IGOR STAMBOROWSKI

FINANCE MODELS TO ENABLE SMALL FARMERS TO AFFORD NEW TECHNOLOGIES

São Paulo
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Trabalho apresentado à Escola Politécnica da Universidade de São Paulo para obtenção do Diploma de Engenheiro de Produção.

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Orientador:
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RESUMO

Propósito: Os pequenos agricultores são a espinha dorsal das economias de muitos países, fornecendo recursos essenciais como alimentos, emprego e rendimento para cerca de 3 bilhões de pessoas em todo o mundo. A ONU compreendeu recentemente a sua importância, tornando-a um dos Objetivos de Desenvolvimento Sustentável (ODS) que visam duplicar a produtividade agrícola e o rendimento dos pequenos produtores alimentares até 2030. Independentemente da sua importância, os pequenos agricultores enfrentam barreiras estruturais ao seu crescimento, tais como como rendimentos mais baixos, acesso limitado à tecnologia e informação, barreiras de mercado e de certificação e escassez de mão-de-obra. A adoção de novas tecnologias agrícolas pode ajudar os pequenos agricultores a superar estas barreiras. Este trabalho visa encontrar modelos de finanças para ajudar os pequenos agricultores a adquirir novas tecnologias agrícolas.

Objetivo: Para desenvolver esses modelos, duas Questões de Pesquisa (QP) foram respondidas:

QP1: Quais modelos de finanças podem ajudar os pequenos fazendeiros nos custos iniciais do investimento (CaPex) na nova tecnologia?

QP2: Quais modelos de finanças podem ajudar os pequenos fazendeiros nos custos de manutenção e uso (OpEx) da nova tecnologia?

QP3: Quais são as barreiras mais significantes que limitam a adoção por parte dos pequenos agricultores dos modelos de finanças benéficos?

Metodologia: Essa pesquisa usou o método de revisão secundária para analisar os modelos financeiros já existentes. Esse método consiste em sistematicamente coletar, analisar e resumir dados existentes de estatísticas governamentais, artigos públicos, análises de casos, artigos acadêmicos e orgãos organizacionais.

Resultados: Os resultados encontrados foram que os modelos de financiamento de Supply Chain Finance (SCF), Microcrédito e Seguro de Crédito Comercial (TCI) foram cruciais para ajudar os pequenos agricultores a suportar tanto o CapEx como o OpEx das novas tecnologias. Em contraste, os modelos Crowdfunding e Peer-to-Peer Lending revelaram-se mais eficazes no financiamento CapEx. Os modelos de Mini-Bonds e de financiamento de mercadorias foram considerados ineficazes no contexto dos pequenos agricultores. As barreiras mais significantes encontradas foram a falta de Conhecimento, Treinamento ou Informação, os Maiores Custos e as Leis ou Regulamentações.

Palavras-Chave: Pequenos Fazendeiros, Modelos de Finanças, Novas Tecnologias de Agricultura

ABSTRACT

Purpose: Small farmers are the backbone of many countries' economies, providing essential resources such as food, employment and income for around 3 billion people worldwide. The UN recently understood their importance, making it one of the Sustainable Development Goals (SDGs) that aim to double small-scale food producers' agricultural productivity and income by 2030. Regardless of their importance, small farmers face structural barriers to their growth, such as lower income, limited access to technology and information, market and certification barriers, and labour shortages. Adoption of new farming technologies can help small farmers overcome these barriers. This paper aims to find finance models to help small farmers afford new farming technologies.

Objective: To develop these models, three Research Questions (RQ) were answered:

RQ1: Which Finance Models can help small farmers afford the initial investment (CapEx) for new technology?

RQ2: Which finance models can help small farmers afford the maintenance and usage of new technology (OpEx)?

RQ3: What are the most significant barriers limiting small farmers' adoption of beneficial finance models?

Methodology: This research used a secondary review methodology to analyse existing finance models. This method consisted of systematically collecting, analysing, and synthesising existing data from governmental statistics, published articles, case studies, academic articles, and organisational bodies.

Findings: The results found were that the finance models of Supply Chain Finance (SCF), Micro-financing and Trade Credit Insurance (TCI) were crucial in helping small farmers afford both the CapEx and the OpEx of new technologies. In contrast, the Crowdfunding and Peer-to-Peer Lending models were found to be more effective in the CapEx funding. Mini-bonds and Commodity Financing models were found to be ineffective in the small farmers' context. the most important barriers found where the Lack of Knowledge, Training and Information, the Higher Costs of Implementing and the Law or Regulations.

Keywords: Small Farms, Finance Models, New Farming Technologies

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1 INTRODUCTION

Small farmers, comprising most of the world's agricultural workforce, are not just local producers but global contributors. They form the backbone of many nations' economies, providing essential resources such as food, employment, and income (RACHELE, 2022)[1]. Within the European Union, small farms are prominent, accounting for a substantial two-thirds (66.67%) of the total farms (EUROSTAT, 2020)[2]. Small farms, often overlooked, play a crucial role in global food security, providing environmental, social, cultural, and economic benefits (DHILLON; MONCUR, 2023) Their significance cannot be overstated, as they are a lifeline for around 3 billion rural people, contributing to many countries' economies through food production, employment, and income (RACHELE, 2022).

Small-scale agriculture is not just about farming; it's about resilience. It's about maintaining lively rural and remote areas, preserving the identity of regional production, and offering employment in regions with fewer job opportunities. It's a testament to the remarkable resilience of small farmers(RACHELE, 2022). In addition, they are more sustainable when compared to large-scale farming, as they keep traditional farming practices alive, protecting landscape and biodiversity and having more crop diversity (RICCIARDI; MEHRABI, 2021). UN decision-makers have recently understood the importance of small farmers worldwide, making it one of the Sustainable Development Goals (SDGs) that aim to double small-scale food producers' agricultural productivity and income (UN,).

The path towards a sustainable and secure future for small farmers faces unique challenges. These include lower income, limited access to technology and information, market and certification barriers, and labour shortages (JOUZI H. AZADI; GEBREHIWOT, 2017). Overcoming these hurdles is crucial. It can be achieved by providing small farmers access to new technologies and innovative solutions to enhance their productivity (DHILLON; MONCUR, 2023). Yet, various barriers, such as economic constraints, market difficulties, and limited knowledge and capacity, hinder small farmers' adoption

[1]Here, small farmers refer to those with agricultural land size less than 5ha.
[2]In this data, small farmers are those with SO less or equal than 8000 EUR

of new technologies (FAO, 2023).

Small farmers, by definition, operate with limited revenue and cash for new investments. They also navigate a highly cyclical market as agricultural income streams are characterised by seasonal cash inflows, seasonality, long production cycles, and product quality and quantity uncertainty (TSOLAKIS C. KERAMYDAS; IAKOVOU, 2014)(BERGEN M. STEEMAN; GELSOMINO, 2019). They are typically highly variable farms that yield diverse outcomes, making it challenging to achieve high economies of scale like large farms. This, coupled with the high costs associated with acquiring, implementing, and maintaining new farming technologies, leaves small farmers reliant on credit and savings products. Yet, formal financial services providers often are unwilling or unable to serve smallholders (BRIDLE LEAH;MAGRUDER, 2020). Typically, suppliers will impose higher interest rates to mitigate the higher risk of lending to small farms (such as low collateral and higher chances of default). These higher interest rates, in turn, will attract only borrowers intending not to repay the debt (adverse selection), leading to even higher interest rates (STIGLITZ J. E., 1981). In summary, small farmers grapple with fundamental economic constraints when investing in new technologies, underscoring the urgent need for financial support.

Moreover, small farmers face market problems that make access to new technologies more difficult. The market for agricultural technologies is highly concentrated (HOWARD, 2016)(HENDRICKSON P. HOWARD; CONSTANCE, 2020), with some areas, such as agricultural machinery, having more than 50 per cent of the global market controlled by only three players (MILLS; CLAPP, 2017). These few but big players have a high potential for market manipulation. As they seek higher profits, they undermine the livelihoods of small-scale producers by pushing up prices and limiting product choice (CLAPP, 2021), investing in higher-scale technologies, or even making lock-in contractual obligations when selling the technology. For example, it is possible to notice the US corporation Deere & Company (the market leader), known for its biggest brand, John Deere. After selling their technologies, such as tractors, harvesters, or excavators, they obligate the client to buy all the parts for the machinery with them, as they will not fit with other brands (DEERE,).

Finally, it is essential to notice other challenges that small farmers face when looking for new technologies to implement. Firstly, there is a lack of information, and it is difficult for small farmers to understand the properties of new technologies; in the absence of opportunities to experiment, they have trouble predicting outcomes under a range of different conditions they could experience in the future (for example worst or better

weather conditions). Therefore, various specific information is necessary for farmers to decide which technologies to use at which point (BRIDLE LEAH;MAGRUDER, 2020). Second, labour constraints exist, such as additional labour requirements for using the new technologies. Finally, some behavioural problems, such as risk or uncertainty aversion, can also increase the difficulty, as farmers tend to make highly complex choices over long time-frames.

2 LITERATURE REVIEW

2.1 What are Small Farms?

It is important to note that, so far, there is no universal, unambiguous, and precise definition of a small farm (GIOIA, 2017). Most definitions will refer to a farm's size based on its structural size, economic size, herd size, or labour force (GUIOMAR et al., 2018). Physical size is the most widespread definition nowadays because of its simplicity and easiness of universal application; it is used, for example, by the European Parliament (RACHELE, 2022) and the Food and Agriculture Organization (FAO) (GUIOMAR et al., 2018). They define a small farm as an agricultural area of less than 5ha. Nevertheless, this criterion can be misguiding as it does not capture all the complexities of the farming system, such as the quality of resources, types of crops grown, or disparities across countries and regions (NAGAYETS, 2005), factors that heavily influence the income and character of a farm. Another commonly used measure to consider these aspects is economic output, assessed in terms of the Standard Gross Margin (SGM) (HUBBARD, 2009). According to EUROSTAT, SGM is defined as the "measurement of production or the business size of an agricultural holding. It considers a farm's various activities or 'enterprises' and their relative contribution to overall revenue" (Eurostat, 2024a). It represents the difference between gross production (including subsidies) and variable specific costs, providing an overall measure of a farm's economic size in terms of Economic Size Units (ESUs, where 1 ESU equals a €1200 SGM). However, the Commission Delegated Regulation (EU) No 1198/2014 introduces the usage of Standard Output (SO) expressed in euros (European Union, 2024). SO entails a regional coefficient for each product, averaged over a reference period (typically five years). The total SO per hectare of crop and head of livestock on a farm measures its overall economic size, expressed in euros (Eurostat, 2024b). Following this metric, EUROSTAT, for example, defines small farms based on their SO. Small farms have an SO between EUR 2,000 and EUR 8,000 annually, while tiny farms have less than EUR 2,000 yearly (EUROSTAT, 2020). To also understand the labour input and job creation on the farm, there is a third criterion, the Annual Work Unit (AWU),

being 1 AWU is equivalent to the work of one person working full-time for one year (INSEE (French National Institute of Statistics and Economic Studies), 2024). This value is usually used in combination with one of the other two explained; for example, the Confédération Paysanne in France defines a small farm as one with revenues of less than € 50.000 for 1 (AWU), € 62.500 for 1.5 AWU, € 75.000 for 2 AWU, € 100.000 for 3 AWU, and € 125.000 from the 4th AWU. All these metrics, however, need to capture a final factor that can also affect how the farm operates: Purchasing Power. It is noticeable that the same product can have different costs in different countries, which is the same for farming technologies (DEERE,). Therefore, it is also essential to consider this when discussing small farms. One possible way to do so is by using Purchasing Power Parities (PPPs), the rates of currency conversion that try to equalise the purchasing power of different currencies by eliminating the differences in price levels between countries (OECD, 2024). PPPs allow farmers to compare their income in other countries and account for their purchasing power by measuring them in US dollars. Considering the financial perspective followed in this paper, it's essential to define small farms that can reflect their economic scale of production while also considering the different purchasing power of each country. Therefore, whenever the term "small farm" is mentioned in this paper, it refers to any farm with a Standard Output (SO) equal to or less than 12,900 USD per year after applying the PPP to the farmer's income[1].

2.2 Description of Finance Models

Finance Models, traditionally, are defined as a quantification of the past, present, and forecasted future operations of a company (KOPP; KVILHAUG, 2024). These models are used to understand, represent, and analyse various phenomena and processes and can be powerful decision-making tools for companies that adopt them. In the context of this paper, finance models refer to frameworks or approaches designed to address the specific needs of small farmers. As mentioned, these farmers have less cash available and need help to obtain credit. Moreover, the market for new farming technologies is very concentrated, making it costly and difficult for small farmers to invest. For that, small farmers must look for financial strategies and mechanisms that may enable them to adopt these innovative farming technologies. One possible model is leveraging Supply Chain Finance (SCF). SCF aims to optimise monetary flows among organisations based on financial or technological solutions. SCF seeks to ensure that financial flows align with production

[1]The 12,900 USD income equals the 8,000 EUR income used by the EUROSTAT after applying the European Union's most recent PPP of 0.62 (OECD, 2024)

and information flows within the Supply Chain (SC), enhancing cash flow management from an SC perspective. This method might present numerous gains, including lower debt expenses, more loaning opportunities and less working capital through the SC. Additionally, SCF encourages more significant commitment, confidence, and profitability among supply chain actors (GELSOMINO et al., 2016). Different SCF solutions can be used, such as:

- **Reverse Factoring** is a supplier finance solution that allows farmers to make early payments to suppliers against approved invoices. With a reverse factoring solution, suppliers use their invoices as collateral to request early payment from the bank or other finance provider grid, and the buyer pays the finance provider on the invoice due date. When buyers offer their suppliers reverse factoring access, they help reduce the risk of supply chain disruptions while building stronger relationships with suppliers and enhancing their working capital positions (Taulia, 2024).

- **Dynamic Discounting** allows buyers to pay off their invoices early, and in return, the seller receives cash faster at a reduced price (LinkedIn, 2024).

- **Inventory Financing** is financing offered by banks or other financial institutions as a short-term loan or a revolving line of credit using businesses' inventory as collateral (MEDINA; CANIATO; MORETTO, 2023).

- **Factoring** is a solution in which a third-party financing provider purchases the supplier's invoices at a discount, providing immediate cash (LinkedIn, 2024).

- **Purchase Order Financing** is a cash advance on Purchase Orders (PO). In this context, a lender provides the financing that the seller needs to adjust its operations for outstanding customer orders, such as opening up a new production line, making specific investments, or helping it issue orders to its suppliers. Once the order has been completed, the buyer pays the invoice directly to the PO lender. The financing company deducts its fees and pays the net amount to the seller (BONZANI; CANIATO; MORETTO, 2018).

- **Asset-based lending** is the business of loaning money in an agreement that is secured by collateral. It may be secured by inventory, account receivables, equipment, and other properties (KAGAN; CATALANO, 2020). If the company seeking the loan cannot show enough cash flow or cash assets to cover a loan, the lender may offer to approve the loan with its physical assets as collateral.

- **Payment financing** is when buyers extend the payment terms to suppliers, allowing them to receive early payment from a financial institution at a discount. This helps optimise the buyer's cash flow while providing suppliers with access to liquidity (SCF...,).

- **Invoice Auctions** are online platforms or marketplaces that enable corporations to sell their account receivables to third-party investors, e.g. corporate investors, banks, asset managers, and private citizens (BONZANI; CANIATO; MORETTO, 2018). One example of these platforms is "C2FO"[2].

Understanding better the supply chain these farmers operate is crucial for using SCF. The first category of the SC is **Production** (MYRAN, 2018); here, it's vital to account not only for the farmers but also for input producers, like fertilisers, pesticides, seeds, and machinery sellers. These are highly concentrated markets, with few big companies controlling most of the production (MILLS; CLAPP, 2017). Many of those producers, for example, Syngenta, Bayer, and Deere & Company, have a lot of cash and investing capabilities, with cash available past the $3 Billion in the past years[3]. However, because they are so big, these companies might not be willing to partner with such small farmers, especially given that most of their revenue comes from selling those technologies.

The second part of the SC is **Processing** (EIT Food; QUB,); here, it's crucial to account for primary processing (cutting, cleaning, packaging, storage and refrigeration of raw foods), secondary processing, which transforms the initial product into minimally processed foods, for example, cheese, flour, edible oils, sugars/sweeteners and starches, and ultra-processed (produced by combining primary food products and other secondary food products to create a ready-to-eat food and drink product with high sensory appeal, e.g., cakes, sweets, jams, soft drinks, and ready meals). This part of the SC has many more companies since it depends significantly on the initial and final products sought. Processing companies could benefit from partnering with small farmers and helping them afford new farming technologies, as they would also benefit from the increased production and reduced production costs of their raw materials.

Thirdly, there is the **Trading** part of the SC (MYRAN, 2018). This consists of the Spot Market (for first-hand sales of commodities) and Wholesalers (that purchase the product in bulk and subdivide it, supplying retailers and food service establishments across the country and exporting to foreign markets for sale to the consumer). Spot

[2]For more information visit ⟨https://c2fo.com/⟩

[3]Cash availability extracted from companies' latest financial reports.

Market actors, such as commodity traders, are hardly affected by small farmers, as most commodities production comes from big farms (MILLS; CLAPP, 2017), so it wouldn't benefit them to partner with or help small farmers finance new technologies. On the other hand, wholesalers could benefit from these new technologies and increased production of small farmers, as they usually operate with relatively constant margins (LEONARD, 2019). Increased production, therefore, would lead to increased profit.

The final part of the SC is **Retailing** to the final consumer (EIT Food; QUB,). There are traditional retailers (such as supermarkets and web-based retailers, which display ready products to consumers in the desired storage cabinets) and food service providers (such as restaurants, that buy, prepare and sell the product to the end customers to eat). Large corporations, such as supermarket chains, are increasingly dominating retail activity (MYRAN, 2018). Therefore, they have good financial capabilities to help small farms finance new technologies. In addition, these retailers would greatly benefit from this, as it would lead to lower costs of raw materials and increased profits from higher production levels.

It is also essential to mention **Agriculture Cooperatives** (businesses formed and owned by a group of farmers or agricultural companies) that operate across different segments of the SC farming sector and can improve market access and enhance economic opportunities for producers. Together with other members, growers can buy input supplies cheaper and sell more products and services in larger markets at higher prices. In the US, some of the biggest Agricultural Cooperatives are CHS Inc., Dairy Farmers of America, and Land O'Lakes Inc., making more than $19 billion in revenues in 2022[4].

Another viable solution for small farmers is to look for informal suppliers of credit that are accessible to small businesses, for example, friends and family, partners, financial assistance programs, or even **Micro Financing Institutions (MFI)**, that provide smaller-scale finance solutions tailored to low-income entrepreneurs, such as small loans, receipt of savings deposits, and more accessible payment services (TAIWO; AGWU; BENSON, 2016). (TAIWO; AGWU; BENSON, 2016) shows that using MFI and the financial and non-financial services they offer small businesses can significantly reduce the resource gap and help investors seek these entrepreneurs.

Nowadays, one of the most significant examples of MFI globally is "Opportunity International"[5]. In addition to their different work, they offer micro banking to Small and

[4]Data available at the US National Cooperative Bank website: ⟨https://www.ncb.coop/⟩.

[5]For more information about Opportunity International and their operations visit ⟨https://opportunity.org/what-we-do/micro-banking/technology⟩.

Medium-sized Enterprises (SMEs). Opportunity International provides SMEs loans to expand operations, create jobs, and employ more people. These larger loans are often invested in developing infrastructure, building capacity, and purchasing inputs and supplies in bulk. They also offer non-financial services that can aid small farmers, such as training in financial literacy and business management. There are also several local MFIs, for example, the Grameen Bank in Bangladesh, the Bharat Financial Inclusion Limited (BFIL) in India, the Compartamos Banco in Mexico, and the FINCA International, which operates across Africa, Asia, and Latin America.

Additionally, small farmers can look for other non-traditional finance solutions that are very important in the SME context, such as:

- **Minibonds:** These are debt securities issued by private industrial companies for amounts lower than $50m (MEDINA; CANIATO; MORETTO, 2023). Because they have smaller denominations, minibonds are more accessible to small farmers and allow diversified funding sources.

- **Crowdfunding:** Consists of collecting small donations from a large number of people, including friends, family, strangers, businesses, and more, usually through online platforms. Small farmers can use this method if they are looking for people to support small businesses or food providers. Some examples of these platforms are Kickstarter, Indiegogo, and Fundable.

- **Peer-to-peer (P2P) lending:** Is a direct connection between lenders and borrowers through online platforms like Lending Club or Prosper, eliminating the need for financial intermediaries. It potentially offers borrowers capital at lower interest rates and fees than traditional institutions.

- **Trade Credit Insurance:** This risk management tool protects businesses against losses from partners' non-payment. It covers receivables so that cash flow is guaranteed (LinkedIn, 2024). It can help companies to extend their credit dates and sell their products more precisely.

- **Commodity Finance:** This term refers to all financing activities related to the trade of commodities, such as agricultural products. Commodity producers (such as some small farmers) can use these finance structures to receive capital and ensure that cash flow is available for optimum output (TRADE...,).

2.3 Characteristics of the Technologies

There are several new technological advancements in the market for farmers nowadays. Some of the most noticeable ones that can benefit small farmers are listed in the topics below (DHILLON; MONCUR, 2023) (MAFFEZZOLI et al., 2022).

2.3.1 Unmanned Aerial Vehicles (UAVs) and Drones

UAVs and Drones refer to aerial platforms equipped with sensors or crop input delivery mechanisms for various agricultural tasks, like crop monitoring, mapping, and spraying. They provide farmers with real-time information and can be a helpful tool for monitoring crop health, identifying pest infestations, assessing field conditions, and creating accurate maps of their farms. This information enables them to make timely and informed decisions, leading to better crop management and higher yields.

The costs for acquiring agricultural UAVs and Drones vary greatly, depending on their different characteristics (fuel used, battery life, field cover rate, camera, etc.). Entrance models, such as the DJI Terra Pro Permanent or Parrot Anafi AI, cost around USD$4,500 per drone, with yearly maintenance fees of USD 4,440. Other middle-quality models, like the senseFly eBee X, cost around USD 13,500 per drone. The most expensive UAVs, such as the MMC UAV Griflion H, can cost up to USD$100,000 per drone[6]. .

2.3.2 Smart Sensors

Wi-Fi-enabled crop, soil, or weather sensors and data transfer systems can be spread around the farm to gather data on soil moisture, temperature, humidity, and crop growth. Innovative farming platforms can then analyse this data to provide farmers with insights and recommendations for optimised decision-making. Since these are highly scalable and customisable tools, they can also be suitable for small farmers managing farms, greenhouses, and high tunnels through notifications and alerts.

Different kinds of smart sensors can be used depending on their intended use. In total, there are 11 types (RAJAK et al., 2023): electromagnetic, Acoustic, Light Detection and Ranging (LIDAR), Optical, Mechanical, Mass Flow, field-programmable gate array (FPGA) based, Electrochemical, Eddy Covariance, Airflow, and Ultrasonic Ranging. The price for implementing one Smart Sensor can vary from $4 per sensor for the cheapest

[6]Prices available at ⟨https://www.dronefly.com/sensefly-ebee.html⟩.

ones to $50,000 for the most expensive ones. Appendix A, extracted from (RAJAK et al., 2023), details the usage of each sensor alongside its price range.

2.3.3 Internet of Things (IoT)

A system of interrelated computing devices and digital machines that can transfer data over a network without requiring human-to-human or human-to-computer interaction. The integration of IoT with smart sensors can be applied in different areas of smart farming, such as monitoring crop growth, humidity, temperature, soil quality, plant diseases, crop production, and pests (RAJAK et al., 2023). IoT systems are sold in different ways. Some companies, such as Farmobile and Onomono, charge subscriptions for data management, with prices around $1,250 per year. Other companies offer the service for free when you purchase their products; that's the case with the John Deere Operations Center account or AGI Monitoring services, for example.

2.3.4 Robotics, Automation and Artificial Intelligence (AI)

Unmanned machines that automate processes to offload physical human labour and increase productivity and product quality. They can reduce labour costs, improve efficiency, and enable continuous operations. Small farmers can use this system to cut labour costs and address shortages.

With AI systems, automation can also be used for Variable Rate Technology (VRT), the varying application rate of inputs such as seed, fertiliser, pesticides, and water across the field. This optimises resource usage and reduces input costs and environmental impact.

The biggest producers of farming robotics now are John Deere and CNH Industrial (MILLS; CLAPP, 2017). For example, John Deere sells automation and AI software for the machinery as an extra feature of its tractors, with programs such as "AutoTrac™," "AutoPath™," and TruSet™ Tillage Technology. Activating these technologies ranges from around $850 for the RowSense to $3,500 for the AutoTrac™, plus the machinery, ranging from $10,000 for simple tractors to $770,000 for harvesters or planters.

Raven Industrial, a brand of CNH Industrial, sells both types of machinery already implemented with automation, such as the "Case IH Trident™ 5550 applicator with Raven Autonomy and software, like their most famous automation software, "OMNiDRIVE™". They cost around $50,000 for activation plus a yearly fee of $3,000 for continuous usage[7].

[7]Prices extracted from the Raven Industrial website

2.3.5 Yield Monitoring

Systems that measure the number of crops harvested from fields in real-time as harvesting equipment moves through the fields. Yield monitoring quantifies crop productivity variation across different field areas, allowing farmers to identify factors influencing productivity and make data-driven decisions. Yield monitoring is usually partnered with data logging and analysis software like IoT and AI-backed systems. Simple yield monitors, like the AGCO Datatronics, start at around $900; other more complex monitors, such as the John Deere Gen 4 extended monitor and FarmTRX Harvest Bundle, can get up to $5,700 per piece of equipment[8] .

2.3.6 Vertical Farming

It involves growing crops in controlled indoor environments with precise light, nutrients, and temperatures. In vertical farming, growing plants are stacked in layers that may reach several stories tall, using hydroponics, aeroponics, or aquaponics systems (BIRKBY, 2016). Vertical farming can lead to continuous production year-round, reduced pesticide usage, protection from weather variations, water conservation and recycling, and overall sustainability improvements (BIRKBY, 2016). This can help reduce waste costs while also improving overall productivity. Two famous vertical farming producers are Ifarm and Green Web; their initial setup and activation cost is around $1,000 per square meter. Besides that, it is crucial to account for operating expenses, such as energy consumption (that can vary from $2,000 - $8,600 monthly, depending on where the farm is located) and specialised labour costs (from $13,000 to $26,000).

2.3.7 Biotechnology and Genomic Tools

Biotechnology tools, such as gene editing techniques like CRISPR or genetically modified organisms (GMOs), can enhance some crop traits, such as nutritional content, drought tolerance, or pest resistance. Genomic tools can help develop new crop varieties faster and more precisely. This can lead to higher profits and more reliable yields, and farmers can become less impacted by climate changes or diseases. The United States National Center for Biotechnology Information divulged the costs of inserting a gene into a crop line to be from $10,000 to $200,000 per gene; however, once a crop has been modified, it

[8]Prices extracted from ⟨https://www.agriexpo.online/agricultural-manufacturer/yield-sensor276.html⟩

can be bred at no additional cost that small farmers can buy genetically modified crops from more prominent players or share the initial modification expenses with them.

2.3.8 Blockchain in Agriculture

By recording transactions and data related to production, processing, and distribution on a tamper-proof ledger, this technology can help create transparent, trustworthy, and traceable supply chains in agriculture, making it easier for consumers to get information on the origin and quality of the food (EDENGREEN,). It can make it possible for small farmers to access premium markets, increase consumer confidence and trust, and create opportunities for value-added branding and marketing initiatives. Because of different challenges, such as implementation, integration, and maintenance, blockchain is not yet dispersed among farmers. Still, it is anticipated to impact agriculture and various allied verticals significantly (K, 2022).

2.3.9 Summary

In summary, new farming technologies' main applications are (MAFFEZZOLI et al., 2022): **Water management** (optimising water usage with improved irrigation techniques and processes); **Crop management and monitoring** (monitoring of parameters related to crop growth and health); **Precision microclimatic prediction and monitoring** (control of climatic parameters); **Agrochemical and fertiliser management** (management of fundamental inputs in agriculture that can lead to input reduction); **Land and soil monitoring** (evaluate land suitability); **Livestock regulation and monitoring** (monitoring of crucial parameters related to livestock growth and health); **Greenhouse cultivation** (such as vertical farming); **Autonomous vehicles and machinery navigation system** (employment of autonomous machines and robots to increase operation efficiency in the fields); **Hydroponics and aquaponics** (provides efficient usage of water; cultivates plants without soil); **Product monitoring along the chain** (identifies, tracks, and traces the elements of a product as it moves through the supply chain from raw material to finished product).

Looking at the different applications, a possible way of reducing the costs arising from implementing these technologies is for small farmers to share them among themselves. For example, neighbouring agriculturists can share water management techniques, such as the amount of irrigation needed or land and soil monitoring, because they have similar soil characteristics. They could also share micro-climatic predictions or greenhouse cultiva-

tion because they operate in the same area. Besides that, if they sell the same product type, they could benefit from sharing autonomous vehicles and machinery (for example, programming a harvester to pass on both lands), fertiliser management, and product monitoring along the chain (if they have a similar supply chain). However, some applications are more challenging to use in a shared way; for example, if shared, crop and livestock management could lead to data appropriation of one farmer from another.

Understanding the concepts of capital expenditures (CapEx) and operational expenditures (OpEx) is vital for better studying the different investments needed for the technologies presented. In the context of this paper, CapEx represents the initial money invested to acquire or upgrade a technology (usually one-time). At the same time, OpEx refers to expenses that occur during the usage of the technology (usually with a frequency, such as monthly or annually).

Based on that definition, it is possible to divide the presented technologies into two types:

1. **CapEx-driven:** Technologies that require the most significant expenditures (more than 50%) to implement and maintain for the first ten years deriving from the initial investment. This includes Smart Sensors, Yield Monitoring, and Biotechnology tools.

2. **Mixed technologies:** CapEx is not the most significant expenditure in this case, but both CapEx and OpEx play an essential part in the investment. This is the case with UAVs and Drones, IoT, Robotics and Automation, and Vertical Farming.

3 STUDY OBJECTIVE

Considering the relevance of small farmers in today's agricultural production, their difficulties in acquiring technologies, and the importance of new farming technologies in the growth, development, productivity, and profitability of agricultural producers, this study aims on finding finance models that enable small farmers to adopt innovative farming technologies and understanding the difficulties they face on using those models. It is possible to develop the study by answering three Research Questions (RQ):

RQ1: Which Finance Models can help small farmers afford the initial investment (CapEx) for new technology?

RQ2: Which finance models can help small farmers afford the maintenance and usage of new technology (OpEx)?

RQ3: What are the most significant barriers limiting small farmers' adoption of beneficial finance models?

4 METHODOLOGY

4.1 Research Design

This research used a secondary review methodology to analyse existing finance models that can help small farmers adopt new technologies and the difficulties in using them. This method consisted of systematically collecting, analysing, and synthesising existing data from governmental statistics, published articles, case studies, academic articles, and organisational bodies.

The decision to adopt this method arose from the need for a comprehensive and multifaced understanding of finance models and new farming technologies. By accessing a more comprehensive range of sources, including academic articles, government reports, NGO publications, and case studies, this method can ensure a more extensive coverage of the topic and bring a more diverse perspective than Literature Review. Besides that, secondary research is more Time and Cost-effective. Leveraging existing data is cheaper and faster than conducting primary research, such as surveys, and it also makes it possible to perform a global-scale study.

4.2 Data Collection

The collection of data for this research was conducted with a first step of **identification**, which consisted of initial searches conducted in different databases, such as Google Scholar, Emerald, FAO, Eurostat, European Parliament, google, etc, using various keywords and strings such as “finance models for small farmers”, “finance models for SMEs”, “Supply Chain Finance”, “Microfinancing”, “New farming technologies”, “Capex funding in SMEs”, “OPEX funding in SMEs”, “Technology adoption for small farmers”, “Barriers for SCF usage”, etc. It is vital to note that the initial search was not limited to small farmers but also to Small and Medium-sized enterprises (SMEs), so finance models that already allow for SMEs to afford their investments could also be used in the study of small

farmers, given their similarities in terms of economic constraints.

The second step consisted of **screening**, meaning shortlisting relevant publications based on the inclusion and exclusion criteria. The inclusion criteria were as follows: Articles from the past 20 years were used to ensure contemporary relevance; studies and reports focused on the finance models listed before; and studies that were reviewed and had transparent methodology and findings. The exclusion criteria were Publications over 20 years old[1] and sources without transparent methodology or deemed irrelevant to the finance models presented.

The third step of data collection was the **organisation**. This meant separating the studies by which models they referred to: Supply Chain Financing (SCF), Micro-financing, Mini-bonds, Crowdfunding Peer-to-peer (P2P) lending, Trade Credit Insurance or Commodity Financing. After that, inside each model, the studies were labelled as to what information they brought about the model: (i) general information, (ii) drivers to the adoption, (iii) benefits of the model or (iv) barriers to the adoption. Finally, this organisation was summarised in a table with three columns: the first with the reference to the study, the second with which finance model was explained in the research and the final with which of the information was available about the model in question. To summarise the data found, the **Table 1**, below is the number of articles found for each finance model in the initial identification and the number of articles included or excluded based on each exclusion criteria.

Finance Model	Total Studies Found	No transparent methodology	More than 20 years	Not relevant to the model	Total Studies included
SCF	18	1	0	4	13
Microfinancing	32	8	1	8	15
Minibonds	12	1	0	2	9
Crowdfunding	15	2	1	0	12
P2P Lending	16	4	0	2	10
Trade Credit Insurance	18	3	0	3	12
Commodity Financing	26	3	2	4	17
Total	**137**	**22**	**4**	**23**	**88**

Table 1: Summary of data collection.

[1]There is one article older than 20 years in the bibliography (STIGLITZ J. E., 1981), but it is not used in the data analysis, only in the introduction.

4.3 Data Analysis

The first step of Data Analysis was extracting information from the selected sources. This part consisted of organising the table from the data collection part by finance model, then deeply analysing each of the articles and gathering the data about (i) the general information about the model, (ii) the drivers for adoption, (iii) the benefits and (iv) the barriers for the adoption[2]. In this part, it was first essential to be as exhaustive as possible, looking at all the information available in each source. The data was then triangulated to see if multiple sources brought the same information. Finally, this was analysed in the agriculture and SMEs' context to make it relevant to small farmer studies. For each finance model, a summary table was made containing three columns: Drivers, Benefits and Barriers of the solution in the small farmer's context so that it was easier to understand these models and their possible usage in helping small farmers afford new technologies.

To better understand the possible usage of each finance model, the Drivers, Benefits and Barriers were compared, first to see if the drivers for adopting the model were linked to any of the problems faced by small farmers in affording new technologies. The benefits observed in the sources were studied to see if they helped small farmers with the issues they faced and the barriers to adopting the model were analysed to see if small farmers could overcome them.

In sequence, all the barriers and difficulties found were summarised in a table, making it possible to understand what are the main difficulties small farmers face in using the finance models studied.

Finally, all the data collected and the analysis of each finance model were summarised to understand which Finance Models could be used to finance the initial investment (CapEx) or the operation cost (OpEx) of the technologies. This meant gathering all the finance models that could solve some of the problems found by small farmers in the adoption of technologies (those that had superable barriers and that had essential drivers and benefits in the small farmers' context) and understanding, based on the benefits that each model brought, if it helped the farmer gather funds or finance the initial investment of the technology (for example by giving better liquidity or reducing interest rates for the farmer) or the day-to-day expenses of it (by lowering the Cash Conversion Cycle or improving the relationship in the SC, for example).

[2]Exclusively for the SCF model, there was also the topic of Solutions and Usage, since SCF has more than one solution

4.4 Research Rigour

By using the strengths of secondary research and addressing its limitations, this study maintains high research rigour, providing valuable insights into finance models that help small farmers afford new technologies.

Firstly, to guarantee high reliability, this study applied a systematic approach to data collection, using the same search criteria and inclusion and exclusion standards across all sources. Besides that, the data analysis was well structured and explained; the different studies and articles found were all carefully read and analysed, then grouped by Finance Model type, giving important insight on each model studied so that later it was possible to group models that were useful for the CapEx or OpEx funding of each technology. This consistency in data collection and analysis makes the study easily replicable and supports the reliability of the research outcomes.

Secondly, to ensure high validity, the study selected secondary data relevant to the research (including only more recent articles and those that analysed the models studied) and with transparent methodology (to ensure the data findings were valid). Furthermore, the research applied triangulation between the different studies by comparing and cross-verifying the information with multiple sources, enhancing the conclusions' accuracy. In summary, by using a thorough method in the selection of data and ensuring the relevance of the information found, the findings of this research give accurate conclusions as to which finance models can allow small farmers to afford new technologies.

However, it is essential to look at some of the possible limitations of the study. Firstly, this research might overlook aspects not well-documented in the existing literature, and some missing information in secondary data can limit its completeness. There is also a risk of misinterpretation of data without the original context. Finally, it is interesting to remember that positive financial model results are more likely to be published, potentially affecting the findings.

5 RESULTS

5.1 Supply Chain Finance (SCF)

5.1.1 Introduction

As mentioned, SCF aims to align financial flows with product and information flows within the **supply chain** (SC), thus enhancing cash flow management from an SC perspective. This way, SCF provides a way out of short-term liquidity problems as well as a reduction in the long-term financial burden in the supply chain, for example, by reducing the total amount of necessary liquidity in a supply chain (WUTTKE et al., 2013).

SCF allows the buyer and supplier to free up their working capital and maintain a higher level of liquidity by introducing an intermediary financial institution. It permits the buyer to hold the payment for a more extended period, whereas the supplier gets paid earlier. SCF is, therefore, a financial agreement between a buyer, seller, and a third party (usually a financial institution) (ABBASI; WANG; ALSAKARNEH, 2018). According to (GELSOMINO et al., 2016), this is achieved by affecting one or more axes of the "Supply Chain Finance cube", composed of (i) **cost of capital** (or rate), (ii) **duration** and (iii) **volume**. An invoice discounting solution, for example, can affect the financing duration. At the same time, reverse factoring can change the cost of capital and duration, and asset-based lending, on the other hand, can affect both volume and rate.

To summarise, Figure 1, extracted from (ABBASI; WANG; ALSAKARNEH, 2018), below better illustrates the Supply Chain Financing process and Figure 2, from (WUTTKE et al., 2013), gives an illustrative example of how SCF can provide a "win-win-win" situation where all parties profit.

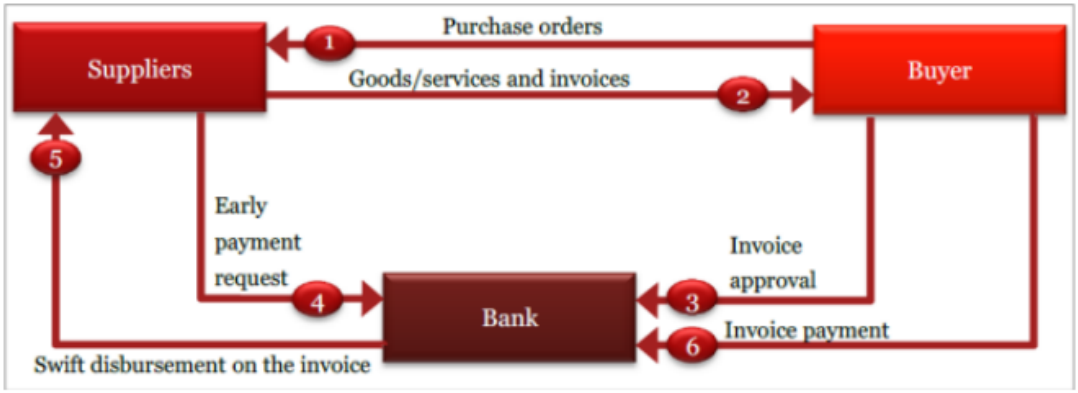

Figure 1: SCF process.

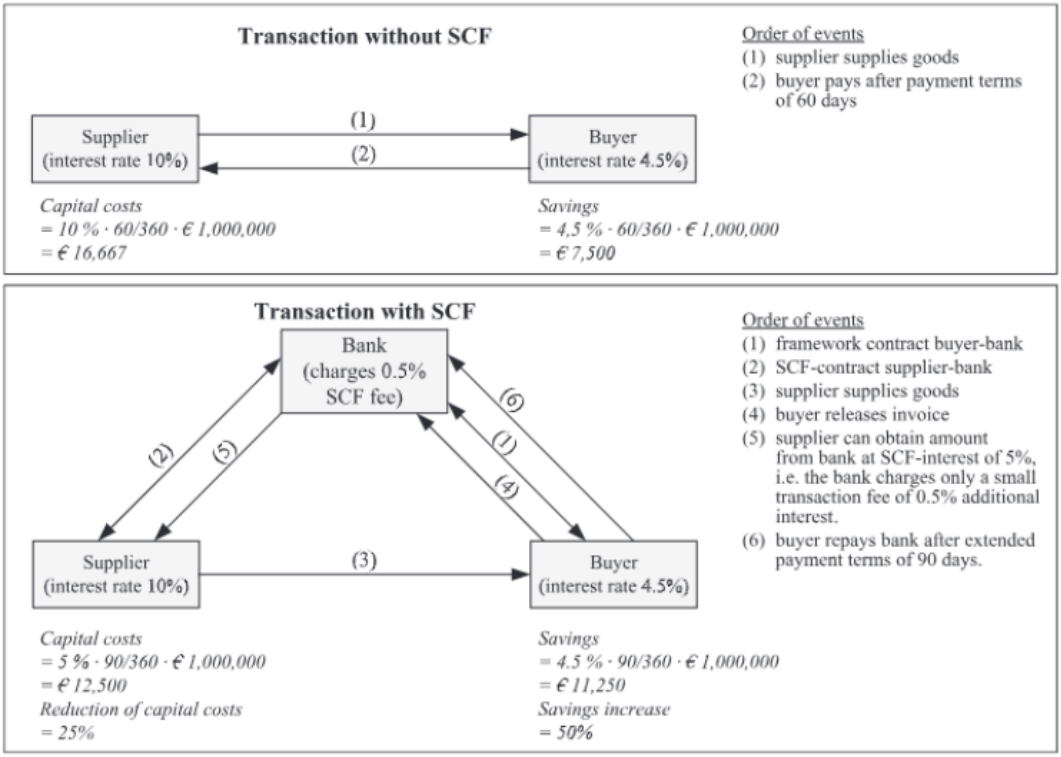

Figure 2: Illustration of how SCF can benefit all parties.

5.1.2 Drivers for SCF Adoption

Supply Chain Finance usage has seen a significant surge in recent years (BERGEN M. STEEMAN; GELSOMINO, 2019)(GELSOMINO et al., 2016)(NGUYENA et al., 2022), driven by a variety of factors (MEDINA; CANIATO; MORETTO, 2023) (NGUYENA et al., 2022):

- **Bankruptcy risk of suppliers:** SCF is a crucial tool to manage and mitigate

suppliers' risks, preventing potential bankruptcies;

- **Need to assure quality:** Financial support to suppliers ensures supply quality and continuity. Besides that, better information exchange when SCF is used can help in the traceability of the product;
- **Payment terms:** Need for better payment conditions, such as higher days sales outstanding (DSO) and/or lower days payables outstanding (DPO);
- **Level of stock:** SCF can be used to leverage high days inventory holding (DIH);
- **Lack of liquidity:** Firms' need for liquidity;
- **Lack of access to financial services:** Inadequate access to financial services at reasonable rates;
- **Exploit the excess of liquidity:** Need to utilize and remunerate liquidity excess of a cash-rich firm;
- **Long production cycle:** Extended lead time between the start of the production and the sales to the final customer;
- **Lack of collateral:** Inability to use traditional assets as collateral to obtain loans;
- **Short maturity period:** Loans granted for a shorter period than the requested time;
- **Social and economic sustainability:** Enhancing the sustainability of the supply chain from a financial and social perspective;
- **Open account trading and lengthened supply chain cycles:** Need for alternative sources of finance and efficient credit structures;
- **Supply chain automation techniques:** Can be transformed into valuable information or 'triggers' for SCF offerings;
- **Increase in B2B automation platforms and networks:** Support a widening out from a niche business based on large-value transactions to a widespread SME support based on automation.

Significantly, many of these drivers already indicate a fundamental link to small farmers' financial obstacles in their day-to-day operations and their ability to finance new investments. For example, lack of liquidity, long production cycles, risk of bankruptcy, and quality assurance are all issues mentioned as barriers small farmers face.

5.1.3 Benefits of SCF

As mentioned, SCF can benefit the three parties involved in the transactions differently. Since small farmers in their SC participate in both the supplier side (as suppliers of raw materials) and buyer side (as buyers of fertilisers, pesticides, seeds, and machinery sellers), the study will focus on those two participants of the Supply Chain.

In its general usage, SCF can bring different benefits (GELSOMINO et al., 2016) (BONZANI; CANIATO; MORETTO, 2018) (ABBASI; WANG; ALSAKARNEH, 2018) (WUTTKE; ROSENZWEIG; HEESE, 2019). For the **Suppliers** side, SCF solutions can bring:

- **Financial benefits:** such as a reduction of the Cash Conversion Cycle (either in a decrease in days needed to collect payments (DSO) or an increase in days required to pay its obligations (DPO)), improvement of indicators (such as reductions in net debt or increase in return on capital employed (ROCE)), reduction of cost of financing (by leveraging better credit rating from the buyers), and increase in cash (enabling alternative channels that differ from the traditional banking credit lines);
- **Economic benefits:** like improvement in turnover (resulting from the potential increase in the volume of goods transacted with a specific buyer) and reduced costs (through better administrative processes);
- **Operational benefits:** for example, efficiency improvement (with the digitalisation needed for the adoption of SCF) and effectiveness enhancement (allowed by the more accurate and punctual exchange of information that happens with SCF participants);
- **Intangible benefits:** mainly the advancement in supply chain relationships.

For the **Buyers**, the benefits are similar. On the financial side, it is also possible to see a decrease in the cash conversion cycle and an improvement in the indicators. From an economic perspective, buyers can leverage their bargaining power in the SCF environment to get price discounts and reduce their purchasing costs. Besides that, the operational benefits are maintained: higher effectiveness with the better exchange of information and better efficiency, allowed by digitalisation. Finally, looking at the intangible benefits, buyers can get not only a better relationship with their suppliers but also with their banks or third parties, as well as a sustainability enhancement.

More specifically, in the agriculture sector, (BERGEN M. STEEMAN; GELSOMINO, 2019) and (MEDINA; CANIATO; MORETTO, 2023) show many of these benefits can also apply. The most significant advantage is the decrease in the Cash Conversion Cycle (CCC), meaning a reduction in "the average days required to turn a dollar invested in raw materials into a dollar collected from a customer" (GELSOMINO et al., 2016). The agri-food industry is usually characterised by production seasonality, long production cycles and uncertainty in product quantity and quality due to weather conditions (TSOLAKIS C. KERAMYDAS; IAKOVOU, 2014), meaning the agriculture industry is usually under working capital pressure, and the reduced CCC can highly benefit them (BERGEN M. STEEMAN; GELSOMINO, 2019). (MEDINA; CANIATO; MORETTO, 2023) shows other possible benefits for the agrifood sector, such as de-risking of suppliers, quality assurance, improving liquidity distribution, enhancing credit conditions and indicators, and better supply chain relationships and information exchange.

Finally, looking at the SMEs context, the case study (NGUYENA et al., 2022) shows that statistically speaking, supply chain finance has a substantial positive impact on SMEs' overall performance and SC effectiveness while maintaining a negative effect (reducing) supply chain risk. Besides that, (BRYANT; CAMERINELLI, 2013) shows the potential of SCF for SMEs in making financing more available (primarily through non-traditional methods), improving relationships between SMEs and other SC participants and enhancing banks' support with better relationships and information exchange.

5.1.4 SCF Solutions and their Usage

As for the different SCF solutions, (BONZANI; CANIATO; MORETTO, 2018) showed that reverse factoring is the most used model and brings most of the benefits listed before. However, **Purchase Order Financing** can improve even more the financial, intangible, and operational benefits for the suppliers; **Inventory Financing** and **Invoice Auction** can enhance the financial and operational parts for the suppliers; and **Dynamic Discounting** brings more advantages in the financial and operational areas, both for suppliers and buyers in the supply chain.

More specifically, in the agrifood industry, (MEDINA; CANIATO; MORETTO, 2023) analysed which SCF solutions were adopted by the different participants in the supply chain. On the producers' side, they realised that agriculture producers mainly use **Inventory Financing (IF)**, **Reverse Factoring (RF)**, and **Dynamic Discounting (DD)** models. Dealing with products with long production cycles, liquidity is trapped in stocks,

increasing the NOWC; IF can help cope with those problems and with the lack of access to financial services (MEDINA; CANIATO; MORETTO, 2023). Upstream SC stages can also adhere to RF and DD when offered by their buyers. RF and DD are provided to decrease suppliers' DSO while maintaining or increasing buyers' DPO, meaning an overall decrease in the Cash Conversion Cycle.

5.1.5 SCF Barriers

Due to its recent appearance, SCF solutions still face some barriers to broader adoption (GELSOMINO et al., 2016) (MEDINA; CANIATO; MORETTO, 2023) (BRYANT; CAMERINELLI, 2013). There is a **lack of knowledge** and training about SCF (there is no precise market terminology, and confusion remains as to what SCF encompasses) and a **lack of collaboration** between different participants of the SC, who usually remain attached to core banking relationships and traditional forms of credit, reducing SCF transaction volumes.

There are also **technological and regulatory barriers**; law and regulatory barriers slow down SCF implementation; there are risk, regulatory, tax, VAT, and accounting issues. The paper-based manual processes, low digitalisation, and poor visibility on the goods movement in the organisations also make implementation harder.

Finally, there is also a **macro-institutional challenge** (MEDINA; CANIATO; MORETTO, 2023), represented by geographical, cultural, and language differences between parties involved and the need for buyers' and suppliers' collaboration for SCF implementation. However, (BRYANT; CAMERINELLI, 2013) states those barriers are "not insurmountable, provided they are actively managed."

5.1.6 Summary

To summarise the study on the Supply Chain Finance solution, Table 2 , below shows the model's most important drivers, benefits, and barriers in the context of the difficulties and problems small farmers have encountered before.

Drivers	**Benefits**	**Barriers**
Bankruptcy risk of suppliers	Reduction of the Cash Conversion Cycle	Lack of knowledge and training
Need to ensure quality	De-risking of SC	Lack of collaboration
Open account trading and lengthened supply chain cycles	Improvement of credit conditions and financial indicators	Law and regulatory barriers
Social and economic sustainability	Increase in liquidity	Macro-institutional challenge
Lack of liquidity	Quality assurance	Low Digitalization
Lack of access to financial services	Better exchange of information	
Long production cycle	Better SC relationship	
Lack of collateral	High financing availability	
Short maturity period	Improvement of SC effectiveness	
Level of Stock		
Payment Terms		

Table 2: Summary of SCF Solution.

In conclusion, the Supply Chain Finance solution shows a good correlation between the drivers for its adoption and the problems the small farmers face. The benefits seen by this model also have high relevance, showing a solution to the difficulties small farmers face in adopting and funding new technologies. The barriers to the usage of SCF are only five, and according to the studies, they are "not insurmountable", meaning that if small farmers focus on fixing those problems when adopting the SCF solutions, they can bring substantial benefits and help them embrace new technologies.

5.2 Microfinancing

5.2.1 Introduction

As mentioned, **microfinance** is a term for financial services offered to poor, low-income households and microenterprises who usually lack access to formal financial institutions (ZHIRI, 2017) (KAGAN, 2024). This can be done with different mechanisms, such as **microcredit**, **fund transfer**, **microinsurance**, **small loans**, **receipt of savings deposits**, **savings accounts**, and **more accessible payment services** (TEAM,). Through **Micro Financing Institutions (MFIs)**, lower-income entrepreneurs can obtain collateral-free loans at relatively low interest rates and flexible repayment terms (ZHIRI, 2017) (FINCORP, 2023). This is done by pooling borrowers together as a buffer. After receiving loans, **recipients** repay their debts together. Because the program's success depends on everyone's contributions, this creates a form of peer pressure that can help ensure repayment (KAGAN, 2024).

The primary objective of **microfinance** is to provide finance to small entrepreneurs to expand their businesses and eventually attain self-sustainability. Other common goals include **boosting** small businesses, **decreasing** unemployment, **promoting** economic development, etc. (TEAM,) (FINCORP, 2023). Furthermore, **MFIs** can provide non-financial services to their customers, such as **financial**, **business**, and **entrepreneurship training**.

Microfinancing has been proven to have a **positive** impact on poverty levels and entrepreneurship development in developing countries (ZHIRI, 2017). Besides that, **MFIs** and the financial and non-financial services they offer can promote financial inclusion, allowing small businesses to reduce the resource gap by being sought by investors significantly (TAIWO; AGWU; BENSON, 2016) (MAGAR et al., 2023).

5.2.2 Drivers for Microfinancing Adoption

The main **drivers** found for smallholders and people to seek Microfinancing solutions were (ZHIRI, 2017) (SIEDEK; PINI, 2020) (MAGAR et al., 2023):

- **Inability to access traditional financial services** (lower-income businesses and people have difficulty in getting financed by conventional banks, as they are a riskier counterparty);
- **Improvement of social-economic well-being** (poor people or entrepreneurs can

use Microfinancing to improve their poverty level);

- **Need for tailored financial services** (need for flexible payment terms, lower interest rates or reduced collateral);
- **Enhance the flow of finance to SMEs** (SMEs and micro institutions have low flow of finance from the banking sector);
- **High risk of micro activities**(Traditional Banks perceive micro activities as bad risk, hence have little interest in funding the industry; this is coupled with issues of high transaction costs and short tenor of payback period when funding is considered);
- **Need of people with few assets to save** (people in the lower socio-economic areas have few money available to save and need special accounts for that);
- **Need of insurance**;
- **High mortality rate among SMEs** (few newly established businesses survive in the first years);
- **Difficulty of smallholders to afford employers** (smallholders have difficulty hiring employees and end up relying on family labor);
- **Lack of hard collateral** (small businesses have lower assets side and less liquidity and, consequently, lower hard and liquid collateral for loans);
- **Lack of knowledge** (new entrepreneurs have lower knowledge about business development, entrepreneurship or financial management and need training).

Some drivers are more specific to the agricultural area (SIEDEK; PINI, 2020):

- **Increase in importance of small farmers** (as shown before, small farmers play a pivotal part in reducing world hunger and providing food to lower-income countries, and this role is estimated to increase in the following years);
- **Need of loans for machinery or seeds purchase** (small farmers cannot afford machinery, as the small amount of loans they receive end up being used to pay for their supply of seeds, fertilisers, and pesticides. This results in subsistence farming and small quantities of goods exported or commercialised, making it even more difficult to expand operations);

- **The risk of crops being damaged** (in certain areas where the main assets are livestock, the lack of proper collateral becomes a significant obstacle to accessing formal credit. If smallholders cannot repay a loan because their crops are damaged or destroyed by extreme weather events, parasites, or local conflicts, there is not much that can be done, turning them into even riskier counterparties in the lender's view).

5.2.3 Benefits of Microfinancing

As mentioned, microfinancing can bring different benefits to low-income households or small businesses, such as (ZHIRI, 2017) (KAGAN, 2024) (TEAM,) (FINCORP, 2023) (ONE,) (FORUM, 2023) (MURIDAN; IBRAHIM, 2016): **Expansion of business** (Business owners can use MFI's loans to run and expand their businesses and accumulate capital for future needs); **Financial Inclusion** (Micro-financing offers banking services to those traditionally excluded from the formal banking sector. This empowers individuals to save, access credit, and build credit histories, which can eventually enable them to access larger loans from traditional financial institutions); **Financial independence** (the primary goal of Microfinance is to allow for small businesses to expand and eventually attain self-sustainability); Economic resilience (helps individuals and business owners work effectively, becoming more resilient and able to cover significant unforeseen expenses); **Overall growth of the economy** (When entrepreneurs borrow microfinance, they create more employment opportunities in the economy and help the nation develop faster); **Access to finance without collateral requirement** (microfinance allows people and small businesses to obtain loans without pledging any asset as security, and these loans help meet financial requirements and promote self-reliance and entrepreneurship); **Access to education** (many MFIs provide non-financial services, mainly training and education about business development, financial management and entrepreneurship); **Improvement of entrepreneurship levels** (MFIs reduce the mortality rate in SMEs, enhancing entrepreneurship and overall economy in the region).

More specifically, in the agrifood industry, microfinancing can bring different benefits (SIEDEK; PINI, 2020) (SERVICES, 2024), such as **Enhanced Agricultural Productivity** (Access to microfinance allows farmers to invest in better resources and technologies, leading to increased crop yields and improved food security); **Risk Reduction** (Insurance products and savings accounts offered by MFIs can help farmers mitigate risks and recover more quickly from adverse events); **Market Access** (Loans can enable farmers to invest in processing and storage facilities, reducing post-harvest losses and allowing

for better market timing, which can lead to higher incomes); **Empowerment** (Microfinance can empower rural communities by providing them financial independence and the means to contribute to their household's income and decision-making processes); **Sustainable farming** (MFIs ensure that smallholder farmers receive technical support to manage their crops and livestock farming and promote education on green and efficient farming methods); **Tailored Financial Products** (farmers have particular needs and microfinance can help to develop financial products that align with the agricultural cycle and address those needs).

Notably, most of the benefits found in adopting microfinancing are closely linked to the problems small farmers face. Furthermore, (SIEDEK; PINI, 2020) affirms that "Microfinance cannot resolve all these enormous problems. But it can play an important role in helping some of these smallholders to prosper," showing a crucial part of MFIs in solving small farmers' difficulties and helping them afford new technologies and expand their operations.

5.2.4 Microfinancing Barriers

Regardless of their importance in the development of countries' economies and the growth of entrepreneurship, especially in the small businesses' context, microfinancing adoption still faces some critical barriers and problems in its adoption (TEAM,) (KAGAN, 2024) (FORUM, 2023) (MAGAR et al., 2023) (DOSSOU et al., 2020) (ABDULRAHEEM; ADEMOLA, 2015) (GEEKS, 2024): **High interest rates** (for-profit MFIs bring high interest rates with the appearance of "loan sharks" looking to make money from people with low incomes. This is one of the primary criticisms of microfinancing because, while these rates are necessary to cover administrative costs and mitigate the risk of lending to people experiencing poverty, they can sometimes become burdensome for borrowers, potentially leading to over-indebtedness); **Low credit supply** (Microloans might be too small to provide an actual path to independence and the supply of microfinance is still too low in some areas); **Overemphasis on Individual Responsibility** (Micro-financing places significant responsibility on borrowers to manage their loans and businesses effectively. However, not all borrowers possess the necessary entrepreneurial skills, financial literacy, or access to adequate support services, which can hinder their ability to succeed); **Not Suitable for All** (Microfinance is not a one-size-fits-all solution. The success of microfinance depends on various factors, including the local economic context, the nature of the businesses funded, and the borrowers' entrepreneurial skills. Some individuals may not benefit from microfinance due to a lack of business acumen or

viable business opportunities).

Microfinance's most significant criticism and challenge is, as mentioned, the for-profit characteristic of many MFIs. This factor makes interest rates too high in microfinance. It can cause over-indebtedness in small businesses looking for this solution, as in pursuit of profit, some MFIs might engage in aggressive lending practices, encouraging clients to take on more debt than they can handle. This also brings a problem of aggressive debt collection practices, as, to maintain profitability, MFIs may employ aggressive debt collection practices, which can be distressing and harmful to borrowers. This can lead to social and financial stress for individuals and communities.

Another problem brought about by the for-profit characteristic is prioritising profits over social impact: There's a concern that for-profit MFIs might prioritise financial returns over their original social mission of poverty alleviation and economic inclusion. This shift in focus can lead to practices not in clients' best interest, such as the appearance of "loan sharks" and the disappearance of grace periods or provision of loans without proper assessment of the borrower's ability to repay.

In the agriculture sector, microfinancing solutions face some more specific challenges (SERVICES, 2024): **Repayment Schedules** (The traditional microfinance model of short-term loans with frequent repayment schedules does not align well with the agricultural cycle, which often requires longer-term investment); **Education** (Farmers frequently need training and support to utilise financial services for agrarian improvement effectively); **Environmental Risks**(Climate change and environmental degradation pose significant risks to agriculture, making lending to farmers riskier for MFIs).

5.2.5 Summary

To summarise the study on the Microfinance solution, Table 3, below shows the model's most important drivers, benefits, and barriers in the context of the difficulties and problems small farmers have encountered before.

Drivers	**Benefits**	**Barriers**
Inability to access traditional financial services	Expansion of business	High interest rates
Need for tailored financial services	Financial Inclusion	Low credit supply
High risk of activities	Financial independence	Overemphasis on Individual Responsibility
Need of insurance	Economic resilience	Not Suitable for All
Difficulty in affording employers	Access to finance without collateral requirement	Repayment Schedules
Lack of hard collateral	Access to education	Education
Lack of knowledge	Enhanced Agricultural Productivity	Environmental Risks
Increase in importance of small farmers	Risk Reduction	
Difficulty in affording new machinery	Market Access	
	Empowerment	
	Sustainable farming	

Table 3: Summary of Microfinancing Solution.

In conclusion, the microfinance solution shows a good correlation between the drivers for its adoption and the problems small farmers face. The benefits seen in this model also have high relevance, with different benefits providing solutions to the challenges small farmers encounter in adopting and funding new technologies. However, it is essential to note that microfinance faces some barriers. Many of these issues are readily solvable and are already being addressed by MFIs; for example, the lack of education, the overemphasis on individual responsibility, the unsuitability for all, and the low credit supply are being tackled by the training offered by MFIs and the pooling of risk and counterparties when

providing microloans. The most significant criticism of microfinance remains the high interest rates charged, which can cause over-indebtedness in small businesses. Despite this, the future of microfinancing holds promise, and it is a crucial solution to small farmers' problems, as empirical data still points to positive results for small businesses and entrepreneurship with the adoption of microfinance (TAIWO; AGWU; BENSON, 2016) (ZHIRI, 2017) (KAGAN, 2024) (SIEDEK; PINI, 2020) (FORUM, 2023).

5.3 Minibonds

5.3.1 Introduction

Minibonds, as mentioned, are medium- or long-term loans issued for a value lower than €50 million and intended for non-listed companies that fall under the SME category. Minibonds offer an alternative finance tool, as SMEs can raise funds from investors quickly and efficiently without relying on traditional bank loans (MEDINA; CANIATO; MORETTO, 2023).

It is important to note that minibond investment is restricted to professional institutional investors and other qualified entities, including banks, investment companies, asset management companies (AMC), harmonised management companies, etc. Investing in minibonds can be beneficial for financial institutions, as the return is typically higher and less volatile than other financial tools (MODEFINANCE, 2022).

It is also possible for SMEs to pursue the basket bond approach for their issue. Basket bonds are portfolios that gather emissions of a group of companies, usually united by a thematic or territorial connection. The enterprise can apply for a basket bond operation on dedicated portals. Subsequently, the arranger will select the enterprises that will form the portfolio a

5.3.2 Drivers for Minibonds Adoption

The main drivers found for companies looking to adopt and issue minibonds were (CERQUETI et al., 2024; LAZZARIN, 2020; PARTNERS, 2019; STORANI, 2022): **Need for Diversified Financing** (Minibonds offer an alternative to bank loans, which may not always be accessible or suitable for medium-sized businesses. This diversification helps companies reduce their reliance on bank funding); **Facilitating Growth** (Issuing minibonds can fund growth initiatives like business expansions, technology investments,

or enhancing production capabilities); **Capital Market Access** (Minibonds provide a gateway for companies and SMEs to tap into capital markets that might otherwise be challenging to reach compared to corporations); **Reduced Reliance on Bank Loans** (minibonds emerged as a way for companies to secure financing without depending on traditional bank credit lines); **Need for Enhanced Liquidity Management** (By issuing minibonds, companies can improve liquidity management by managing cash flow and meeting term financial commitments); **Regulatory Backing** (some governments, for example in Italy, have introduced regulations supporting the minibond market, simplifying access to this financing avenue for businesses).

More specifically, in the agrifood industry, (MEDINA; CANIATO; MORETTO, 2023) shows that the drivers of agricultural minibond usage are primarily related to liquidity and financial constraints faced by producers and cooperatives. This is particularly important for producers and cooperatives in the agri-food industry, where cash flow management is crucial due to the seasonal nature of agricultural production and the need for timely financing to maintain operations and invest in future production.

5.3.3 Benefits of Minibonds

Studies show many benefits for companies that decide to issue and adopt minibonds as a source of credit. The most important ones found were (MODEFINANCE, 2022), (VERBEEK; FACKELMANN; MCDONAGH, 2019), (S.P.A.,), (BOCCALETTI; ROSSI; ROSSOLINI, 2022), (KLIMENTYEV, 2018):

- **Access to Capital**: Minibonds reduce the reliance on traditional banking methods by providing an alternative funding source for companies, especially SMEs.
- **Terms Flexibility**: The companies issuing the bonds can choose the repayment structure, allowing them to match their cash flow needs better.
- **Longer-term Financing**: Minibonds traditionally have medium to long-term maturity, usually up to 7 years, providing a more stable and longer-term credit option when compared to traditional loans.
- **Branding and Signaling**: Issuing minibonds can help companies signal their quality and creditworthiness, helping reduce funding costs in the future as relationships with investors are strengthened.

- **Lower Funding Costs**: Minibonds can be a cost-effective way for businesses to raise capital due to reduced regulatory requirements compared to larger bonds.

5.3.4 Minibonds Barriers

Regardless of their importance in the SME context and their relevance in making funding available, companies looking to issue minibonds still face some significant barriers (MODEFINANCE, 2022), (STORANI, 2022), (KLIMENTYEV, 2018), (ELY; MARTELL, 2016), (FUND, 2016):

- **Higher Costs of Issuance**: The issuance of minibonds can be more expensive than traditional financing methods due to the need for underwriters and other intermediaries.
- **Information Asymmetry**: Minibonds are less transparent for investors, making it hard for them to assess the creditworthiness of the issuer, leading to higher interest rates and lower demand.
- **Limited Liquidity**: The secondary market for minibonds is often less liquid than traditional bond markets, making it harder for companies to sell their minibonds quickly if needed.
- **Regulatory Complexity**: In many countries, companies must comply with various regulations and requirements, such as preparing audited financial statements, which can be a costly and time-consuming process.

5.3.5 Summary

To summarise the study on the Minibond solution, Table 4, below shows the model's most important drivers, benefits, and barriers in the context of the difficulties and problems small farmers have encountered before.

Drivers	Benefits	Barriers
Need for Diversified Financing	Access to Capital	Higher Costs of Issuance
Facilitating Growth	Terms Flexibility	Information Asymmetry
Market Access	Longer-term financing	Limited Liquidity
Reduced Reliance on Bank Loans	Branding and Signaling	Regulatory Complexity
Need for Enhanced Liquidity Management	Lower Funding Costs	Investors Restrictions
Regulatory Backing		Maximum Purchase Amount
		Credit Risk
		Marketing and Promotion Costs
		SME Characterisation

Table 4: Summary of Minibonds Solution.

Initially, the usage of minibonds looks promising for small farmers, as many drivers for its adoption and its benefits closely relate to the difficulties faced by the farmers in their operations. However, there are giant barriers to the usage of minibonds that make their usage almost impossible for small farmers. The most important ones are the minibonds market's lower liquidity, the high issuance and promotion costs and the limitation regarding the issuer's need to be considered an SME in the countries' regulation, something that for many small farmers will not be the case.

5.4 Crowdfunding

5.4.1 Introduction

Crowdfunding refers to the act of drawing funds from a large group of people, usually with the use of online platforms (LUKKARINEN et al., 2016). It allows entrepreneurs to fund their ventures through small contributions from many funders without standard financial intermediaries, and different models can be used (reward, donations, lending,

equity) (CORREIA; SOUSA; BRANDãO, 2019). Donation-based crowdfunding is used to collect charitable funding to support causes and projects. In rewards-based crowdfunding, funders receive non-monetary rewards in exchange for their contribution. Debt-based crowdfunding offers a credit contract, whereas equity-based crowdfunding offers an equity stake in the target company (LUKKARINEN et al., 2016).

5.4.2 Drivers for Crowdfunding Adoption

The most important drivers found that incentivize companies to adopt crowdfunding were (LUKKARINEN et al., 2016) (CORREIA; SOUSA; BRANDãO, 2019) (MARTíNEZ-CHáFER; MOLINA-MORALES; PEIRó-PALOMINO, 2023) (VENSLAVIENė; VAICIUKEVIčIūTė, 2021):

- **Need for Diversified Funding Sources**: Crowdfunding allows companies to access capital from a broader range of investors beyond traditional sources.
- **Market Validation**: The success of raising funds from crowdfunding can signal to the market the quality of the project, showing that the team and the idea are valid and show potential for growth.
- **Disclosure and Transparency**: Crowdfunding provides detailed information about the project and the company, increasing investors' confidence.
- **Marketing and Exposure**: Leveraging social media and private networks to promote the crowdfunding campaign can help reach a broader investor base and drive funding.
- **Need for Tailored Solutions**: Factors like campaign duration, funding target, and minimum investment are defined by the issuer, allowing a more tailored solution.
- **Feedback**: Companies can validate a business idea or project through feedback from crowdfunders.

5.4.3 Benefits of Crowdfunding

Crowdfunding can bring different benefits to the companies using it, such as (MACHT; WEATHERSTON, 2014) (CAPITAL,) (AICONTENTFY, 2023) (GUIRADO; ZORITA; CASTRO, 2018) (ESTRIN; GOZMAN; KHAVUL, 2018):

- **Higher Access to Capital**: As mentioned, crowdfunding allows companies to access capital from diverse sources, beyond traditional ones.
- **Signaling of Quality and Potential**: The success of crowdfunding projects and the participation of large early investors show a positive signal to the market about the company's creditworthiness and potential for growth, making it easier for them to receive more funding.
- **Branding**: Crowdfunding campaigns can generate media attention and bring awareness to the company.
- **Loyalty**: Early backers become loyal to the brand and the project, creating a community of supporters and spreading product awareness.
- **Faster Funding**: Crowdfunding usually offers faster and more efficient financing than traditional methods.
- **Flexibility**: Crowdfunding campaigns can be tailored to specific funding goals, allowing businesses to raise the exact amount needed for their projects.
- **Global Reach**: Crowdfunding solutions, being digitalized, are not limited by geographical factors.
- **Risk Reduction**: By validating ideas and receiving funds upfront, companies can mitigate the financial risks associated with new product development.

5.4.4 Crowdfunding Barriers

Crowdfunding seems an exciting model for companies looking to finance projects, but it's essential to look at some of the barriers to its adoption and the adverse effects of its usage (BEREZHNOY, 2019) (ISLAM, 2020) (GUIRADO; ZORITA; CASTRO, 2018) (CATALONIA, 2015) (ESTRIN; GOZMAN; KHAVUL, 2018):

- **Need for Digitalisation**: Crowdfunding demands a high level of digitalisation, and learning how to operate and use the platforms can be difficult for some businesses.
- **Limited Access**: Access to markets with crowdfunding is often limited through regulation and legal requirements, and some platforms frequently target only accredited investors.

- **Inertia to Adoption**: Building trust with investors is vital for crowdfunding to work, but the absence of know-how or lack of awareness of crowdfunding makes it harder for companies trying to adopt this method to kickstart their project funding.
- **Regulation**: Compliance with regulations, especially in the early stages, can be time-consuming and costly, as well as bring barriers to market access.
- **Information Asymmetry**: Lack of transparency and information about the project or the team makes investors less inclined to invest in the crowdfunding option.
- **Risk of Failure**: There is a risk of failure from the project funding or default from the issuer, which can harshly damage the company's image.
- **Promotion Costs**: To attract investors, companies looking for crowdfunding must heavily increase their exposure and marketing, as well as be as transparent as possible about the project and the company's financial situation, something that can be costly and time-consuming.

These barriers can make it harder for small farmers, having limited resources and less experience in crowdfunding, to adopt this model. Still, mitigating some problems and making the model more attractive is possible. For example, the information asymmetry and inertia to adoption can be mitigated if farmers make their financial information and intentions of using the funds available for investors. Limited access and regulations can be mitigated by issuing more than one project in different locations or partnering crowdfunding with other funding methods. Finally, the need for digitalisation and the lack of know-how can be mitigated if farmers thoroughly study the crowdfunding process and implement it in smaller projects.

5.4.5 Summary

To summarise the study on the Crowdfunding solution, Table 5, below shows the model's most important drivers, benefits, and barriers in the context of the difficulties and problems small farmers have encountered before.

Drivers	Benefits	Barriers
Need for diversified Funding Sources	Higher Access to Capital	Need for Digitalisation
Market Validation	Signalling of Quality and Potential	Limited access
Disclosure and Transparency	Branding	Inertia to Adoption
Marketing and Exposure	Loyalty	Regulation
Need for tailored solutions	Faster funding	Information Asymmetry
	Flexibility	Risk of Failure
	Global Reach	Promotion Costs
	Risk Reduction	

Table 5: Summary of Crowdfunding Solution.

In conclusion, Crowdfunding can bring attractive benefits for small farmers and be an efficient tool in helping them afford new technologies. Many of the problems they face, such as difficulty in getting traditional funding or lack of awareness, can be solved by this method. The barriers to the adoption of this method are not insuperable. If farmers dedicate time and effort to understanding how crowdfunding works, they can benefit greatly.

5.5 Peer-to-Peer (P2P) Lending

5.5.1 Introduction

Peer-to-peer (P2P) lending, or social lending, is a method that packages small amounts of money from different lenders to provide a loan to a borrower. Rates in P2P lending are usually lower than in traditional banking because there is no intermediary (HARTFORD, 2024). P2P lenders typically include wealth advisors, fixed-income funds, asset managers, or individuals; they view this kind of loan as an investment that pays a fixed income rate, and the amount needed to invest can be as low as $25.

Most peer-to-peer loans are unsecured personal loans that work through online P2P lending platforms, such as Zopa, Prosper, and Lending Club. The platform collects and

verifies the borrowers' personal and financial information, performs credit scoring and checking, processes monthly payments, and services the loans. According to the Small Business Administration, P2P lending is growing, with online lending platforms filling a niche market for small business capital (HARTFORD, 2024). Business owners use P2P loans for various reasons, such as purchasing equipment and tools, consolidating debt, covering training costs for employees, and expanding.

The first peer-to-peer (P2P) lending platforms appeared in 2005-2007 in the UK and the US, and although P2P lending only represented 0.7% of retail lending in the US in 2015, it has been growing exponentially (HAVRYLCHYK et al., 2017). The entry of new FinTech players in the market could diversify the intermediation between savers and borrowers, which would make the financial sector more stable and efficient and could ensure greater access to financial services (HAVRYLCHYK et al., 2017).

5.5.2 Drivers for P2P Lending Adoption

Companies borrowing money from P2P platforms are usually looking for (HARTFORD, 2024) (HAVRYLCHYK et al., 2017) (KHAN,):

- **Access to capital:** Companies looking for reduced dependence on traditional funding can use P2P lending as an alternative financing option to access a wider pool of investors.
- **Speed and Efficiency:** P2P lending platforms leverage technology and the internet to automate various processes, like borrower verification, credit scoring, and loan disbursement. This can help make the process of financing more efficient and cost-effective.
- **Flexible funding:** P2P lending options offer more flexible repayment terms, helping companies tailor the solution to their needs.
- **Need for transparency and trust:** Online P2P platforms can offer a highly transparent system in terms of loan information, interest rates, repayment schedules, etc., allowing for a more trustworthy environment.

5.5.3 Benefits of P2P Lending

Peer-to-Peer Lending can provide borrowers with (HARTFORD, 2024) (HAVRYLCHYK et al., 2017) (KHAN,) (HADDAD, 2023) (CAPITAL, 2023) (BILYEAU, 2024):

- **Broader investors:** P2P lending, just like crowdfunding, provides an alternative financing method, especially for small businesses that have trouble obtaining traditional banking methods, as they allow companies access to a more extensive range of investors beyond financial institutions.
- **Faster funding:** As mentioned, P2P platforms leverage technology to make processes more efficient and faster, allowing companies to receive approval for loans quickly.
- **Flexible Terms:** P2P lending offers flexible terms and repayment schedules and lower collateral needs compared to traditional banking.
- **Lower costs:** P2P lending platforms provide lower interest rates than conventional financial institutions, helping small businesses reduce their financing costs.
- **Tailored solutions:** Companies can directly negotiate terms with investors, allowing for funding more tailored to their needs.
- **Positive Signaling and awareness:** Like crowdfunding, successful P2P lending campaigns can give a positive signal of a company's creditworthiness and quality, making it easier for them to get additional funds.
- **Simplified processes:** P2P lending platforms usually offer a less bureaucratic and more direct application process.
- **Brand Loyalty:** Like crowdfunding, P2P lending allows companies to create a community of supporters around their brand.
- **Risk Reduction:** Like in crowdfunding options, P2P lending can be used to validate ideas and receive funds upfront, which can mitigate some risks associated with new product development.

5.5.4 P2P Lending Barriers

Peer-to-peer lending solutions still face some barriers to their adoption and can lead to adverse effects on their usage, for instance (HAVRYLCHYK et al., 2017) (HARTFORD, 2024) (SULASTRI; JANSSEN, 2023) (STREET, 2024) (BONDORA, 2022):

- **Charges:** P2P lending platforms often charge significant fees, reducing the overall money received.

- **Regulatory Uncertainty:** The regulatory environment for P2P lending is still evolving, which can create uncertainty and risk for both borrowers and investors.
- **Information Asymmetry:** Investors may have limited information about the borrowers and the loans, making it difficult to assess their creditworthiness and increasing interest rates.
- **Technical Issues:** Technical issues with the platforms can lead to delays or errors in the lending process.
- **Fraud and Security Concerns:** The reliance on technology platforms to facilitate lending can expose participants to fraud and security risks.
- **Negative Signaling:** Like in the case of crowdfunding, failure to gather resources from P2P lending can heavily damage a company's image. Additionally, stakeholders might interpret the usage of P2P lending as a signal that the company is not performing well and, therefore, is unable to use traditional borrowing methods.
- **Loan Amount Limits:** Some platforms impose limits on the maximum loan amount, which might be lower than the company's needs.

5.5.5 Summary

To summarise the study on the P2P Lending solution, Table 6, below shows the model's most important drivers, benefits, and barriers in the context of the difficulties and problems small farmers have encountered before.

Drivers	Benefits	Barriers
Access to Capital	Broader investors	Charges
Reduced dependence on traditional funding	Faster Funding	Regulatory Uncertainty
Speed and Efficiency	Flexible Terms	Information Asymmetry
Flexible funding	Lower costs	Technical Issues
Need for transparency and trust	Tailored solutions	Fraud and Security Concerns
	Positive Signalling	Negative Signalling
	Simplified processes	Loan Amount Limits
	Brand Loyalty	

Table 6: Summary of P2P Lending Solution.

In conclusion, P2P Lending can benefit small farmers and be an efficient tool in helping them afford new technologies. Many of the problems they face, such as difficulty in getting traditional funding or lack of awareness, can be solved by this method. The barriers to adopting this method, like crowdfunding, are not insuperable. With the crescent adoption of P2P lending among different companies, they tend to be mitigated, making this model an exciting solution for small farmers, especially in the future

5.6 Trade Credit Insurance (TCI)

5.6.1 Introduction

Trade Credit Insurance (TCI) is a tool for risk management used by companies to guard against the loss of bad debts due to customer insolvency (COFACE, 2023). TCI can be used to hedge against bad debts or defaults by customers, making it easier for companies to have more regular cash flow (INSURANCE,). It allows sellers to offer improved payment terms and provides financial information concerning buyers' creditworthiness (INSURANCE,). Additionally, TCI can be used as collateral with some financial institutions, improving access to borrowed funds (BDC,). Lastly, Trade Credit Insurance can help in settling unpaid bills through debt collectors, resulting in effective cash flow management and good relations with clients (COFACE, 2023).

In the particular case of small farmers, this insurance helps them provide attractive

credit terms like deferred payments and ensures exported goods are insured, making them more competitive, thus promoting sales and attracting new businesses (BDC,). In addition, TCI helps to secure a predictable, continuous revenue stream from these small farmers who could become victims of insolvent customers (ALLIANZ,) (GROUP, 2022). The risk assessment and credit information that trade credit insurers provide can help small farmers make more informed decisions and negotiate with customers. Finally, TCI policies can be used as collateral with banks or lenders, making financing more available for the farmers. In summary, TCI can offer small farmers more confidence to offer credit terms, grow their customer base, and manage their cash flow and financial risks.

5.6.2 Drivers for TCI Adoption

The main drivers for companies adopting TCI solutions are (ALLIANZ,) (PARTNERS, 2024) (RESEARCH, 2023) (COMMERCIAL, 2024):

- **Risk Management:** TCI can be used as a risk management tool, helping protect businesses against the default of their customers by reducing the risk of non-payment.
- **Credit Management:** TCI can enable companies to offer more competitive credit terms to customers, increasing confidence in expanding to new markets or improving the customer base without fear of financial loss. TCI also provides access to insurers' credit risk assessments and monitoring services.
- **Need for Predictable Finance:** TCI improves cash flow by protecting against late or non-payment, ensuring more predictable income streams. This also improves access to finance, as lenders view businesses with insured receivables as lower risk.
- **Peace of Mind:** TCI can reassure stakeholders about the company's financial stability, making them more confident about the company's future.
- **Efficiency:** By having access to insurers' expertise, companies using TCI can have more efficiency in assessing customers' creditworthiness and receiving payments.
- **Expansion:** Companies looking to expand, especially to foreign markets, can use TCI to be protected against the risks of exporting to new markets.
- **Protection of Accounts Receivable:** Companies looking to protect their asset side balance sheet can use TCI, as it protects the accounts receivable from loss caused by bankruptcy, insolvency, or credit risks, such as extended default.

5.6.3 Benefits of TCI

The benefits found by companies adopting Trade Credit Insurance were (ALLIANZ,) (COMMERCIAL, 2024) (VELOTRADE, 2020) (INSURANCE, 2024) (ABI,):

- **Expanding Sales:** TCI allows businesses to safely increase sales to existing customers or expand to a new customer base.
- **Entry in New International Markets:** TCI helps protect businesses against the risks of exporting overseas, reducing uncertainty for firms and allowing them to expand to international markets.
- **Better Finance Terms:** Financial institutions lend more capital to businesses that have TCI in place, offering more favorable lending terms. TCI can also be used as collateral.
- **Knowledge:** Insurers provide businesses with extensive know-how and knowledge of companies, sectors, and economic trends to help them grow and operate safely.
- **Increase in Capital:** TCI helps free up capital from bad-debts reserves, and premiums are tax-deductible.
- **Risk Reduction:** TCI pays out a percentage, around 90% typically, of the outstanding amount owed if a customer becomes insolvent or defaults on payment, mitigating the risk of non-payment.
- **Faster Business Growth:** TCI allows order volumes with fast-growing customers to be increased rapidly, enabling faster business expansion.
- **Cash Flow Improvement:** TCI provides a more stable and predictable cash flow, as it allows companies to maintain cash flow if customers become insolvent or do not pay their bills on time.
- **Reducing Concentration Risk:** TCI mitigates risk for businesses whose most significant operations are dependent on a low number of customers.
- **Efficient Collection:** Insurers provide access to cost-effective collection of payments.
- **Portfolio Monitoring:** TCI includes access to professional portfolio monitors that track customers' ability to meet their financial obligations.

5.6.4 TCI Barriers

There were still some adverse effects of TCI and barriers found to its adoption (COFACE, 2023) (ALLIANZ,) (BRAUN; FISCHER; SCHREIBER-OROSZ, 2023) (RATING, 2023) (BOARD, 2022):

- **Disruption of Trade:** A reduction in TCI cover may lead sellers to demand advance payments from buyers, resulting in liquidity or financing constraints that disrupt trade. Sellers may also stop trading with some buyers, reducing trade volumes.
- **Cumulative Effect of Defaults and Losses:** If sellers retain the credit risk themselves due to reduced TCI cover, buyer defaults could lead to losses that spread through the economy in a domino effect during crisis times.
- **Negative Externalities on the Broader Economy:** The disruption of trade and economic activity caused by TCI withdrawal can create negative externalities that affect third parties beyond the insured relationships.
- **Low Flexibility:** Low flexibility on policy terms and conditions from the insurers can make it harder for companies to adopt the solution.
- **Exposure Risk:** Significant exposure to high-risk countries or sectors, or large exposures to single buyers, can make insurers more cautious and act as a barrier for TCI usage.
- **Costs:** The cost of premiums and fees paid to insurers can be significant, especially for smaller enterprises.

5.6.5 Summary

To summarise the study on the Trade Credit Insurance solution, Table 7, below shows the model's most important drivers, benefits, and barriers in the context of the difficulties and problems small farmers have encountered before.

Drivers	Benefits	Barriers
Access to Capital	Broader investors	Charges
Reduced dependence on traditional funding	Faster Funding	Regulatory Uncertainty
Speed and Efficiency	Flexible Terms	Information Asymmetry
Flexible funding	Lower costs	Technical Issues
Need for transparency and trust	Tailored solutions	Fraud and Security Concerns
	Positive Signalling	Negative Signalling
	Simplified processes	Loan Amount Limits
	Brand Loyalty	

Table 7: Summary of TCI Solution.

In conclusion, after analysing the drivers for Trade Credit Insurance usage and its benefits and barriers, it is possible to notice this solution can provide a strong alternative for small farmers and their financial challenges in adopting new technologies. Many of the benefits found closely relate to small farmers' problems, and the harmful effects of TCI are mainly in periods of financial crisis. The other barriers, namely costs and low flexibility, can be easily offset by the expansion in sales and better financing terms brought by the same model.

5.7 Commodity Financing

5.7.1 Introduction

Commodities are the basic generic goods traded in the international markets. They are generally raw materials used in the production processes. Commodity financing refers to non-speculative activities related to global commodity flows. It involves financial products and services used to support commodities' production, processing, trading, and marketing (HUANG, 2019). Producers, traders, processors, and distributors are the leading players involved in commodity financing, and the usage of this model is different for each of them. This paper will focus on the **drivers, benefits, and barriers** of commodity financing for the **producer's** side of the value chain.

5.7.2 Drivers for Commodity Financing Adoption

The main drivers for farmers looking to adopt **Commodity Financing** are (MCKINSEY, 2023) (AALTONEN, 2024) (COVO, 2023) (FORTUNATO, 2024) (DUDDA et al., 2022) (CONTOUR, 2023) (ZAKAI; RU, 2018) (PIRRONG, 2015) (OECD, 2023) (MANOGNA; KULKARNI, 2024):

- **Access to Capital**: Commodity finance can be an alternative to help farmers access capital, especially for smallholder farmers that often face limited access to traditional banking channels.
- **Price Volatility**: Commodities are highly volatile products, and commodity financing can help farmers hedge themselves against future price drops with the usage of derivatives, for example.
- **Risk Management**: As mentioned, commodity financing can be a good tool for farmers looking to hedge against risks associated with price fluctuations, weather conditions, and market volatility.
- **Market Connectivity**: Commodity financing can help facilitate market connectivity by ensuring that farmers have a stable supply chain and can sell their products at competitive prices.
- **Need for Innovative Financing Mechanisms**: Changes in the agricultural supply chain bring a need for more flexible and accessible financing solutions for producers.
- **Collateral Requirements**: The volatility of commodity prices has increased the need for financing, leading to heavier collateral requirements and more significant margin calls for producers.
- **Market Trends**: The commodity trading market has increased in the past years, and this trend is expected to continue, creating opportunities for companies to adopt commodity financing strategies.
- **Contribution to the Real Economy**: Mainly for the food supply chain, commodity financing can contribute to the real economy by ensuring food supply security and other essential commodities.

5.7.3 Benefits of Commodity Financing

Commodity Financing has demonstrated various benefits for farmers who have adopted it, such as (FORTUNATO, 2024) (DUDDA et al., 2022) (CONTOUR, 2023) (PACKMAN, 2020) (NIGATU et al., 2020) (OROMIA, 2022) (HAYES, 2024) (EXCHANGE, 2018):

- **Enhanced Access to Credit**: Commodity financing offers farmers improved financing opportunities and more appealing and affordable lending rates, making it a feasible option for credit access.
- **Improved Saving Trends**: Commodity financing enables farmers to store commodities, preserving them for sale when prices are higher. They can also save their surplus production and avoid post-harvest losses, leading to improved saving trends.
- **Enhanced Financial Situation**: Commodity financing equips farmers with additional working capital and empowers them to invest their surplus in other profitable ventures, enhancing their overall financial well-being.
- **Reduced Market Risks**: By hedging against market fluctuations, farmers can mitigate their exposure to price risks and maintain a stable income stream and more predictable cash flow.
- **Efficient Raw Material Supply**: Commodity financing ensures that processors have a consistent supply of raw materials, which can lead to increased efficiency and productivity.
- **Improved Market Information**: Commodity financing furnishes farmers with information about market trends and prices, enabling them to make informed decisions about their production and sales.
- **Know-How**: Commodity financing often includes training services for farmers, aiding them in enhancing their storage and management practices. Additionally, regulatory bodies often monitor commodity financing, ensuring the correct storage and management, reducing the risk of loss or mismanagement.
- **Increased Transparency**: Electronic commodity trading platforms promote fair price discovery and eliminate the possibility of price manipulation.
- **Continuous Production**: Commodity finance enables producers to continue operating without large upfront payments, reducing the gap between production and final sale.

- **Reduces Collateral**: By hedging the commodities, farmers have lower haircuts [1] on their collateral, and their perceived risk is reduced, allowing them better loan terms.

5.7.4 Commodity Financing Barriers

Regardless, Commodity Financing can still bring some adverse effects for farmers, and there are some barriers to its adoption (DUDDA et al., 2022) (CONTOUR, 2023) (MCKINSEY, 2023) (PACKMAN, 2020) (NIGATU et al., 2020) (OECD, 2023) (MANOGNA; KULKARNI, 2024):

- **Regulatory and Policy Issues**: There are different regulations and compliance requirements for farmers to use commodity finance.
- **Depressed Commodity Prices**: Chronic overproduction has severely reduced commodity prices, leading to farmers losing money on many primary commodities, such as soybeans, corn, cotton, dairy, and hogs.
- **Risk of Side Selling**: The risk of side selling, when farmers deliver their crops to a buyer other than the one that provided pre-harvest financing, can lead to financial losses for farmers.
- **Increased Financial Burden**: The financialisation of agricultural commodities can increase the financial burden on farmers, who already face high operational costs and risks.
- **Increased Concentration of Industry**: Commodity financing can lead to increased industry concentration, making it more difficult for smaller farmers to compete.
- **Reduced Farm Revenues**: Long periods of low crop prices, caused by commodity financing, can drastically reduce farm revenues.

5.7.5 Summary

To summarise the study on the Commodity Financing solution, Table 8, below shows the model's most important drivers, benefits, and barriers in the context of the difficulties and problems small farmers have encountered before.

[1] A haircut is the lower-than-market value placed on an asset when it is being used as collateral for a loan

Drivers	Benefits	Barriers
Access to Capital	Broader investors	Charges
Reduced dependence on traditional funding	Faster Funding	Regulatory Uncertainty
Speed and Efficiency	Flexible Terms	Information Asymmetry
Flexible funding	Lower costs	Technical Issues
Need for transparency and trust	Tailored solutions	Fraud and Security Concerns
	Positive Signalling	Negative Signalling
	Simplified processes	Loan Amount Limits
	Brand Loyalty	

Table 8: Summary of Commodity Financing Solution.

Initially, commodity financing seems like a potential solution to help small farmers afford new technologies, as it presents many benefits for farmers using it, especially regarding risk mitigation and better financing access. However, there are some structural constraints for this solution to be used by small farmers; firstly, it is only available to farmers producing commodities (generic goods traded in the international markets); this is a highly competitive market, with big farmers controlling most of it (HUANG, 2019). For that reason, many smallholder farmers choose not to participate in the production of commodities and focus on other crops instead. Additionally, the growth of commodity financing and the financialisation of agricultural products can lead to speculative movements, high price volatility, and long periods of reduced price, leading to lower income for producers, which can heavily affect small farmers' survivability. In conclusion, commodity financing might be used by a very niche group of small farmers (those producing and specialising in commodities) in their operations and investments in new technologies. Still, most of them will not be able to benefit from this finance model.

5.8 Summary of Benefits

To better understand the finance models studied and the benefits that each one can bring to the small farmers adopting it, Table 9, below is a summary of the most important benefits found for the models and which one (marked with an X) brought it when used.

Table 9: Summary of Benefits

Benefit	SCF	Micro-financing	Mini-bond	Crowd fund-ing	P2P Lend-ing	TCI	Commo-dity Fi-nance
Liquidity/ Cash Flow Improve-ment	X		X			X	X
Better Access to Financing	X	X	X	X	X	X	X
Reduction of Opera-tional Risk	X	X				X	X
Reduction of Risk of New In-vestments				X	X		
Improved Finance Indicators	X	X				X	X
Better Financing Terms	X	X	X			X	X
Tailored/ Flexible Financing		X	X	X	X		

Continued on next page

Benefit	SCF	Micro-financing	Mini-bond	Crowd fund-ing	P2P Lend-ing	TCI	Commo-dity Fi-nance
Operational Benefits (Efficiency, Effective-ness, and Know-How)	X	X				X	X
Intangible Benefits	X						X
Branding/ Loyalty			X	X	X		
Expansion of Market Access and Business Growth		X				X	

5.9 Summary of Difficulties

To better understand the finance models studied and the difficulties that each one can bring to the small farmers adopting it, Table 10, below is a summary of the most significant difficulties found for the models and which one (marked with an X) brought it when used.

Table 10: Summary of Difficulties.

Barrier	SCF	Micro-financing	Mini-bond	Crowd fund-ing	P2P Lend-ing	TCI	Commo-dity Fi-nance
Lack of Knowl-edge, Training or Infor-mation	X	X	X	X	X		
Law and Regulatory Barriers	X		X	X	X		X
Low Digi-talization/ Technol-ogy barriers	X		X		X		
High Interest Rates/High Costs		X	X	X	X	X	
Low Credit Supply		X	X		X		
Not Suitable for All/ Low Flexibility		X	X			X	X

Continued on next page

Benefit	SCF	Micro-financing	Mini-bond	Crowd fund-ing	P2P Lend-ing	TCI	Commo-dity Fi-nance
Difficult Repay-ment Schedules/ Financial Burden		X					X
Risk of farmers		X	X	X			
Inertia to adoption/ Negative Signalling				X	X		
Cumulative effect in Crisis						X	X

6 DISCUSSION

Based on the results found for each of the finance models, the benefits and barriers to adoption of them, it was possible to understand better which models can help small farmers in the funding of the initial investment of the technologies (CapEx) and which ones can help in affording the operational costs of the technology (OpEx). The topics below show the results alongside with the difficulties that small farmers currently have in adopting these models and the risks or problems they can bring.

It is important to remember here that the finance models of Minibonds and Commodity Financing are not part of the discussion as it was easy to conclude the majority of the small farmers can't use them. Minibonds, as mentioned, have low market liquidity and high issuance and promotion costs and are limited regarding the issuer's need to be considered an SME in the countries' regulation. This factor will drastically reduce the number of small farmers who are available to use the model. Commodity Financing, additionally, faces some structural constraints for its adoption by small farmers as it is only available to farmers producing commodities (generic goods traded in the international markets), a market controlled mainly by big farmers (most smallholder farmers choose not to participate in the production of commodities, being such a competitive market, and focus on other crops instead). Besides that, commodity financing can lead to high price volatility and long periods of reduced price, leading to lower income for producers, which can heavily affect small farmers' survivability.

6.1 CapEx Funding

As mentioned, small farmers, by definition, have less cash available for investing in new technologies. This means they depend highly on financing to afford the initial investment. However, most traditional financial institutions refuse to serve smallholder farmers or charge higher interest rates and fees, as they have a high perceived risk. This means that the finance models that can help small farmers afford the CapEx of new

technologies will either improve farmers' liquidity, give them more access to financing, or provide them with better and more flexible finance terms.

The first model studied that can help with those factors is **Supply Chain Finance** (SCF). Firstly, SCF was shown to improve farmers' liquidity, with a reduced Cash Conversion Cycle (CCC), achieved either by a decreased DSO or increased DPO. Secondly, SCF improved the availability of financing by providing small farmers an alternative to traditional options. Most importantly, SCF has shown to give small farmers better financial conditions. This could be achieved by improving financial indicators (such as net debt and ROCE) and reducing risk in the SC. These factors could be leveraged by farmers when negotiating debts with financing providers, giving them lower rates and better terms. It is important to note that the SCF solutions that provided most of these benefits were inventory financing, reverse factoring, and dynamic discounting, meaning farmers should focus most of their efforts on using these solutions to help them afford the CapEx of new technologies.

Nevertheless, it is essential to note some of the barriers to SCF usage and how they can be resolved. It was found that there is a lack of knowledge about SCF and collaboration from different actors. There were also technological and regulatory barriers and macro challenges, mainly geographical and cultural differences between actors in the SC. As it was studied, these barriers are not insurmountable, and small farmers can focus on solving them when adopting the solution. Firstly, the lack of knowledge about SCF can be solved with training and studies about the model, but it also tends to be solved in the future with crescent usage and research. Secondly, as studied, different actors in the supply chain could benefit from collaboration with small farmers, mainly retailers, wholesalers, and food producers. If farmers show these participants the benefits of using SCF, the partnership could increase, leading to a win-win situation. The technological, regulatory, and geographical barriers also tend to be relieved as the world faces fast technological advances and the model is used increasingly.

The second model found to help small farmers afford the CapEx of new technologies was **Microfinancing**. This model has been shown to improve smallholders' access to financing options. Micro Financing Institutions (MFI) aim to offer banking services to those traditionally excluded from the traditional options, like small farmers. Besides that, MFI can offer more tailored conditions and loans without collateral requirements. This can be leveraged by small farmers so that their credit ratings and history improve. In the future, they can get even more financing from traditional banks, helping them finance the CapEx of the technologies and expand their operations.

However, mainly because of the crescent surge of for-profit MFIs, microfinancing can have some barriers to its usage by small farmers, which can cause over-indebtedness. Therefore, small farmers must be careful when adopting microfinancing, profoundly studying the different MFIs available to find those with better financing terms and lower rates and avoid aggressive borrowing that could lead to a failing of the business in total. Regardless of that, empirical data still points to positive results for small businesses and entrepreneurship from the adoption of microfinance, and the future of this model holds promise as regulations and available options increase.

Besides that, **Crowdfunding** and **Peer-to-peer lending** were found to bring attractive benefits for small farmers looking to afford the CapEx of new technologies. The models are similar, and the benefits seen from each one are the same. Firstly, they offer an alternative financing option for small farmers, extending access to capital from different investors and sources worldwide, allowing farmers to gather funds for the initial investment needed for new technology. These models also offer a faster funding method with high flexibility in the financing terms, allowing for a tailored financial product for borrowers. Finally, crowdfunding and P2P lending projects can be used as a thermometer to see the potential of the investment and validate the idea with experts in online platforms.

As for the barriers found for these models, the most important ones were the risk of failure (that can heavily damage the image of the project and the farm), information asymmetry and the initial costs (such as marketing costs, fees from the platforms, etc.). Therefore, it is crucial for the usage of these models that farmers spend an initial effort in studying the technology they are looking to afford, making forecasts and making a clear layout of the expected benefits and returns from this investment so that the information asymmetry and risk of failure are as low as possible. Secondly, it is noticeable that farmers need the initial capital to start a P2P lending or crowdfunding project. One way to afford those initial investments would be to use the different finance models together. For example, a small loan acquired from MFI could kickstart a P2P lending project and gather funds for the initial investment in technology, increasing the farmer's income and making him able to afford the interest expenses.

Finally, the **Trade Credit Insurance** (TCI) model can also help small farmers with some of the factors regarding the initial funding of new technologies. Most importantly, TCI reduces farmers' risk and can be used as collateral in loans, improving small farmers' access to and financing conditions in traditional institutions. As for the barriers of this model, the worst ones were only in periods of financial crisis, such as the cumulative effects

of losses and the disruption of trade. The other barriers, namely costs and low flexibility, can be easily offset by the expansion in sales and better financing terms brought by the same model.

6.2 OpEx Funding

For the funding of the operational costs of the technologies, on the other hand, it is essential to look at finance models that improve farmers' efficiency, give them more access to expand their operations, improve cash flow management, reduce operational risk and/or give farmers a better branding and loyalty from customers.

The first model found to bring those benefits was **Supply Chain Finance**. As mentioned, SCF can be used to reduce the CCC, leading to better cash flow conditions for small farmers. Besides that, the model showed some operational benefits, mainly a reduction in costs and operational risks in the Supply Chain and an improvement in the efficiency and effectiveness of farmers using SCF due to a better exchange of information between different players in the SC. Finally, SCF has been shown to improve the relationship in the SC and help in the assurance of the quality of the product, something that small farmers can use to negotiate terms with buyers and increase their income, allowing them to afford the operational costs from the new technologies.

The second model important in the funding of OpEx for the new technologies is **Trade Credit Insurance**. TCI has been shown to improve cash flow predictability and constancy by reducing the risks associated with insolvency from customers. The model can also make it easier for small farmers to expand their operations and enter new markets by safely giving buyers better payment and credit conditions. Finally, insurance providers can bring their extensive business know-how and help farmers grow safely and effectively. These factors can help small farmers increase their income and leverage the benefits of the new technologies in an expanding market, allowing them to afford the OpEx of said technologies.

Thirdly, the **Microfinancing** model can bring exciting benefits to small farmers who need to afford the expenses of new technologies (Reduction of Operational Risk, education, expansion). Firstly, MFI can reduce operational risk by offering tailored insurance savings accounts to smallholders. Besides that, Microfinancing improved entrepreneurship levels and provided education to business owners about financial and business management, a product that small farmers can use to study the possible options and improve

their efficiency, increasing their income and helping them afford the OpEx of the new technologies.

Finally, the models of **Crowdfunding** and **Peer-to-Peer Lending** have little effect on OpEx funding if leveraged to improve the branding and image of small farmers, helping them attract new customers and expand their operations after acquiring the new technologies.

6.3 Difficulties

Lastly, it is interesting to understand which are the most significant difficulties small agricultors face when trying to adopt the finance models mentioned.

The most important barrier found in the study was the **lack of knowledge, training or information** about the models. This problem was found in almost all of the solutions and has different causes. In some cases, there is no universal definition of what the model comprehends, making it difficult for those trying to adopt it to understand what they should look for. For other solutions, there is limited knowledge on the farmers' side about what the model is and how they can use them. Besides that, there is also a problem of information asymmetry affecting many of the models, as credit suppliers and farmers end up with low transparency or low collaboration among them, increasing interest rates and making it harder to use the finance model in question.

Another important barrier found refers to the **costs of implementing** the models in question. P2P Lending and Crowdfunding, for example have a high cost of promotion and marketing to kickstart the project. Minibonds and TCI, on the other hand, can have higher interest or administrative expanses when compared to traditional financing approaches, making it harder for small farmers to afford these solutions.

In addition, there are also problems related to the **Law and Regulation** that limit the access to the models in question. For some cases, such as P2P lending, this is caused by the relative novelty of the model, making the regulation and the future uncertain for it. For SCF and Crowdfunding, on the other hand, regulation and laws are more established, but compliance rules, taxes and bureaucracy limit the usability of the models.

These are the three most significant barriers found in the studies, affecting the majority of the models. However, as mentioned, it is relatively easy to solve most of them. The lack of definition, knowledge or training about the models tend to be resolved as more studies are being published about them and small farmers can have easy access

to the information. The higher initial costs of the solutions can be solved by leveraging more than one model for the financing. Studies also show that the higher interest rates or administrative costs are usually offset by the benefits of the financial model, bringing positive results for the small entrepreneurs. Lastly, problems related to regulation and law also tend to reduce in the future, as more studies show the benefits of the models and the importance of small farmers, authorities will look to reduce bureaucracy and help the adoption of the solutions.

Finally, it is important to mention other barriers found that did not affect the majority of the model. There is the presence of **technology barriers**, caused by the need of higher digitalization or platforms' complexity. There is the problem of possible **negative signalling** for failed Crowdfunding or P2P lending projects. For Microfinancing and TCI there is **limited flexibility** and for some of the models, the **risk of farmers**, related to seasonality, climate changes and default also increase costs or limit supply of credit. These barriers affected only one or two of the finance models, but most of them they can still be solved with a combination of models or more study and, in the future, some of them can be solved with improved technology and more awareness.

7 CONCLUSIONS

In conclusion, this paper showed the importance of small farmers worldwide, as they are a lifeline for around 3 billion rural people, contributing to many countries' economies through food production, employment, and income (RACHELE, 2022). Regardless of their importance, small farmers' path towards a sustainable, food-secure future faces unique challenges. These include lower income, limited access to technology and information, market and certification barriers, and labour shortages (JOUZI H. AZADI; GEBREHIWOT, 2017). Overcoming these hurdles is crucial. It can be achieved by providing small farmers access to new technologies and innovative solutions to enhance their productivity and help their growth, development, and profitability.

This paper started with an extensive literature review to find the finance models available in the existing literature and the new technologies farmers can adopt. Seven different finance models were found (SCF, Microfinance, Minibonds, Crowdfunding, Peer-to-Peer (P2P) lending, Trade Credit Insurance (TCI) and Commodity Finance), and eight different new farming technologies were found in the literature. After deeply analysing the costs related to each technology, they were divided into two types:

1. **CapEx-driven:** Technologies that require the most significant expenditures (more than 50%) to implement and maintain for the first ten years deriving from the initial investment. This includes Smart Sensors, Yield Monitoring and Biotechnology tools.

2. **Mixed technologies:** CapEx is not the most significant expenditure in this case, but both CapEx and OpEx play an essential part in the investment. This is the case with UAVs and Drones, IoT, Robotics and Automation and Vertical Farming.

After that, this study aimed to find which finance models will enable small farmers to afford the new farming technologies. To develop these models, three Research Questions (RQ) were answered:

- **RQ1:** Which Finance Models can help small farmers afford the initial investment

(CapEx) for new technology?

- **RQ2:** Which finance models can help small farmers afford the maintenance and usage of new technology (OpEx)?
- **RQ3:** What are the most significant barriers limiting small farmers' adoption of beneficial finance models?

To answer these questions, this paper used a secondary review methodology. This method consisted of systematically collecting, analysing, and synthesising existing data from governmental statistics, published articles, case studies, academic articles, and organisational bodies. The study showed that the most important barriers small farmers face are the Lack of Knowledge, Training and Information, the Higher Costs of Implementation and the Law or Regulations. Some secondary difficulties were also found, such as technology barriers, possible negative signalling, limited flexibility and risk to farmers. As for the finance models, bringing financial and structural benefits, it was found that supply chain finance, microfinancing, crowdfunding, P2P lending and trade credit insurance can help small farmers afford the initial investment (CapEx) for new technology, while the models of SCF, microfinancing and TCI can help small farmers afford the maintenance and usage of new technologies (OpEx). Notably, the minibonds and commodity financing models were ineffective in the small farmers' context, having considerable barriers to their adoption by smallholders.

The paper makes an important contribution to the academics of small farmers, SMEs, finance models and new farming technologies by reviewing and summarising existing studies in these fields and giving an exciting summary of the next steps to be followed by academics. Additionally, the research gives some practical implications for small farmers and their supply chain, as well as for governments and policymakers. For the first group, this paper offers a direction regarding how these players should make managerial decisions for the future, helping them understand the finance models they should include in their operations and studies. For the second group, this paper showed the barriers some of these finance models face nowadays; many can be solved with a deeper involvement from the government and policymakers.

This work still bears some limitations that generate opportunities for future research. Firstly, by using a secondary review, this research might overlook aspects not well documented in the existing literature, and some missing information in secondary data can limit its completeness. The following studies could leverage other methodologies, such as primary research, to fill these gaps. For instance, qualitative approaches like interviews

or focus groups with small farmers and financial stakeholders could provide more insights into the benefits, opportunities and challenges of adopting these models.

Besides that, this research did not look into how small farmers can practically adopt the finance models. Future studies could focus on developing a step-by-step framework or model for how small farmers can structure and implement these options in their daily operations, considering their unique socioeconomic contexts.

Furthermore, a more local and regional study, in countries like Brazil, where small-scale farming plays a critical role in the economy, could provide specific insights. Studies like that could assess the feasibility of these finance models, evaluate their impact on farm productivity, and explore deeply how cultural, regulatory, and market factors influence their adoption. Finally, cross-regional comparative studies could be conducted to better identify beneficial practices and regional adaptations of each finance model.

In addition, other researchers could look more into the role of cooperatives in facilitating access to finance for small farmers. Cooperatives, can pool resources and leverage collective bargaining power, providing a structured way of accessing credit, negotiating better terms with financial institutions, and reducing risks for individual farmers. Future studies could investigate how existing cooperatives can use new finance models to benefit their members or examine case studies of successful cooperative-led financing initiatives. This line of work could also explore how cooperatives can act as intermediaries between small farmers and emerging technologies.

REFERENCES

AALTONEN, D. A. *Embracing Innovation in Agricultural Finance: Transforming the Future of Commodity Trading*. 2024. Accessed June 2024. ⟨https://www.linkedin.com/pulse/embracing-innovation-agricultural-finance-future-trading-aaltonen-bjrzf/⟩.

ABBASI, W. A.; WANG, Z.; ALSAKARNEH, A. Overcoming smes financing and supply chain obstacles by introducing supply chain finance. *HOLISTICA*, v. 9, n. 1, p. 7–22, 2018.

ABDULRAHEEM, M. I.; ADEMOLA, A. O. Impact of micro credit financing on agricultural production. *Anglisticum Journal (IJLLIS)*, v. 4, n. 8, p. 8–15, 2015.

ABI. *Benefits of Trade Credit Insurance*. Accessed June 2024. ⟨https://www.abi.org.uk/products-and-issues/choosing-the-right-insurance/business-insurance/trade-credit-insurance/benefits-of-trade-credit-insurance/⟩.

AICONTENTFY. *The Benefits of Crowdfunding for Early-Stage Companies*. 2023. Accessed June 2024. ⟨https://aicontentfy.com/en/blog/benefits-of-crowdfunding-for-early-stage-companies⟩.

ALLIANZ. *What is trade credit insurance?* Accessed June 2024. ⟨https://www.allianz-trade.com/en_global/our-solutions/trade-credit-insurance.html⟩.

BDC. *Trade credit insurance*. Accessed June 2024. ⟨https://www.bdc.ca/en/articles-tools/entrepreneur-toolkit/templates-business-guides/glossary/trade-credit-insurance⟩.

BEREZHNOY, I. *5 Barriers to Entry for Crowdfunding Business and How to Beat Them*. 2019. Accessed June 2024. ⟨https://lenderkit.com/blog/crowdfunding-barriers/⟩.

BERGEN M. STEEMAN, M. R. M. V.; GELSOMINO, L. Supply chain finance schemes in the procurement of agricultural products. *Journal of Purchasing and Supply Management*, v. 25, n. 2, p. 172–184, 2019.

BILYEAU, N. *Guide to Peer-to-Peer Lending for Business*. 2024. Accessed June 2024. ⟨https://www.sofi.com/learn/content/peer-to-peer-business-loans/⟩.

BIRKBY, J. Vertical farming. *ATTRA Sustainable Agriculture*, v. 2, n. 1, p. 1–12, 2016.

BOARD, E. S. R. *Issues note on macroprudential aspects of trade credit insurance*. 2022. Accessed June 2024. ⟨https://www.esrb.europa.eu/pub/pdf/reports/esrb⟩.

BOCCALETTI, S.; ROSSI, E.; ROSSOLINI, M. How can smes signal their quality and growth orientation to the market? an analysis of the cost of italian corporate mini-bonds. *Journal of International Financial Management and Accounting*, v. 33, n. 2, p. 219–251, 2022.

BONDORA. *P2P Lending: Pros, Cons, and How it Compares to Other Investments*. 2022. Accessed June 2024. ⟨https://bondora.com/en/blog/p2p-lending-pros-cons-and-how-it-compares-to-other-investments/⟩.

BONZANI, A.; CANIATO, F.; MORETTO, A. Costs and benefits of supply chain finance. 2018.

BRAUN, A.; FISCHER, M.; SCHREIBER-OROSZ, C. Why banks insure structured commodity trade finance risk: evidence from a worldwide survey. *Geneva Papers Risk Insur Issues Pract*, 2023.

BRIDLE LEAH;MAGRUDER, J. C. T. Experimental insights on the constraints to agricultural technology adoption. *UC Berkeley: Center for Effective Global Action*, 2020. Disponível em: ⟨https://escholarship.org/uc/item/79w3t4ds⟩.

BRYANT, C.; CAMERINELLI, E. *Supply Chain Finance EBA European market guide*. [S.l.], 2013.

CAPITAL, F. *Benefits Of Crowdfunding Platforms To Entrepreneurs*. Accessed June 2024. ⟨https://fastercapital.com/topics/benefits-of-crowdfunding-platforms-to-entrepreneurs.html⟩.

CAPITAL, L. *The Rise of Peer-to-Peer Lending for Small Businesses: Benefits and Challenges*. 2023. Accessed June 2024. ⟨https://lankfordcapital.com/small-business-funding/the-rise-of-peer-to-peer-lending-for-small-businesses-benefits-and-challenges/⟩.

CATALONIA, S. A. S. *Deliverable 2.5 – Main barriers to crowdfunding investment in Renewable Energy sector and potential solutions*. [S.l.], 2015.

CERQUETI, R. et al. *Identifying minibonds issued level's determinants to empower companies' funding managerial strategies*. 2024.

CLAPP, J. The problem with growing corporate concentration and power in the global food system. *Nature Food*, n. 2, 2021.

COFACE. *Trade Credit Insurance in a nutshell*. 2023. Accessed June 2024. ⟨https://www.coface.com/news-economy-and-insights/trade-credit-insurance-in-a-nutshell⟩.

COMMERCIAL, M. *Transport and trade credit insurance: How to grow and protect your business*. 2024. Accessed June 2024. ⟨https://www.marshcommercial.co.uk/articles/transport-and-trade-credit-insurance-how-to-grow-and-protect-your-business⟩.

CONTOUR. *Deep dives into commodities digitalisation: The developments that will drive adoption in 2023*. 2023. Accessed June 2024. ⟨https://www.contour.network/blog/deep-dives-into-commodities-digitalisation-the-developments-that-will-drive-adoption-in-2023/⟩.

CORREIA, S.; SOUSA, M.; BRANDãO, E.

Drivers of fundraising success in equity crowdfunding — University of Porto, Porto, 2019.

COVO, A. *Leveraging Impact Linked Finance to Drive the Transition of Agricultural Supply Chains*. 2023. Accessed June 2024. ⟨https://ksapa.org/leveraging-impact-linked-finance-to-drive-the-transition-of-agricultural-supply-chains/⟩.

DEERE, J. Accessed April 2024. Disponível em: ⟨https://www.deere.com/en/parts-and-service/parts/all-makes-parts/⟩.

DHILLON, R.; MONCUR, Q. Small-scale farming: A review of challenges and potential. *Sustainability*, n. 15, 2023.

DOSSOU, S. A. R. et al. Microfinance services for smallholder farmers: an assessment from rice farmers' expectations in central benin. *Agricultural and Food Economics*, v. 8, n. 20, 2020.

DUDDA, T. L. et al. Common drivers of commodity futures? *QMS Research Paper*, v. 05, 2022.

EDENGREEN. [Accessed April 2024]. Disponível em: ⟨https://www.edengreen.com/blogcollection/blockchain-technology-in-agriculture⟩.

EIT Food; QUB. *Mapping the Agri-Food Chain*. Accessed May 2024. Disponível em: ⟨https://www.futurelearn.com/info/courses/understanding-food-supply-chains/0/steps/74763⟩.

ELY, T. L.; MARTELL, C. R. Costs of raising (social) capital through mini-bonds. *Municipal Finance Journal*, v. 37, n. 3, p. 23–43, 2016.

ESTRIN, S.; GOZMAN, D.; KHAVUL, S. The evolution and adoption of equity crowdfunding: entrepreneur and investor entry into a new market. *Small Business Economics*, v. 51, n. 1, 2018.

European Union. *European Union Law*. 2024. Accessed March 2024. Disponível em: ⟨https://eur-lex.europa.eu/legalcontent/EN/ALL/?uri=CELEX%3A32014R1198⟩.

EUROSTAT. *Eurostats small farms*. 2020. Accessed March 2024. Disponível em: ⟨https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Farms_and_farmland_in_the_European_Union_-_statistics#Farms_in_2020⟩.

Eurostat. *Glossary: Standard Gross Margin (SGM)*. 2024. Accessed March 2024. Disponível em: ⟨https://ec.europa.eu/eurostat/statisticsexplained/index.php?title=Glossary:Standard_gross_margin_(SGM)⟩.

Eurostat. *Glossary: Standard Output (SO)*. 2024. Accessed March 2024. Disponível em: ⟨https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Standard_output_(SO)⟩.

EXCHANGE, L. M. *Commodity Financing: How Hedging on-Exchange Can Benefit Both Borrowers and Lenders*. 2018. Accessed June 2024. ⟨https://www.lme.com/en/education/online-resources/lme-insight/commodity-financing-how-hedging-benefits-both-borrowers-and-lenders⟩.

FAO. *Pathways to profit - Experimental evidence on agricultural technology adoption*. [S.l.], 2023.

FINCORP, H. *Microfinance Meaning - Types, Benefits, History and How It Works*. 2023. Accessed June 2024. ⟨https://www.herofincorp.com/blog/what-is-microfinance⟩.

FORTUNATO, M. *Why Financing Smallholders Farmers Matters*. 2024. Accessed June 2024. ⟨https://www.agtechnavigator.com/Article/2024/06/04/Why-financing-smallholder-farmers-matters⟩.

FORUM, G. D. *Empowering the Marginalised: Unveiling the Benefits and Pitfalls of Micro-financing in Developing Countries*. 2023. Accessed June 2024. ⟨https://www.linkedin.com/pulse/empowering-marginalised-unveiling-benefits-pitfalls/⟩.

FUND, E. I. *Breaking Down Investment Barriers at Ground Level*. [S.l.], 2016.

GEEKS, G. for. *Microfinance: Meaning, Benefits, Drawbacks, Regulations & Challenges*. 2024. Accessed June 2024. ⟨https://www.geeksforgeeks.org/microfinance-meaning-benefits-drawbacks-regulations-challenges/⟩.

GELSOMINO, L. M. et al. Supply chain finance: A literature review. *International Journal of Physical Distribution & Logistics Management*, v. 46, n. 4, 2016.

GIOIA, A. Small farms in europe: time for a redefinition. *Eco Ruralis*, v. 17, p. 71–88, 2017.

GROUP, A. B. *What is agricultural and horticultural credit insurance?* 2022. Accessed June 2024. ⟨https://www.alanboswell.com/news/what-is-agricultural-and-horticultural-credit-insurance/⟩.

GUIOMAR, N. et al. Typology and distribution of small farms in europe: Towards a better picture. *Land Use Policy*, v. 75, p. 784–798, 2018. ISSN 0264-8377. Disponível em: ⟨https://www.sciencedirect.com/science/article/pii/S0264837717305227⟩.

GUIRADO, C. E.; ZORITA, C. M. d. I.; CASTRO, C. G. Beyond signed t-shirts: A socio-technological model of equity crowdfunding adoption. *Journal of Innovation Economics & Management*, v. 2, n. 26, p. 137–172, 2018.

HADDAD, W. *3 Ways Peer-To-Peer Lending Benefits Borrowers*. 2023. Accessed June 2024. ⟨https://www.beehive.ae/3-benefits-of-p2p-lending-to-smes/⟩.

HARTFORD, T. *Peer-to-Peer Lending*. 2024. Accessed June 2024. ⟨https://www.thehartford.com/business-insurance/strategy/alternative-funding-startup/peer-to-peer-lending⟩.

HAVRYLCHYK, O. et al. *What drives the expansion of the peer-to-peer lending?* 2017. Accessed June 2024. ⟨http://dx.doi.org/10.2139/ssrn⟩.

HAYES, A. *Commodity Market: Definition, Types, Example, and How It Works*. 2024. Accessed June 2024. ⟨https://www.investopedia.com/terms/c/commodity-market.asp⟩.

HENDRICKSON P. HOWARD, M. E. M.; CONSTANCE, D. *Food System Concentration and its Impacts*. [S.l.], 2020.

HOWARD, P. H. *Concentration and Power in the Food System*. [S.l.]: Bloomsbury, 2016.

HUANG, W. *Commodity Finance: Principles and Practice*. [S.l.]: Harriman House Limited, 2019.

HUBBARD, C. Small farms in the eu: How small is small? *European Association of Agricultural Economists, 111th Seminar, June 26-27, 2009, Canterbury, UK*, 01 2009.

INSEE (French National Institute of Statistics and Economic Studies). *Definition - INSEE*. 2024. Accessed March 2024. Disponível em: ⟨https://www.insee.fr/en/metadonnees/definition/c1039⟩.

INSURANCE, A. *9 Benefits of Trade Credit Insurance*. 2024. Accessed June 2024. ⟨https://blog.axisinsurance.ca/trade-credit-insurance-benefits⟩.

INSURANCE, P. *5 things you need to know about trade credit insurance*. Accessed June 2024. ⟨https://www.pib-insurance.com/news/5-things-you-need-to-know-about-trade-credit-insurance⟩.

ISLAM, M. T. Inertia to the adoption of crowdfunding in bangladesh: A study on start-up entrepreneurs. *Cogent Business & Management*, v. 7, n. 1, 2020.

JOUZI H. AZADI, F. T. K. Z. Z.; GEBREHIWOT, K. Organic farming and small-scale farmers: Main opportunities and challenges. *Ecological Economics*, v. 132, p. 144–154, 2017.

K, L. Survey on the applications of blockchain in agriculture. *Agriculture*, v. 12, n. 9, 2022.

KAGAN, J. *Microfinance Definition: Benefits, History, and How It Works*. 2024. Accessed June 2024. ⟨https://www.investopedia.com/terms/m/microfinance.asp⟩.

KAGAN, J.; CATALANO, T. *What Is Asset-Based Lending? How Loans Work, Example and Types*. 2020. Accessed 16 April 2024. Disponível em: ⟨https://www.investopedia.com/terms/a/assetbasedlending.asp⟩.

KHAN, M. T. I. Drivers of lending decision in peer-to-peer lending in malaysia. *Review of Behavioral Finance*, ahead of print.

KLIMENTYEV, I.

Pros and Cons of Minibonds for International Investors and SMEs in the Italian Market: A Systematic Literature Review — Lahti University of Applied Sciences, 2018.

KOPP, C. M.; KVILHAUG, M. J. B. S. *Financial Modeling Definition and What It's Used For*. 2024. Accessed March 2024. Disponível em: ⟨https://www.investopedia.com/terms/f/financialmodeling.asp⟩.

LAZZARIN, S.

The governance of Mini-bond issuers on ExtraMOT PRO — Politecnico di Milano, Milan, 2020.

LEONARD, K. *The average gross profit margin for small wholesale businesses in terms of finances and taxes*. 2019. Accessed May 2024. Disponível em: ⟨https://smallbusiness.chron.com/calculate-inventory-balance-using-fifo-19228.html⟩.

LinkedIn. *Beginner's Guide: What is Supplier Financing?* 2024. Accessed April 2024. Disponível em: ⟨https://www.linkedin.com/pulse/beginners-guide-what-supplier-financing-myitronline/⟩.

LUKKARINEN, A. et al. Success drivers of online equity crowdfunding campaigns. *Decision Support Systems*, v. 87, p. 26–38, 2016.

MACHT, S.; WEATHERSTON, J. The benefits of online crowdfunding for fund-seeking business ventures. *Strategic Change*, v. 23, 2014.

MAFFEZZOLI, F. et al. Agriculture 4.0: A systematic literature review on the paradigm, technologies and benefits. *Futures*, v. 142, 2022.

MAGAR, S. et al. Determinants of microfinance adoption, challenges encountered, and principal solutions: An empirical analysis using theory of planned behaviour. *Journal of Innovation in Nepalese Academia*, v. 2, n. 2, p. 114, 2023.

MANOGNA, R. L.; KULKARNI, N. Does the financialization of agricultural commodities impact food security? an empirical investigation. *Borsa Istanbul Review*, 2024.

MARTíNEZ-CHáFER, L.; MOLINA-MORALES, F. X.; PEIRó-PALOMINO, J. On the drivers of successful crowdfunding: The case of the platform verkami. *Business Research Quarterly*, v. 26, n. 3, p. 182–195, 2023.

MCKINSEY. *The future of commodity trading*. 2023. Accessed June 2024. ⟨https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-future-of-commodity-trading⟩.

MEDINA, E.; CANIATO, F.; MORETTO, A. M. Exploring supply chain finance along different supply chain stages: case-based research in the agri-food industry. *Supply Chain Management: An International Journal*, v. 28, n. 7, p. 77–96, 2023.

MILLS, E. N.; CLAPP, J. *Agrifood Atlas*. [S.l.]: Atlas, 2017.

MODEFINANCE. *Minibond, a profitable loan facility for both Italian enterprises and investors*. 2022. Accessed June 2024. ⟨https://www.modefinance.com/en/company/blog/minibond-a-profitable-loan-facility-for-both-italian-enterprises-and-investors⟩.

MURIDAN, M.; IBRAHIM, P. Microfinancing for microenterprises in malaysia: A review. *International Business Management*, v. 10, n. 17, p. 3884–3891, 2016.

MYRAN, C. *GOOD FOOD GLOSSARY: SUPPLY CHAIN VS. VALUE CHAIN*. 2018. Accessed April 2024. Disponível em: ⟨https://www.newventureadvisors.net/good-food-glossary-supply-chain-vs-value-chain/⟩.

NAGAYETS, O. Small farms: current status and key trends. In: *The Future of Small Farms*. [S.l.: s.n.], 2005. p. 26–29.

NGUYENA, D. N. et al. The effect of supply chain finance on supply chain risk, supply chain risk resilience, and performance of vietnam smes in global supply chain. *Uncertain Supply Chain Management*, v. 10, p. 225–238, 2022.

NIGATU, G. et al. *Factors Contributing to Changes in Agricultural Commodity Prices and Trade for the United States and the World*. [S.l.], 2020.

OECD. *Oil Commodity Trading and Addressing the Risk of Illicit Financial Flows*. Paris: [s.n.], 2023.

OECD. *Purchasing Power Parities (PPP) (Indicator)*. 2024. ⟨https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm⟩.

ONE, A. *Microfinance and its Benefits*. Accessed June 2024. ⟨https://www.angelone.in/knowledge-center/income-tax/microfinance-and-its-benefits⟩.

OROMIA, C. B. of. *CCF (Collateralized Commodity Financing)*. 2022. Accessed June 2024. ⟨https://coopbankoromia.com.et/collateralized-commodity-financing-ccf/⟩.

PACKMAN, H. *Farmers are Losing Money on Many Major Commodities*. 2020. Accessed June 2024. ⟨https://nfu.org/2020/09/03/farmers-are-losing-money-on-many-major-commodities/⟩.

PARTNERS, L. . *MINI BOND: WHAT THEY ARE, REQUIREMENTS, EMISSIONS, LEGISLATION*. 2019. ⟨https://www.antoniolaierno.eu/en/mini-bond-what-are-requirements-emissions-normative/⟩.

PARTNERS, T. I. *Trade Credit Insurance Market is expected to reach US$ 27.56 Billion by 2031*. 2024. Accessed June 2024. ⟨https://www.theinsightpartners.com/pr/trade-credit-insurance-market⟩.

PIRRONG, C. *The Economics of Commodity Trading Firms*. Houston: Trafigura, 2015.

RACHELE, R. Small farms' role in eu food system. *Land Use Policy*, v. 75, p. 784–798, 2022.

RAJAK, P. et al. Internet of things and smart sensors in agriculture: Scopes and challenges. *Journal of Agriculture and Food Research*, v. 14, 2023.

RATING, M. *Trade Credit Insurers Methodology*. 2023. Accessed June 2024. ⟨https://ratings.moodys.com/api/rmc-documents/397709⟩.

RESEARCH, G. V. *Trade Credit Insurance Market Size, Share & Trends Analysis Report By Enterprise Size, By Coverage, By Application (Domestic, International), By End-use (Energy, Automotive), By Region, And Segment Forecasts, 2024 - 2030*. 2023. Accessed June 2024. ⟨https://www.grandviewresearch.com/industry-analysis/trade-credit-insurance-market-report⟩.

RICCIARDI, V.; MEHRABI, Z. Higher yields and more biodiversity on smaller farms. *Nature Sustainability*, n. 4, p. 1–7, 2021.

SCF Forum. Accessed April 2024. Disponível em: ⟨http://supplychainfinanceforum.org/techniques/payables-finance/⟩.

SERVICES, B. U. M. *Agriculture and microfinance*. 2024. Accessed June 2024. ⟨https://www.linkedin.com/pulse/agriculture-microfinance-buldanaurban-jqtyf/⟩.

SIEDEK, H.; PINI, E. *Development Solutions: Opportunity for the vulnerable*. [S.l.], 2020.

S.P.A., E. S. *Debt financing and the Italian Minibond instrument in alternative finance: practices and players*. Accessed June 2024. ⟨https://azimutdirect.com/sites/default/files/documents/Minibond_epic_eng.pdf⟩.

STAMBOROWSKI, I. Finance models to enable small farmers to afford new technologies. 2023.

STIGLITZ J. E., . W. A. Credit rationing in markets with imperfect information. the american economic review. *Journal of Financial Risk Management*, n. 71, p. 393–410, 1981. Disponível em: ⟨http://www.jstor.org/stable/1802787⟩.

STORANI, S.

Minibond issuers: a quantitative exploration of the Italian market — University of Macerata, 2022.

STREET, Y. *Investing in Peer-to-Peer Lending: Risks and Rewards*. 2024. Accessed June 2024. ⟨https://www.yieldstreet.com/blog/article/peer-to-peer-lending-investing-guide/⟩.

SULASTRI, R.; JANSSEN, M. *Challenges in designing an inclusive Peer-to-Peer (P2P) lending system*. 2023. Accessed June 2024. ⟨https://dl.acm.org/doi/fullHtml/10.1145/3598469.3598475⟩.

TAIWO, J. N.; AGWU, P. E.; BENSON, K. The role of microfinance institutions in financing small businesses. *JIBC*, v. 21, n. 1, 2016.

Taulia. *Taulia Glossary: What is Reverse Factoring?* 2024. Accessed April 2024. Disponível em: ⟨https://taulia.com/glossary/what-is-reverse-factoring/⟩.

TEAM, C. *Corporate Finance Institute*. Accessed June 2024. ⟨https://corporatefinanceinstitute.com/resources/commerciallending/microfinance⟩.

TRADE Finance Global. [Accessed April 2024]. Disponível em: ⟨https://www.tradefinanceglobal.com/finance-products/commodity-finance/⟩.

TSOLAKIS C. KERAMYDAS, A. T. D. A. N.; IAKOVOU, E. Agrifood supply chain management: a comprehensive hierarchical decision-making framework and a critical taxonomy. *Biosystems Engineering*, v. 120, p. 47–64, 2014.

UN. *United Nations Sustainable Goals*. Accessed March 2024. Disponível em: ⟨https://www.un.org/sustainabledevelopment/hunger/⟩.

VELOTRADE. *What is the Value of Trade Credit Insurance?* 2020. Accessed June 2024. ⟨https://www.velotrade.com/blog/what-is-the-value-of-trade-credit-insurance/⟩.

VENSLAVIENė, S.; VAICIUKEVIčIūTė, A. Assessment of successful drivers of crowdfunding projects based on visual analogue scale matrix for criteria weighting method. *Mathematics*, v. 9, n. 14, 2021.

VERBEEK, A.; FACKELMANN, S.; MCDONAGH, B. *Feeding future generations: How finance can boost innovation in agri-food*. [S.l.], 2019.

WUTTKE, D. A. et al. Managing the innovation adoption of supply chain finance—empirical evidence from six european case studies. *Journal of Business Logistics*, v. 34, n. 2, p. 148–166, 2013.

WUTTKE, D. A.; ROSENZWEIG, E. D.; HEESE, H. S. An empirical analysis of supply chain finance adoption. *Journal of Operations Management*, v. 65, p. 242–261, 2019.

ZAKAI, H.; RU, N. d. Commodity finance market report. *TXF News*, 2018.

ZHIRI, D. D. Impact of microfinance services on performance of small and medium scale enterprises (smes) in zaria metropolis. *International Journal of Scientific Research in Social Sciences & Management Studies*, v. 2, n. 1, 2017.

APPENDIX A – SMART SENSORS BREAKDOWN

This appendix, extracted from (RAJAK et al., 2023), aims to explain better the costs and usages associated with implementing Smart Sensors for farmers.

The first type is Acoustic Based Sensors, which are used for detecting and monitoring pest populations and harvesting fruits by measuring alterations in noise levels in agricultural fields. Prices, extracted from the Rika Sensors website, vary from 88−409 per sensor.

After that, there are Electromagnetic sensors that record electromagnetic response, measure residual nitrate levels and organic matter concentrations in soil, and offer real-time measurements of transpiration rate. They employ electrical circuits that record the conduction or accumulation of electrical impulses in soil. Extracted from Acursens, Hawell Magnets, and Honeywell websites, costs vary from 2−1,300 per sensor.

Light detection and ranging (LIDAR) are used for agricultural land-based utilities such as 3D modelling, soil erosion monitoring, agricultural land mapping, and soil type detection. LIDAR sends light wave pulses to the target object. After colliding with the target object, light wave pulses return to the sensor. Cost, extracted from the Sentera website, varies from $2,800$−15,000 per sensor.

Optical sensors are employed to sense soil parameters like soil texture, mineral contents, clay content, moisture, and colour of soil. They capture changes in light reflectance. The cost, extracted from Davis Instruments, goes from 225−425 per sensor.

Mechanical sensors measure soil mechanical resistance and particle compactness by measuring the force assessed by load cells or strain gauges. Extracted from Win-Source and Emerson websites, costs vary from 4−476 per sensor.

Mass flow sensors assist in assessing yield production by measuring the grain flow through a combined harvester. Sensors record the mass flow of grains through various

modules such as moisture content sensors, data storage, and an internal system. Price varies from 33−240 (Extracted from Siemens, Emerson and Vögtlin Instruments websites).

FPGA (Field programmable gate array) based sensors measure moisture content, humidity, transpiration rate of plants, and irrigation. They Employ digital circuits surrounding silicon-based chips and logic blocks. Price ranges from 85−1,900, extracted from Davis Instruments and AquaSpy websites.

Electrochemical sensors help in the measurement of nutrient status and pH of soil. Individual sensors record electrochemical gradients in agricultural soil. Cost can go from 11−1299 (Extracted from Acursens and Hindawi websites).

Eddy covariance-based sensors record changes in levels of various gases, including greenhouse gases such as CO2, methane, water vapour, etc., in agricultural lands. They measure continuously over significant agricultural lands. Prices range from $10,000-50{,}000$ (extracted from Gasmet and Li-cor websites).

Airflow sensors assess soil-air air permeability, moisture content, and mobile or static conditions. They sense several soil properties using unique identifying characteristics and can cost from 235−650 (Davis Instruments websites)

Ultrasonic ranging sensors can help in pest detection, crop canopy monitoring, and weed recognition. They employ an ultrasonic sensor that sends and receives ultrasonic pulses to detect the object's proximity. The price varies from $4 to 210$ (Acursens and Ceramtec websites).