	0.48	0.50	0	1	0.38
Washing machine	518	0.17	0.37	0	1	0.41
Three-wheeled motorcycle	518	0.01	0.11	0	1	0.07
Truck	518	0.00	0.04	0	1	0.12
No motorcycles	518	0.18	0.38	0	1	-0.30
Have 1 motorcycle	518	0.36	0.48	0	1	-0.16
Have 2 motorcycles	518	0.31	0.46	0	1	0.11
Have 3 motorcycles	518	0.16	0.36	0	1	0.38
Car	518	0.10	0.30	0	1	0.31

Table A6-3a PCA non-production asset

Component	Eigen value	Difference	Proportion	Cumulative
Comp1	2.43	0.89	0.19	0.19
Comp2	1.54	0.11	0.12	0.31
Comp3	1.43	0.27	0.11	0.42
Comp4	1.16	0.09	0.09	0.50
Comp5	1.07	0.08	0.08	0.59
Comp6	0.99	0.05	0.08	0.66
Comp7	0.94	0.05	0.07	0.74
Comp8	0.89	0.17	0.07	0.80
Comp9	0.72	0.01	0.06	0.86
Comp10	0.71	0.09	0.05	0.91
Comp11	0.62	0.11	0.05	0.96
Comp12	0.51	0.51	0.04	1.00
Comp13	0.00	.	0.00	1.00

Table A6-3b Internal validity of non-production asset index: Results based on the first principal component

	1 (20% Poorest)	**2**	**3**	**4**	**5 (20% richest)**	**Total**
Refrigerator	0.08	0.10	0.23	0.78	0.90	0.39
Mobile phone	0.46	0.93	0.99	0.99	1.00	0.87
Television	0.92	0.97	0.97	1.00	1.00	0.97
Parabola	0.41	0.29	0.20	0.20	0.15	0.25
Internet	0.00	0.22	0.76	0.61	0.87	0.48
Washing machine	0.00	0.00	0.02	0.16	0.70	0.17
Three wheeled motorcycle	0.00	0.01	0.00	0.04	0.02	0.01
Truck	0.00	0.00	0.00	0.00	0.01	0.00
No motorcycles	0.58	0.15	0.09	0.01	0.02	0.18
Have 1 motorcycle	0.40	0.47	0.44	0.29	0.16	0.36
Have 2 motorcycles	0.03	0.37	0.41	0.44	0.32	0.31
Have 3 motorcycles	0.00	0.02	0.06	0.26	0.50	0.16
Car	0.00	0.02	0.04	0.07	0.41	0.10

To the test the validity of the index, smallholder dairy farm households were divided into quantiles. Overall, farmers at the fifth quantile (20% richest) show much higher levels of asset ownership compared to farmers in the other quantiles. One exception is the ownership of parabola. Parabola has function to capture more tv channels for places with blank spot. Richer households less likely to have parabola, because richer household may have used more advanced tools for television receiver. Richer household may not have parabola anymore because they have better location that does not need parabola anymore. Poorer households more likely to have parabola because their location maybe less developed (blank spot) which need parabola to capture tv channels.

Table A6-4 Dairy farm equipment index derived from Principal Component Analysis (PCA)

Asset variables	Obs	Mean	SD	Min	Max	Weights from PCA (first component)
Hand tractor	518	0.00	0.06	0	1	0.16
Cow barn	518	0.92	0.27	0	1	0.10
Warehouse	518	0.33	0.47	0	1	0.26
Water pump	518	0.34	0.48	0	1	0.22
Spray pump	518	0.21	0.41	0	1	0.09
Recording facility	518	0.12	0.33	0	1	0.31
Rubber floor	518	0.59	0.49	0	1	0.30
Chaff cutter	518	0.18	0.39	0	1	0.06
Aluminium milking can	518	0.84	0.37	0	1	0.15
Stainless steel milk can	518	0.30	0.46	0	1	0.23
Plastic buckets	518	0.98	0.13	0	1	0.02
Milking machines	518	0.01	0.11	0	1	0.28
Drum can	518	0.18	0.39	0	1	0.18
Litre measurement tool	518	0.40	0.49	0	1	0.33
Milk filter	518	0.98	0.14	0	1	0.06
Teat dipper	518	0.20	0.40	0	1	0.26
Scale	518	0.07	0.25	0	1	0.23
Brush	518	0.96	0.20	0	1	0.12
Broom	518	0.98	0.13	0	1	0.04
Mattock	518	0.93	0.25	0	1	0.08
Metal fork tool	518	0.51	0.50	0	1	0.31
Hose	518	0.82	0.38	0	1	0.20
Plastic boots	518	0.99	0.08	0	1	0.00
Milk processing tool	518	0.21	0.41	0	1	0.00
Biogas	518	0.08	0.28	0	1	0.21
Manure tool	518	0.02	0.12	0	1	0.17

Table A6-4a PCA dairy farm equipment

Component	Eigen value	Difference	Proportion	Cumulative
Comp1	2.81	1.25	0.11	0.11
Comp2	1.56	0.10	0.06	0.17
Comp3	1.46	0.10	0.06	0.22
Comp4	1.36	0.08	0.05	0.28
Comp5	1.28	0.04	0.05	0.33
Comp6	1.24	0.04	0.05	0.37
Comp7	1.21	0.10	0.05	0.42
Comp8	1.11	0.05	0.04	0.46
Comp9	1.06	0.03	0.04	0.50
Comp10	1.04	0.04	0.04	0.54
Comp11	1.00	0.01	0.04	0.58
Comp12	0.99	0.06	0.04	0.62
Comp13	0.93	0.05	0.04	0.66
Comp14	0.88	0.04	0.03	0.69
Comp15	0.84	0.02	0.03	0.72
Comp16	0.82	0.03	0.03	0.75
Comp17	0.79	0.04	0.03	0.78
Comp18	0.75	0.02	0.03	0.81
Comp19	0.73	0.05	0.03	0.84
Comp20	0.68	0.01	0.03	0.87
Comp21	0.67	0.05	0.03	0.89
Comp22	0.62	0.02	0.02	0.92
Comp23	0.60	0.05	0.02	0.94
Comp24	0.55	0.03	0.02	0.96
Comp25	0.53	0.04	0.02	0.98
Comp26	0.48	.	0.02	1.00

Table A6-4b Internal validity of dairy farming equipment index: Results based on the first principal component

	1 (20% Poorest)	2	3	4	5 (20% richest)	Total
Hand tractor	0.00	0.00	0.00	0.00	0.02	0.00
Cow barn	0.82	0.92	0.92	0.96	0.98	0.92
Warehouse	0.09	0.18	0.27	0.45	0.67	0.33
Water pump	0.13	0.23	0.34	0.40	0.63	0.34
Spray pump	0.17	0.16	0.19	0.24	0.28	0.21
Recording facility	0.00	0.03	0.03	0.16	0.41	0.12
Rubber floor	0.13	0.46	0.64	0.79	0.92	0.59
Chaff cutter	0.16	0.14	0.18	0.21	0.22	0.18
Aluminium milking can	0.64	0.84	0.88	0.87	0.96	0.84
Stainless steel milk can	0.08	0.19	0.24	0.47	0.53	0.30
Plastic buckets	0.97	0.98	0.98	1.00	0.98	0.98
Milking machines	0.00	0.00	0.00	0.00	0.06	0.01
Drum can	0.08	0.09	0.15	0.23	0.37	0.18
Litre measurement tool	0.04	0.16	0.37	0.60	0.83	0.40
Milk filter	0.95	0.97	0.99	0.99	1.00	0.98
Teat dipper	0.01	0.04	0.19	0.26	0.52	0.20
Scale	0.00	0.01	0.03	0.09	0.22	0.07
Brush	0.87	0.95	0.99	0.99	0.99	0.96
Broom	0.95	0.98	1.00	0.99	0.99	0.98
Mattock	0.88	0.94	0.92	0.93	0.99	0.93
Metal fork tool	0.10	0.36	0.52	0.68	0.88	0.51
Hose	0.57	0.78	0.92	0.90	0.96	0.82
Plastic boots	0.99	1.00	0.99	1.00	0.99	0.99
Milk processing tool	0.28	0.15	0.16	0.21	0.24	0.21
Biogas	0.00	0.04	0.08	0.05	0.26	0.08
Manure tool	0.00	0.00	0.00	0.00	0.08	0.02

To the test the validity of the index, smallholder farmers were divided into quantiles. Overall, farmers the fifth quantile (20% richest) show much higher levels of dairy farming equipment ownership compared to farmers in the other quantiles. One exception is the ownership of milk processing tools. The proportion of the poorest and the richest household were almost equal who had milk processing tool. Milk processing tool can be a simple tool like pot to boil milk. The ownership of the tool may be associated whether farmers boil the milk for their family consumption.

Table A6-5 Simple falsification test for validity of exclusion restriction variables

Exclusion restriction variables	Model 1(MNL)				
	Adoption (1,2,3,4,5); Base category (0)				
	1	2	3	4	5
Received information about feed technologies (1=Yes)	0.53 (0.39)	-0.85 (0.41)**	0.34(0.31)	-0.26(0.34)	0.57(0.44)
Off-farm income (1=Yes)	-0.26 (0.46)	-0.64(-.48)	-0.21(0.36)	-0.12(0.39)	0.11(0.49)
Wald test	Chi2 (10) = 21.26				
P-value	***0.02***				
Sample size	518				
Pseudo R-squared	0.14				

Exclusion restriction variables	Model 2 (OLS) Milk production						
	Model 2a All sample	Model 2b Adopt=0	Model 2c Adopt=1	Model 2d Adopt=2	Model 2e Adopt=3	Model 2f Adopt=4	Model 2g Adopt=5
Received information about feed technologies (1=Yes)	-0.06(0.34)	0.02(0.88)	1.58(1.02)	-2.21(1.59)	-0.37(0.68)	-0.53(0.72)	0.46(1.55)
Off-farm income (1=Yes)	-0.46(0.38)	-0.03(1.03)	0.27(1.23)	-0.85(1.68)	-0.51(0.73)	1.04(0.83)	-1.68(1.66)
Wald test	F-stat = 0.74	F-stat = 0.00	F-stat = 1.22	F-stat = 1.09	F-stat = 0.39	F-stat = 1.01	F-stat = 0.52
P-value	***0.48***	***1.00***	***0.31***	***0.35***	***0.68***	***0.37***	***0.60***
Sample size	518	71	55	50	174	120	48
R-squared	0.13	0.39	0.47	0.43	0.16	0.19	0.44

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
0 = Do not adopt any technologies
1 = High-quality grass varieties only
2 = Fertiliser only
3 = Bundle A: High-quality grass varieties and fertiliser
4 = Bundle B: Bundle A plus unrestricted access to drinking water
5 = Bundle C: High protein concentrates with any other technologies

Wald tests show that the two exclusion restrictions jointly affects farmers' decisions to adopt dairy feed practices (Model 1; p-value<0.05), but not affect milk production per cow (Model 2a-2g p-values>0.10).

Table A6-6 Multinomial logit (odds ratio) estimation of the probability of the adoption of technology bundles relative to non-adopters

Variables	**1**	**2**	**3**	**4**	**5**
Age (years)	0.05***	0.05**	0.03*	0.03*	-0.01
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Education (years)	0.19**	0.21**	0.13*	0.18**	0.24***
	(0.08)	(0.09)	(0.07)	(0.07)	(0.09)
Household size	-0.01	-0.05	0.00	0.07	-0.03
	(0.15)	(0.15)	(0.12)	(0.12)	(0.17)
Non-production asset index[12]	0.36*	0.45**	0.36**	0.25	0.24
	(0.20)	(0.21)	(0.16)	(0.18)	(0.22)
Tropical livestock unit (non-dairy)[13]	-0.01	-0.95*	-0.60**	-0.18	-0.02
	(0.09)	(0.50)	(0.25)	(0.16)	(0.08)
House altitude (kilometres)	0.92	-1.82	-0.51	-0.77	0.83
	(1.39)	(1.37)	(1.10)	(1.14)	(1.57)
Total dairy cows	-0.02	0.02	0.03	0.05	0.02
	(0.08)	(0.07)	(0.06)	(0.06)	(0.07)
Dairy farming equipment index[12]	-0.22	0.09	0.21	0.36**	0.62***
	(0.19)	(0.19)	(0.15)	(0.15)	(0.18)
Own land for growing grass (1 = Yes)	-0.48	1.69**	1.55**	1.89***	2.11***
	(0.97)	(0.71)	(0.65)	(0.66)	(0.75)
Hired labour (1=Yes)	0.49	0.84	0.22	0.86	0.24
	(0.63)	(0.62)	(0.54)	(0.55)	(0.66)
Average of lactating cows managed years)	0.00	0.10	0.06	-0.11	0.13
	(0.13)	(0.13)	(0.10)	(0.12)	(0.14)
Average age of first calving of lactating cows years)	0.23	-1.09	0.08	-0.14	0.31
	(0.49)	(0.70)	(0.45)	(0.51)	(0.52)
Ideal calving interval of lactating cows (1=Yes)	0.17	0.09	0.19	0.36	0.58
	(0.39)	(0.41)	(0.32)	(0.34)	(0.43)
Had credit in the last 12 months (1=Yes)	0.87**	0.60	1.05***	1.08***	1.00**
	(0.40)	(0.42)	(0.32)	(0.35)	(0.44)
Received information of feed and technology (1=Yes)	0.53	-0.85**	0.34	-0.26	0.57
	(0.39)	(0.41)	(0.31)	(0.34)	(0.44)
Off-farm income (1=Yes)	-0.26	-0.64	-0.21	-0.12	0.11
	(0.46)	(0.48)	(0.36)	(0.39)	(0.49)
Bandung (1=Yes)	0.35	0.85	-0.19	-0.66	-0.36
	(1.23)	(1.17)	(0.90)	(0.92)	(1.18)
Garut (1=Yes)	-0.10	1.72*	0.80	-0.13	-0.63
	(1.12)	(1.02)	(0.77)	(0.81)	(1.10)
Cianjur (1=Yes)	1.46	0.41	0.30	-0.97	-1.13
	(1.02)	(0.91)	(0.70)	(0.72)	(0.98)
Constant	-6.65***	-0.09	-1.87	-0.96	-5.01*
	(2.51)	(2.69)	(1.97)	(2.11)	(2.66)
Observations	518	518	518	518	518

Standard errors in parantheses
*** p<0.01, ** p<0.05, * p<0.1
0 = Do not adopt any technologies
1 = High-quality grass varieties only
2 = Fertiliser only
3 = Bundle A: High-quality grass varieties and fertiliser
4 = Bundle B: Bundle A plus unrestricted access to drinking water
5 = Bundle C: High protein concentrates with any other technologies

Table A6-7 Multinomial logit (odds ratio) estimation of the probability of the adoption of technology bundles relative to different base categories of bundles

Variables	**3 vs 1**	**4 vs 3**	**5 vs 1**	**5 vs 3**	**5 vs 4**
Age (years)	-0.03	0.00	-0.07***	-0.04**	-0.05**
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)
Education (years)	-0.06	0.05	0.05	0.12*	0.07
	(0.07)	(0.05)	(0.09)	(0.07)	(0.07)
Household size	0.01	0.07	-0.02	-0.03	-0.10
	(0.13)	(0.09)	(0.18)	(0.15)	(0.15)
Non-production asset index[12]	0.01	-0.11	-0.11	-0.12	-0.00
	(0.17)	(0.13)	(0.22)	(0.18)	(0.19)
Tropical livestock unit (non-dairy)[13]	-0.59**	0.42*	-0.01	0.58**	0.16
	(0.25)	(0.24)	(0.05)	(0.25)	(0.16)
House altitude (kilometres)	-1.42	-0.26	-0.08	1.34	1.60
	(1.21)	(0.83)	(1.63)	(1.37)	(1.36)
Total dairy cows	0.05	0.02	0.05	-0.01	-0.02
	(0.06)	(0.03)	(0.07)	(0.04)	(0.04)
Dairy farming equipment index[12]	0.43***	0.15	0.84***	0.41***	0.26*
	(0.16)	(0.11)	(0.19)	(0.14)	(0.14)
Own land for growing grasses (1 = Yes)	2.02**	0.34	2.59***	0.57	0.23
	(0.79)	(0.31)	(0.87)	(0.47)	(0.47)
Hired labour (1=Yes)	-0.27	0.64*	-0.25	0.02	-0.62
	(0.48)	(0.35)	(0.62)	(0.51)	(0.51)
Average of lactating cows managed (years)	0.06	-0.17*	0.13	0.07	0.24*
	(0.11)	(0.09)	(0.14)	(0.11)	(0.12)
Average age of first calving of lactating cows (years)	-0.15	-0.22	0.08	0.23	0.45
	(0.38)	(0.39)	(0.45)	(0.41)	(0.47)
Ideal calving interval of lactating cows (1=Yes)	0.02	0.16	0.41	0.39	0.23
	(0.34)	(0.26)	(0.44)	(0.37)	(0.38)
Had credit in the last 12 months (1=Yes)	0.19	0.03	0.14	-0.05	-0.08
	(0.34)	(0.27)	(0.45)	(0.38)	(0.39)
Received information of feed technology (1=Yes)	-0.19	-0.61**	0.04	0.23	0.84**
	(0.35)	(0.27)	(0.47)	(0.40)	(0.40)
Off-farm income (1=Yes)	0.05	0.09	0.37	0.32	0.23
	(0.40)	(0.29)	(0.51)	(0.42)	(0.43)
Bandung (1=Yes)	-0.54	-0.47	-0.71	-0.17	0.30
	(1.09)	(0.65)	(1.32)	(0.97)	(0.96)
Garut (1=Yes)	0.89	-0.93*	-0.53	-1.43	-0.50
	(0.98)	(0.55)	(1.25)	(0.92)	(0.92)
Cianjur (1=Yes)	-1.16	-1.27***	-2.59**	-1.43*	-0.16
	(0.89)	(0.47)	(1.12)	(0.80)	(0.79)
Constant	4.77**	0.91	1.63	-3.14	-4.05*
	(2.16)	(1.59)	(2.78)	(2.28)	(2.34)
Observations	518	518	518	518	518

Standard errors in parentheses
Levels of significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$
0 = Do not adopt any technologies
1 = High-quality grass varieties only
2 = Fertiliser only
3 = Bundle A: High-quality grass varieties and fertiliser
4 = Bundle B: Bundle A plus unrestricted access to drinking water
5 = Bundle C: High protein concentrates with any other technologies

Table A6-8 Average treatment effects on the treated (ATET) estimated using Multinomial Endogenous Switching Regression (MESR) and Inverse Probability Weighted Regression Adjustment (IPWRA†)‡

Comparisons	MESR				IPWRA			
	ATET	**p-value**	**SE**	**95% CI**	**ATET**	**p-value**	**SE**	**95% CI**
1 vs 0	1.34	0.00	0.45	[0.44 - 2.24]	0.59	0.39	0.69	[-0.75 - 1.94]
2 vs 0	0.90	0.11	0.54	[-0.20 - 1.20]	0.74	0.36	0.80	[-0.83 - 2.30]
3 vs 0	1.13	0.00	0.22	[0.70 - 1.56]	0.97	0.09	0.58	[-0.16 - 2.10]
4 vs 0	1.23	0.00	0.25	[0.73 - 1.72]	1.26	0.12	0.82	[-0.35 - 2.87]
5 vs 0	2.53	0.00	0.60	[1.33 - 3.73]	1.86	0.16	1.31	[-0.70 - 4.43]
2 vs 1	1.14	0.04	0.54	[0.05 - 2.23]	2.28	0.01	0.90	[0.52 - 4.03]
3 vs 1	0.18	0.44	0.22	[-0.27 - 0.62]	1.17	0.04	0.73	[0.05 - 2.29]
4 vs 1	1.42	0.00	0.30	[0.83 - 2.00]	1.55	0.03	0.71	[0.16 - 2.93]
5 vs 1	1.92	0.00	0.53	[0.87 - 3.00]	2.02	0.01	0.77	[0.51 - 3.53]
3 vs 2	-0.22	0.37	0.25	[-0.71 - 0.27]	-0.11	0.86	0.62	[-1.32 - 1.10]
4 vs 2	0.47	0.32	0.47	[-0.46 - 1.40]	0.39	0.58	0.71	[-1.00 - 1.79]
5 vs 2	-0.19	0.84	0.90	[-2.01 - 1.63]	-0.63	0.59	1.16	[-2.89 - 1.64]
4 vs 3	0.17	0.38	0.19	[-0.21 - 0.55]	-0.03	0.95	0.47	[-0.94 - 0.88]
5 vs 3	0.91	0.02	0.39	[0.13 - 1.69]	0.73	0.39	0.85	[-0.94 - 2.39]
5 vs 4	1.24	0.01	0.44	[0.36 - 2.12]	0.95	0.23	0.80	[-0.61 - 2.51]

† IPWRA estimation was performed using command *teffects ipwra* in Stata 16.
‡The entire results of MESR and IPWRA regression are available on request.
SE = Bootstrapped standard errors
0 = Do not adopt any technologies
1 = High-quality grass varieties only
2 = Fertiliser only
3 = Bundle A: High-quality grass varieties and fertiliser
4 = Bundle B: Bundle A plus unrestricted access to drinking water
5 = Bundle C: High protein concentrates with any other technologies

Table A6-9 Heterogeneity analysis based on the herd size managed by dairy farm households

Tercile 1 (n =187)					
Adoption of technologies	**Base categories**				
	0	1	2	3	4
1 = High-quality grass varieties only	-0.54				
	(0.82)				
2 = Fertiliser only	6.60	-46.10			
	(0.14)	*(0.03)*			
3 = Bundle A: High-quality grass varieties and fertiliser	1.96	-61.60	-1.39		
	(0.23)	*(0.00)*	*(0.55)*		
4 = Bundle B: Bundle A plus unrestricted access to drinking water	0.77	-57.61	-3.92	-0.44	
	(0.80)	*(0.00)*	*(0.24)*	*(0.56)*	
5 = Bundle C: High protein concentrates with any other technologies	8.31	-40.11	-2.58	2.21	-8.77
	(0.12)	*(0.20)*	*(0.65)*	*(0.08)*	*(0.14)*
Tercile 2 (n=194)					
Adoption of technologies (a)	**Base categories**				
	0	1	2	3	4
1 = High-quality grass varieties only	1.90				
	(0.32)				
2 = Fertiliser only	-1.67	-13.42			
	(0.54)	*(0.02)*			
3 = Bundle A: High-quality grass varieties and fertiliser	-2.63	-18.09	-1.99		
	(0.12)	*(0.00)*	*(0.24)*		
4 = Bundle B: Bundle A plus unrestricted access to drinking water	3.15	-11.14	-2.05	-1.04	
	(0.11)	*(0.02)*	*(0.20)*	*(0.24)*	
5 = Bundle C: High protein concentrates with any other technologies	5.16	-23.45	2.62	-0.40	1.24
	(0.10)	*(0.17)*	*(0.42)*	*(0.75)*	*(0.34)*
Tercile 3 (n=137), MESR cannot converge because of too few observations.					

p-values in the parentheses
0 = Do not adopt any technologies
Milk production differences between farmers who adopt particular technology or bundles (column: Adoption of technologies) and the production of farmers who did not adopt any technologies (column 0) and those who adopt other technology or bundles (column 1 to 4)

Table A6-10 Total herd size managed by dairy farm households

Variable	Obs	Mean	SD	Min	Max
Total dairy cows	518	5.66	4.87	1	39
Tercile:					
Tercile 1	187	2.34	0.69	1	3
Tercile 2	194	4.80	0.85	4	6
Tercile 3	137	11.43	6.21	7	39

Table A6-11 Distribution of adoption of single and bundle of feed technologies by sample and sub-sample (terciles)

Technologies	Sample	Sub-sample		
		Tercile 1	**Tercile 2**	**Tercile 3**
0 = Non -adoption	71	28	35	8
1 = High-quality grass varieties only	55	23	22	10
2 = Fertiliser only	50	21	18	11
3 = Bundle A: High-quality grass varieties and fertiliser	174	66	63	45
4 = Bundle B: Bundle A plus unrestricted access to drinking water	120	38	34	48
5 = Bundle C: High protein concentrates with any other technologies	48	11	22	15
Total	**518**	**187**	**194**	**137**

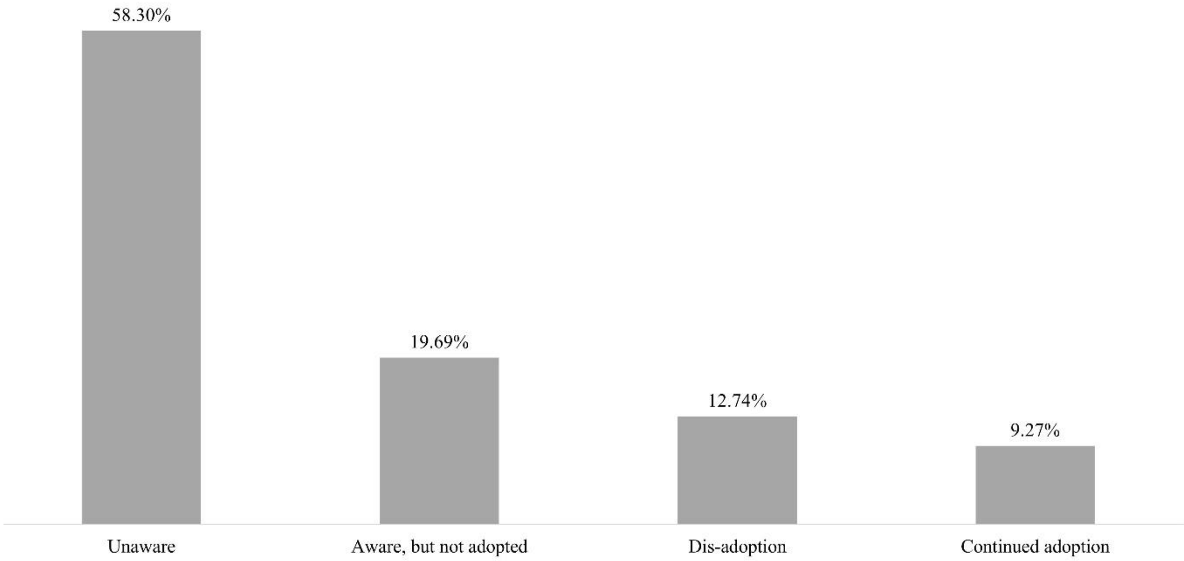

Figure A6-1 Adoption decisions of high protein concentrates (16% protein or higher)

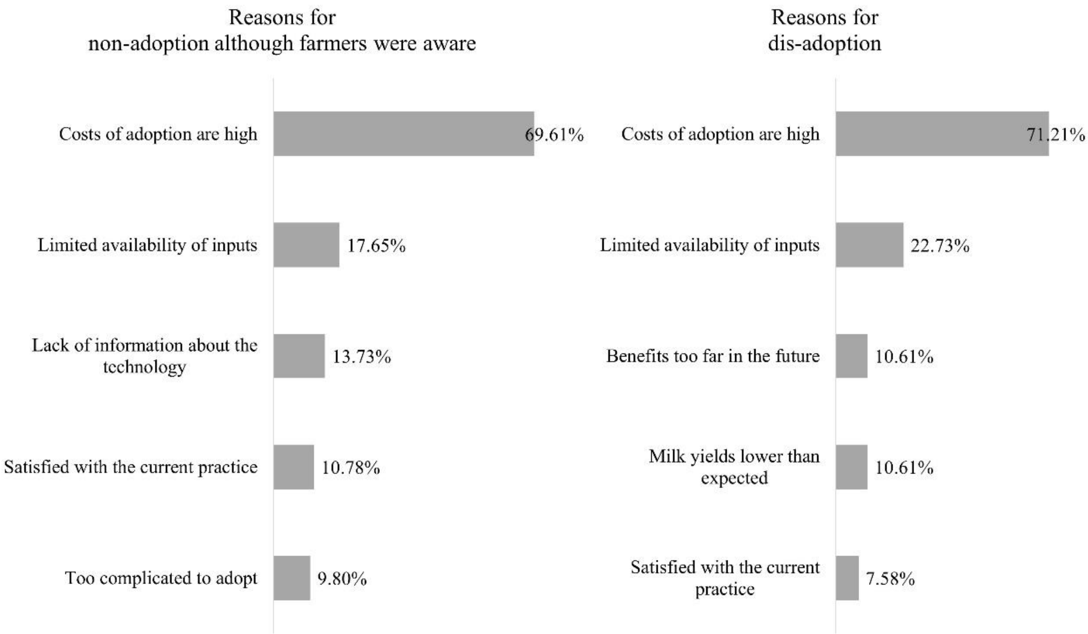

Figure A6-2 Top five reasons for non-adoption of high protein concentrates (multiple responses)

Appendix 7. Appendices for Chapter 4: Institutional failures hinder continuous adoption of agricultural technologies: The case of smallholder dairy farmers in Indonesia

Sampling technique

The Indonesian dairy industry is highly concentrated on Java Island, which accounts for 97% of the dairy cattle population and 98% of its milk production (Ministry of Agriculture Indonesia 2019). The majority of smallholder farmers in Indonesia are located in dairy producing districts in West Java Province, with close proximity to urban areas such as Jakarta, Bandung and Bogor where the demand for dairy products is considerably high. The majority of these smallholder farmers are members of dairy cooperatives (Statistics Indonesia 2015). Therefore, the sample of this study is dairy farmers who are cooperative members in four dairy-producing districts in West Java including Bandung, Garut, Cianjur and Bogor. The survey interviewed 600 randomly selected dairy farm households between August and September 2017.

A purposive proportional random sampling method was utilised to identify the sample. Five dairy cooperatives were identified through a consultation process and purposively selected following the criteria developed by the project such as willingness to share information and to participate in project extension programs. The number of dairy farm households selected from each district was proportional to the share of the total dairy farmers in the district to the total of dairy farm population from the four districts. Respondents were randomly selected using simple random tools from each of the districts according to the proportion that has been set. The final sample distribution by districts is presented in Table A7-1. This sampling design method ensured that our survey sample would be representative of the smallholder dairy farmers in West Java.

Table A7-1 Distribution of population and respondents by districts in the household survey

Districts	Farmers population	Initial proportion (%)	Final Proportion (%)	Respondents
Bandung	2860	62.13	50.00	300
Garut	1268	27.55	23.33	140
Cianjur	170	3.69	13.33	80
Bogor	305	6.63	13.33	80
Total	**4603**	**100.00**	**100.00**	**600**

Explanation of the characteristics of technologies analysed in Chapter 4

Forage conservation for the dry season (e.g. making silage)

In tropical dairy farming conditions, such as in Indonesia, the dry season (peaking from July to September) causes limited availability of forages, hindering dairy production (Maleko et al. 2018; Reiber et al. 2010). Conserving forages, such as making silage, is an alternative management practice that helps ensure sufficient feed resources to maintain dairy cow production during dry seasons (Lewa & Muinga 2013; Reiber et al. 2010). The implementation of the practice requires that farmer have access to complementary inputs, including forage choppers, storage containers and molasses as a substrate (Moran 2005). Besides labour, time and resource intensiveness, the adoption of forage conservation also requires farmers implementing a strict set of guidelines to produce high-quality silage (Balehegn et al. 2020; Moran 2005), thus, this could be considered to be a knowledge-intensive technology.

High crude protein concentrates

Feeding dairy cows rations (diets) that include high (16% or greater) crude protein (CP) concentrate, improves the nutrition of dairy cows, particularly those that are fed primarily tropical forages. Higher protein diets can in-turn lead to increased milk production (Garg 2012; Moran & Chamberlain 2017; Salem & Smith 2008; Stur & Horne 2001). The second analytical chapter (Chapter 3) of this thesis revealed that the adoption of high CP concentrates, bundled with other feed technologies, provided the greatest and most significant positive effects on milk production by smallholder dairy farmers. High CP concentrates are more expensive than standard concentrates, which generally have a protein content of less than 13%. The use of high protein concentrates requires farmers to understand the specific proportion of concentrates and roughage to feed, and also to understand the correct time during the lactation period that high protein concentrate should be fed (Moran 2005). This suggests use of high CP concentrate is also a knowledge-intensive technology.

Teat dipping after milking

Mastitis is the most prevalent disease affecting dairy cow productivity in Indonesia. This disease can decrease milk production and milk quality, leading to substantial economic losses for farmers (FAO 2014; Rajala-Schultz et al. 1999; Sah et al. 2020). Mastitis can be both clinical and subclinical; the latter is more prevalent, because the symptoms of the disease are not visible (FAO 2014). Studies have shown that post-milking teat dipping implementation can effectively prevent subclinical mastitis (Wicaksono et al. 2019; Yanuartono et al. 2020). The implementation of this practice requires farmers to have a teat dipping cup, which can be used multiple times, and disinfectant solutions, such as iodine. After milking the cow, the farmer immerses all four teats/quarters of the dairy cow into the teat dipper containing the disinfectant solution. The implementation of this practice is considered relatively low cost and simple.

Mastitis testing

Mastitis testing aims to quickly determine whether cows infected by mastitis need to undertake treatment as soon as possible. Early detection of mastitis through regular testing is critical for dairy farmers in preventing economic losses due to decreasing milk production and milk quality (Sah et al. 2020; Sumon, Ehsan & Islam 2017). Mastitis testing requires farmers to have the equipment to perform the tests, which is usually a tray/paddle with four small dishes, which can be used multiple times. Reagent liquid is also needed for the tests, and the cost of this depends on the type of tests undertaken.[22]

[22] Two different mastitis tests are familiar to smallholder dairy farmers in Indonesia, including the California Mastitis Test (CMT) and Surf Field Mastitis Test (SFMT). While CMT is more efficient than SFMT, the reagent to perform CMT is more challenging to find and is more expensive, whereas SFMT uses household detergent as the reagent and is relatively cheap and easy to find (Setiawan, Trisunuwati & Winarso 2012).

The implementation of the tests is considered simple. Farmers need to fill each dish with milk from each teat and add the reagent. Despite its easy implementation, farmers still need to have the knowledge to use the process and accurately interpret the test results, which may be challenging for some farmers, illustrating the knowledge-intensive nature of this technology.

Table A7-2 Dis-adoption rates of dairy technologies

Technologies	Number of farmers that have used (a)	Number of farmers that dis-adopted (b)	Percentage of farmers dis-adopted (c = b/a*100)
Forage conservation for the dry seasons (hay, silage)	75	67	89%
High protein concentrates (16% or higher)	118	70	59%
Teat dipping after milking	214	99	46%
Mastitis testing	121	51	42%
Record keeping	125	31	25%
Stainless steel milking equipment	272	18	7%
Rubber floor mat for the barn/cage	373	23	6%
Fertiliser to grow grass	448	27	6%
High-quality grass varieties	450	10	2%
Unrestricted access to drinking water	214	4	2%
Improved milking hygiene to reduce TPC	490	5	1%
Detergents on milking equipment	513	5	1%

Table A7-3 Agents/people who initially introduced the technologies to continuous and discontinuous adopters (%)

Agents introduced	Forage conservation			High protein concentrates			Teat dipping after milking			Mastitis testing		
	Continuous adopters	Discontinuous adopters	Sig.	Continuous adopters	Discontinuous adopters	Sig.	Continuous adopters	Discontinuous adopters	Sig.	Continuous adopters	Discontinuous adopters	Sig.
n	8	67		48	70		99	115		70	51	
Cooperative	12.50	34.33		66.67	52.86		72.17	61.62		54.29	39.22	
Dairy farmer	12.50	4.48		6.25	4.29		4.35	0.00	**	7.14	1.96	
Local government	0.00	13.43		4.17	5.71		10.43	4.04	*	4.29	1.96	
Veterinary doctor	0.00	0.00		0.00	0.00		7.83	4.04		24.29	19.61	
University	12.50	5.97		0.00	1.43		0.00	0.00		2.86	0.00	

Sig. = Significance level from t-tests; * p < 0.10, ** p < 0.05 and *** p < 0.01 indicate significance at the 10%, 5% and 1% levels respectively.
Percentages: the frequency of responses divided by the number discontinuous adopters or continuous adopters.

Table A7-4 Who provided the assistance to continuous and discontinuous adopters (%)

Assistance providers	Forage conservation			High protein concentrates			Teat dipping after milking			Mastitis testing		
	Continuous adopters	Discontinuous adopters	Sig.	Continuous adopters	Discontinuous adopters	Sig.	Continuous adopters	Discontinuous adopters	Sig.	Continuous adopters	Discontinuous adopters	Sig.
n	8	67		48	70		99	115		70	51	
Cooperative	12.50	29.85		45.83	30.00	*	66.09	61.62		44.29	35.29	12.50
Dairy farmer	12.50	5.97		14.58	5.71		4.35	0.00	**	8.57	1.96	12.50
Non-dairy farmer neighbour	0.00	10.45		4.17	5.71		8.70	4.04		4.29	1.96	0.00
Veterinary doctor	0.00	0.00		0.00	0.00		7.83	4.04		22.86	19.61	0.00
University	12.50	5.97		0.00	1.43		0.00	0.00		2.86	0.00	12.50

Sig. = Significance level from t-tests; * p < 0.10, ** p < 0.05 and *** p < 0.01 indicate significance at the 10%, 5% and 1% levels respectively.
Percentages: the frequency of responses divided by the number discontinuous adopters or continuous adopters.

Table A7-5 Comparisons of key characteristics continuous adopters and discontinuous adopters for forage conservation and high protein concentrates

Key characteristics	Forage conservation			High protein concentrates		
	Continuous adopters	Discontinuous adopters	Sig.	Continuous adopters	Discontinuous adopters	Sig.
n	8	67		48	70	
Experience (years)	19.25	21.69		19.10	19.46	
Education (years)	9.63	7.61		8.60	7.17	**
Household size (members)	4.38	3.94		4.00	4.36	
Tropical livestock unit (TLU)†	13.03	0.37	***	2.31	0.22	
Household asset index‡	1.73	0.37	**	0.76	0.67	
Off-farm participation (1=Yes)	0.88	0.42	**	0.46	0.59	
Lactating cows (cows)	5.00	3.54		3.54	4.03	
Hired labour (1=Yes)	0.38	0.30		0.27	0.34	
Dairy equipment index‡	2.83	0.95	**	1.33	0.89	
Own land for growing grass (1=Yes)	0.25	0.33		0.25	0.23	
Minutes to cooperative office	22.50	28.58		33.02	30.41	
Total number of contacts with cooperative extension staff	22.00	14.09		10.71	8.16	
Perception of extension availability was good (1=Yes)	0.63	0.58		0.50	0.43	
Received assistance to adopt conserving forages (1=Yes)	0.50	0.57				
Received assistance to adopt high protein concentrates (1=Yes)				0.73	0.54	**
Received assistance to adopt teat dipping (1=Yes)						

Sig. = Significance level from t-tests; * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ indicate significance at the 10%, 5% and 1% levels respectively.
†TLU is number of tropical livestock units, excluding dairy cows, calculated based on weights from FAO (2011).
‡ Indices were estimated using principal component analysis (PCA) for household and dairy farming equipment assets following Filmer and Pritchett (2001) and McKenzie (2005).

Table A7-6 Comparisons of key characteristics continuous adopters and discontinuous adopters for teat dipping after milking and mastitis testing

Key characteristics	Teat dipping after milking			Mastitis testing		
	Continuous adopters	**Discontinuous adopters**	**Sig.**	**Continuous adopters**	**Discontinuous adopters**	**Sig.**
n	99	115		70	51	
Experience (years)	22.15	20.51		20.84	22.75	
Education (years)	7.48	6.82		6.84	7.29	
Household size (members)	3.99	4.09		4.13	3.65	*
Tropical livestock unit (TLU)†	1.07	0.06		0.07	0.35	*
Household asset index‡	0.67	0.20	**	0.84	0.30	*
Off-farm participation (1=Yes)	0.43	0.33		0.39	0.33	
Lactating cows (cows)	3.50	2.55	**	4.14	3.00	
Hired labour (1=Yes)	0.26	0.15	*	0.30	0.27	
Dairy equipment index‡	1.26	-0.09	**	0.96	0.60	
Own land for growing grass (1=Yes)	0.23	0.17		0.21	0.25	
Minutes to cooperative office	27.51	38.02	***	30.40	23.71	
Total number of contacts with cooperative extension staff	13.57	8.36	**	12.81	11.24	
Perception of extension availability was good (1=Yes)	0.65	0.43	***	0.66	0.51	
Received assistance to adopt mastitis tests (1=Yes)				0.84	0.65	**
Received assistance to adopt record keeping(1=Yes)	0.92	0.70	***			

Sig. = Significance level from t-tests; * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ indicate significance at the 10%, 5% and 1% levels respectively.
†TLU is number of tropical livestock units, excluding dairy cows, calculated based on weights from FAO (2011).
‡ Indices were estimated using principal component analysis (PCA) for household and dairy farming equipment assets following Filmer and Pritchett (2001) and McKenzie (2005).

A7-7 Results of binary logistic regression models, dependent variables (1=Discontinuous adopters and 0 = Continuous adopters)

Variables	**Forage conservation**	**Concentrates**	**Teat dipping**	**Mastitis testing**
Experience (years)	0.12	-0.02	0.01	0.03
	(0.08)	(0.03)	(0.02)	(0.03)
Education (years)	0.12	-0.15*	0.02	0.18**
	(0.21)	(0.08)	(0.07)	(0.09)
Household size (members)	-1.17*	0.17	0.04	-0.20
	(0.69)	(0.16)	(0.14)	(0.18)
Tropical livestock unit†	-0.08	-0.04	-0.59	0.40
	(0.10)	(0.09)	(0.36)	(0.39)
Household asset index‡	-0.87*	-0.13	0.17	-0.21
	(0.47)	(0.21)	(0.17)	(0.22)
Off-farm participation (1=Yes)	-4.93**	0.56	-0.36	-0.50
	(2.16)	(0.50)	(0.43)	(0.53)
Lactating cows (cows)	0.32	0.06	-0.14	-0.08
	(0.32)	(0.07)	(0.12)	(0.09)
Hired labour (1=Yes)	-0.13	0.57	-0.38	0.29
	(2.02)	(0.58)	(0.54)	(0.61)
Dairy equipment index‡	-0.18	-0.07	-0.60***	-0.19
	(0.36)	(0.13)	(0.15)	(0.19)
Own land for growing grass (1=Yes)	2.39	-0.47	0.41	-0.07
	(1.70)	(0.56)	(0.50)	(0.63)
Minutes to cooperative office	-0.02	-0.02	0.02**	-0.02**
	(0.03)	(0.01)	(0.01)	(0.01)
Total number of contacts with cooperative extension staff	-0.08**	-0.01	-0.02	-0.01
	(0.04)	(0.02)	(0.01)	(0.01)
Perception of extension availability was good (1=Yes)	-1.88	-0.22	-1.10***	-0.44
	(1.37)	(0.43)	(0.35)	(0.45)
Received assistance to adopt conserving forages (1=Yes)	1.40			
	(1.40)			
Received assistance to adopt high protein concentrates (1=Yes)		-1.01**		
		(0.45)		
Received assistance to adopt teat dipping (1=Yes)			-2.30***	
			(0.54)	
Received assistance to adopt mastitis tests (1=Yes)				-1.38***
				(0.53)
Received assistance to adopt record keeping(1=Yes)				
Constant	9.63*	2.16	2.40*	1.01
	(5.22)	(1.35)	(1.24)	(1.38)
Observations	75	117	211	121
LR chi2 (14)	23.10	19.77	78.89	29.33
Prob > chi2	0.06	0.14	0.00	0.01
Pseudo R2	0.45	0.12	0.27	0.18

Logistic regressions were estimated per technology
Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.10
†TLU is number of tropical livestock units, excluding dairy cows, calculated based on weights from FAO (2011); ‡ Indices were estimated using principal component analysis (PCA) for household and dairy farming equipment assets following Filmer and Pritchett (2001) and McKenzie (2005).

Table A7-7 above presents the determinants for dis-adoption of each of the technology, with continuous adopters being the control groups. The aim to include this analysis is to observe whether the determinants for dis-adoption are similar to the determinants for adoption but with the opposing signs as what was found in the literature. Overall, the results show that the signs for most of the significant variables have the opposing signs with the determinants for adoption found in the literature, suggesting the results are in conformity with the literature. For example, farmers with a smaller number of household members, not participating in off-farm activities and less number of contacts with dairy cooperative staff have higher probability to dis-adopt conserving forages. In addition, the results show mix determinant factors for each of the technology. However, in general, it can be inferred that farmers with less ownership of production assets (dairy farming equipment), live far distance from the cooperative and not receiving assistance to adopt technologies have higher probability to dis-adopt technologies.

Table A7-8 Reasons for dis-adoption of dairy technologies (multiple responses)

Technologies	Number of dis-adopters	Number of responses	Reasons (frequency of responses)															
			A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**
Forage conservation for the dry seasons (hay, silage)	67	115	9	12	22	21	25	6	2	3		1		2	8	4		
High protein concentrates (16% or higher)	70	100	2	51	3	4	13		7	7	1		2	3	2		3	2
Teat dipping after milking	99	127	10	25	15	14	44			3		2			7		6	1
Mastitis testing	51	57	3	3	2	38	1								5		2	3

Table A7-9 Reasons for dis-adoption of dairy technologies (percentages are frequency of responses divided by total dis-adopters)

Technologies	Number of dis-adopters	Number of responses	Reasons (percentages)															
			A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**
Forage conservation for the dry seasons (hay, silage)	67	115	13	18	33	31	37	9	3	4	0	1	0	3	12	6	0	0
High protein concentrates (16% or higher)	70	100	3	73	4	6	19	0	10	10	1	0	3	4	3	0	4	3
Teat dipping after milking	99	127	10	25	15	14	44	0	0	3	0	2	0	0	7	0	9	1
Mastitis testing	51	57	6	6	4	75	2	0	0	0	0	0	0	0	10	0	3	4

Table A7-10 Codes for reasons in Table A7-8 and Table A7-9

Codes	Reasons	Codes	Reasons	Codes	Reasons	Codes	Reasons
A	Lack of information	F	Excessive labour requirements	K	Price paid for the milk is too low	P	Others
B	High costs	G	Milk yields lower than expected	L	Too much risk involved		
C	Too complicated	H	Benefits too far in the future	M	The existing practice is better		
D	Satisfied with the current practice	I	Other farmers recommend stopping	N	Unsuitable for the local area conditions		
E	Limited availability of inputs	J	Lack of government support	O	No assistance		

Table A7-11 Other responses (code P) in Table A7-8 and A7-9

High protein concentrates (16% or higher)	Freq.
Many cows were sold, so decided to stop	1
The number of cows reduced because of diseases and collapsing the business and have no more capital	1
Teat dipping after milking	
Only have few cows	1
Mastitis testing	
Done by cooperative	1
Stopped since 2013	1
Stop being officer of cooperative	1

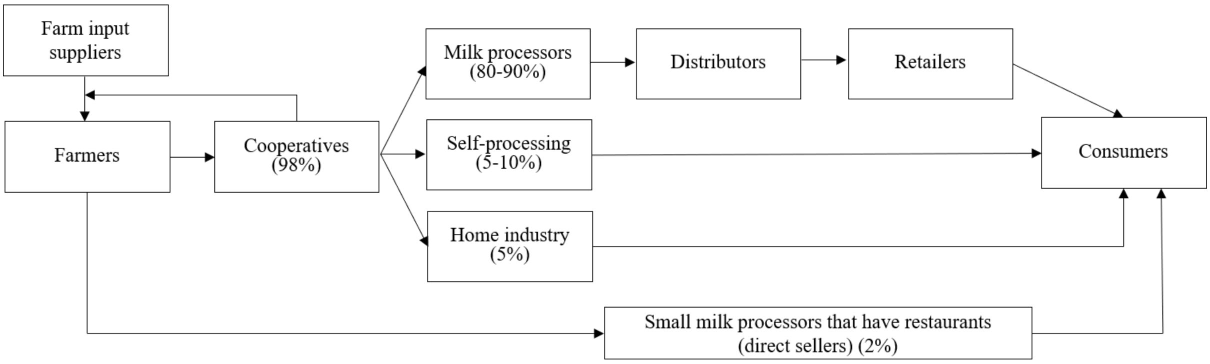

Figure A7-1 Dairy value chain map in West Java, Indonesia (Daryanto & Sahara 2018)

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