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Farm Investment and Adoption of Fixed Milk Price Contracts on Irish Dairy Farms

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Abstract: After the milk quota removal in 2015, the Irish dairy industry has expanded dramatically. Various economic, social and environmental considerations are part of farmer's choice to invest and to expand. This study evaluates selected factors contributing to recent dairy farmer's investment decisions and examines the relationship between the adoption of Fixed Milk Price Contracts as a risk management tool and farm investments. This research applies the two-stage residual inclusion approach to address this research question using Teagasc NFS data from 2016 to 2021. This approach is applied to control for potential endogeneity including risk aversion. The results point to the economic relevance of the FMC adoption towards farm investment decisions although the magnitude of the association is limited. Subsidies play an important role in the investment decision although they are a small proportion in the overall specialised dairy farm income and provide a relatively stable source of income in Ireland. We finally conclude that, there is scope to improve the design of these FMCs in terms of protecting farmers from drastic margin volatility and to increase the adoption rate.

Keywords: Dairy Farm Investment, Contract Farming, Fixed Milk Price Contracts, Risk Management, 2SRI Approach

1 Introduction

After the milk quota removal in 2015, the Irish dairy industry expanded dramatically. With the expansion in the dairy business and large investments, farmers are facing risk and uncertainty in terms of milk prices and farm income. Komarek et al. (2020) describes five major types of risk in agriculture namely production risk, market risk, institutional risk, personal risk, and financial risk. Farm investments are related to the financial risks on the farms. In Ireland, there is a limited suite of risk management tools available to Irish farmers to manage market risks (Loughrey et al., 2021). The available tools include the MilkFlex Scheme (Finance Ireland, 2018), Taxation policy (Revenue, 2021), Single Farm Payment Schemes and Fixed Milk Price Contracts (Loughrey et al., 2021). This study focuses on Fixed Milk Price contracts as a risk management tool.

Fixed milk price contracts were first introduced by Tirlan (formerly known as Glanbia) - Ireland's largest milk processor in 2011, and were eventually offered by all of the other main milk processors after 2015. A fixed milk price contract (FMC) is an agreement between a milk buyer (handler) and a dairy farmer or a cooperative association of dairy farmers to sell a stated quantity of milk, for a stated period in the future at a pre-agreed price (USDA, 2019). There is no one common fixed milk contract in Ireland as each contract varies in the terms and conditions including price and duration. Farmers tend to supply milk to one single milk processor and only a small number of farms supply milk to more than one milk processor. Farmers can simultaneously avail of multiple FMCs from their milk processor as the contracts may overlap in time. Irish dairy farmers possess knowledge about the FMC risk management tool, but only a minority of farmers avail of this tool (Loughrey et al., 2021).

Does being an adopter of such milk price contracts increase investments on farms? We attempt to answer this question, by using data from the Teagasc National Farm Survey (NFS) in Ireland and applying the Two-stage Residual Inclusion model (2SRI). Various economic, social and environmental aspects are potentially involved in decision-making related to the adoption of risk management tools and farm investments. Our study aims to evaluate the factors contributing to recent farmer's investment decisions and to study the relationship between the adoption of FMCs as a risk management tool and investment.

A positive relationship between the adoption of this risk management tool and farm investment can emerge for different theoretical and practical reasons 1) Fixing the price for a proportion of milk production ought to stabilise milk revenue and reduce the exposure of the farm to market risk. Under a given level of risk aversion, the farmer may be willing to make a trade-off between reducing market risk and accepting the greater financial risk through investments 2) the adoption of this risk management tool may be a requirement from a financial institution prior to accessing loans which enable farm investments to take place. These are the two main causal explanations for a possible positive relationship between FMC adoption and farm investments. The first explanation is consistent with expected utility theory, which is often applied in the risk management literature within agricultural economics (Goodwin, 1993; Du et al., 2017). The second explanation is based on the expectation that financial institutions judge the capacity of the farmer to repay loans and that the presence of a fixed milk price contract will be judged as improving the probability of repayment. This is mentioned in Wolf (2012) but this causal explanation is underexplored in the literature.

There is a well-established literature since the late 1980's regarding the investment behaviour of farmers in the dairy sector (Chavas and Klemme, 1986; LaDue et al., 1989; Feinerman and Peerlings, 2005; Levi et al., 2017; Ma et al., 2018; Samson et al., 2016). These studies consider the factors which influence farm investments and the different aspects which farm owners consider while making their investment decisions. There is also an extant literature evaluating the risks faced by farmers, the strategies which are formulated and implemented at farm level as well as studies considering the adoption of available risk management tools (Meraner and Finger, 2019; Schulte and Musshoff, 2018a; Hadrich and Johnson, 2015; Coffey and Schroeder, 2019; Prager et al., 2020). The adoption of price risk management tools in U.S. dairy sector was evaluated (Wolf, 2012, and Wolf and Widmar, 2014) including the extent and determinants of forward contract usage.

The availability of fixed milk price contracts is a recent evolution in the European dairy business. In the past literature, there is no such study evaluating the connection between risk management tools and investments in the dairy sector. In a study of dairy farming in Ireland, Garvey et al. (2019) speculates that farmers with a strong promotion focus (i.e. motivated by growth and accomplishment) may not sufficiently consider the risks associated with milk price volatility thereby implying a negative relationship between tool adoption and farm investment. Vigani and Kathage (2019) examine the connection between risk management tool adoption and farm productivity for crop farms in a selection of European countries. However, no empirical study has been undertaken to-date in relation to the relationship between FMC tool adoption and investment in Ireland or Europe. Thus, the following research fills this gap and contributes to the literature by evaluating this relationship between the adoption of FMCs and farm investment. This research will be of value to policy makers and those involved in the wider dairy supply chain.

The remainder of the paper is aligned as follows: Section 2 reviews the background and discusses the past literature and describes the hypotheses, Section 3 describes the methodology and analytical framework based on the 2SRI approach. In Section 4, we discuss the results and findings from the analysis and the final section is concerned with the conclusions and future work on this research topic.

2 Background and Literature

2.1 Background of Irish Dairy Sector

The dairy sector is the largest agricultural sector in the European Union (EU) and Ireland in monetary terms (Eurostat, 2022). European Dairy has undergone several changes in terms of production and environmental regulations (Dillon et al., 2020). The total milk production in Ireland increased from 5.82 billion litres to 8.56 billion litres from 2014 to 2021 (Fig. 1), an increase of 55% (Eurostat, 2022). This was by far the largest increase among the largest eight milk producing countries in the EU.

The large expansion of milk production in Ireland was achieved with an increase in the size of the dairy herd and higher milk yields (Shalloo et al., 2020). This required large investments in buildings, machinery, and land. Between 2015 and 2020, approximately €2.2 billion has been invested by dairy farmers and around €1.3 billion has been invested by the major milk processors in Ireland (IFA, 2021). The major drivers of investment in the Irish dairy sector are intensified milk production, increased specialisation, environmental regulations and rising labour cost (Murphy et al., 2021).

Figure 1 depicts the annual milk production per year from 2007 to 2021 and the standardised milk prices (prices based on 3.7% fat and 3.3% protein content) per year in Ireland. This shows the milk price volatility over the years and the substantial increase in production levels over these years.

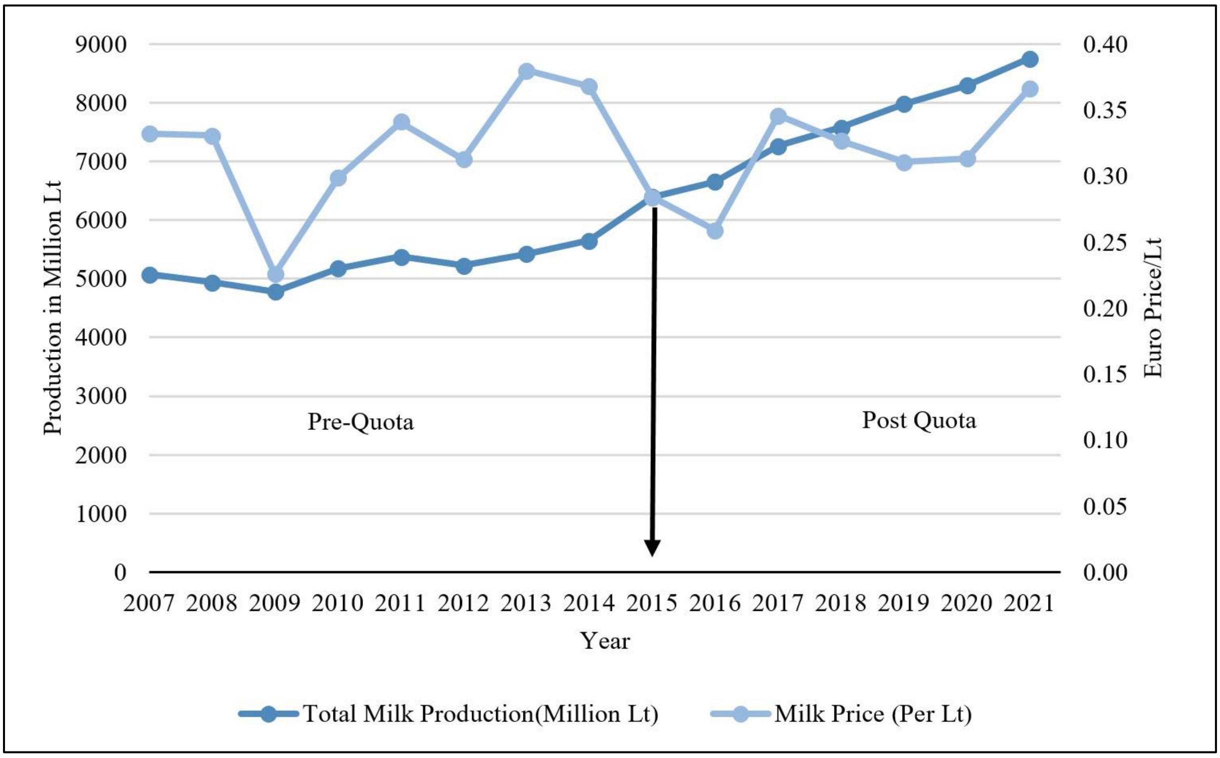

Figure 1. Annual Milk Production and Standardised Milk Price in Ireland

Source: Central Statistics Office (2021)

The building of new milk processing facilities has been crucial for the expansion of milk production in Ireland. From 2011 to 2017, Ireland had the highest investment in milk processing in the EU with 2.5 cents/ litre per year invested (Promar-International, 2018, as cited in Kelly et al., 2020). This investment was mainly undertaken by co-operatives. These co-operatives largely control the Irish milk processing facilities and account for the vast majority of total milk production in Ireland (Müller, 2018). Irish Dairy has a competitive advantage over other countries in terms of climatic conditions (Läpple et al., 2012; Läpple and Sirr, 2019). This competitive advantage has supported the high level of expansion. Ireland adopts a grass based strategy for feed, which reduces production costs and raises the quality of milk production (Finneran et al., 2012; Kelly et al., 2020).

Farm investment plays a vital role in enhancing productivity in the agricultural sector. At the EU level, the implementation of labour-saving technologies has supported the expansion of herd sizes with declines in the total number of dairy farms as part of structural change (Frick and Sauer, 2021). An increase in income risk on dairy farms is documented in several European countries (Duden and Offermann, 2020; Trestini and Chinchio, 2018; Vrolijk and Poppe, 2020). The price and income variability is increased due to EU policy reforms, increasing global production and an increase in dairy market volatility globally. Milk prices in Ireland have fluctuated largely, with a strong decline observed in 2016 followed by a rebound in 2017 (see Fig. 1). The milk producing countries in the EU vary in terms of dairy farms, herd size and production level. However, a common problem, which every country in EU is facing in terms of the dairy sector is milk price volatility. This increased price volatility further contributes to financial risk on dairy farms (Frick and Sauer, 2021). Under the Technology Acceptance Model (TAM), the adoption of risk management tools is determined by perceived usefulness and perceived ease of use (Michels et al., 2019). Farmers tend to adopt risk management tools when these tools are considered to be easy to use and have a clear economic advantage. The increase in price volatility is likely to contribute positively to the perceived usefulness of FMC contracts as a form of risk management. Commercial milk production demands large capital investments and long-term financial stability can be achieved through sound investments in productive assets on farms (Wolf and Karszes, 2023).

2.2 Farm Investment Decisions

One of the major issues facing the dairy industry is understanding the factors which influence farmer's investment decisions when there is so much uncertainty in milk revenue (Schulte et al., 2018b). Dairy farm investment decisions are related to, and dependent on, financial constraints. Investment subsidies can play a vital role in overcoming the financial constraints faced by farmers while making investment decisions (Fertő et al., 2021). In Ireland, there is some evidence of an association between long-term land leasing and dairy farm investment in buildings and machinery as long-term leasing provides greater certainty to tenants relative to short-term land rental (Bradfield et al., 2023). Similarly, the expectation is that the adoption of fixed milk price contracts reduces the uncertainty of milk revenue. Under the assumption of farmers being risk averse, it is expected that a reduction in the uncertainty of milk revenue (via the adoption of a fixed milk price contract) will lead to an increase in farm investment.

Investment behaviour of farmers in the dairy sector was evaluated in the Netherlands (Feinerman and Peerlings, 2005), France (Levi et al., 2017) and New Zealand (Ma et al., 2018), respectively. These studies point out that farmers' heterogeneity needs to be considered while modelling investment behaviour. Focusing on the Netherlands, Samson et al., 2016, explore the determinants of whether or not a dairy farmer invests in stable capacity. Samson et al., 2016, considered external factors as being related to market conditions and policy reforms at national and international level, and internal factors including farm characteristics, farmer's financial status (farm and off-farm income) and individual expansion goals and strategies. The framework explains the social, economic and environmental aspects, which are potentially responsible for dairy expansion decisions. Our study is not focused on one particular form of investment and is different in several respects from Samson et al. Our research is concerned with overall farm investments, which includes investments related to technology adoption, new machinery, new building infrastructure and the upkeep and repair of existing capital assets.

There is an extensive literature regarding the factors influencing farm investment decisions in the U.S. dairy sector although much of this literature is dated from the 1980's and 1990's. The more recent literature is concerned with specific technology adoption decisions (Mayen et al., 2010; Borchers and Bewley, 2015). The earlier literature found that education, herd size and adoption of new technologies were the major drivers of investments in United States (Chavas and Klemme, 1986).

2.3 Risk Management Strategies and Tools

The dairy industry involves a high degree of uncertainty and risk. Risk is considered to be imperfect knowledge about some known probabilities of possible outcomes and uncertainty is considered to be imperfect knowledge about unknown probabilities (Hardaker et al., 2004). Hardaker and Lien (2010) emphasise the importance of substantive risks including major disease and pest outbreaks, institutional risks and risks associated with major farm investments and the health and wellbeing of the farming family. Production risk and price risks can be substantive and much recent research points to the growing importance of these risks (Skevas et al., 2018b; Thorsøe et al., 2020). Variations in milk prices and input cost are two of the main factors, which have been found to affect the on-farm risk management decisions (Hadrich and Johnson, 2015).

Risk management strategies depend on farm owner's personal choice and on the extent of risk in the farming business (Beal, 1996). Leppälä et al. (2015) provide a detailed analysis of the literature on risk management in various agricultural sectors and point out that available farm risk management tools and the information provided regarding these tools is not sufficient as farmers face multiple risks on farm. Arata et al. (2023) reach similar conclusions and emphasise that current approaches to risk management are ‘too simple, partial, and inappropriate to successfully help cope with multifaceted global challenges’.

Along with farm investment, the adoption of risk management tools to manage farm risks is an important goal of policy makers (European Commission Report, 2017). Risk management strategies adopted in the European Union (EU) mostly comprise of commodity-based insurances, price contracts, farm diversification and off-farm activities (Van Asseldonk et al., 2016) and more recently the Income Stabilisation Tool (Severini et al 2021). Large farms are hesitant to engage in off farm employment and mostly focus on price contracts and insurances (Van Asseldonk et al. 2016). This finding fits with previous literature indicating a positive relationship between farm size and the adoption of risk management tools (Van Winsen et al., 2016). One explanation is that the relative probability of contract adoption increases with farm size as large farms are more likely to have the managerial resources available to spend time on risk management (Vigani and Kathage, 2019).

There is a growing interest in the design of contracts and their adoption with the goal of reducing risk and uncertainty. For instance, Petersen and Hess (2018) undertook a discrete choice survey to examine the preferences of milk producers in Germany regarding their milk delivery. The results obtained show that relatively large producers prefer fixed contractual agreements while the small and medium sized milk producers prefer the current cooperative delivery model. In the current cooperative delivery model, there is an agreement that the cooperatives will process all the milk supplied by their members, provided that it meets the quality standards and the suppliers receive the prevailing market prices.

Milk price hedging is one risk management tool available in some EU member states. There are data constraints for researchers interested in undertaking research on this topic. Some studies therefore rely on simulation methods in the absence of actual data relating to the adoption decision. For instance, a study by Hoehl and Hess (2022) use a simulation model to examine the survival of dairy farms in northern Germany under a scenario whereby milk producers can determine the share of milk to be hedged to ensure farm survival. Schulte and Musshoff (2018a) used a simulation model to explore the willingness to hedge milk prices using futures markets. Elsewhere, Loughrey et al. (2015) used data on farmer attitudes to risk to explore the determinants of potential fixed milk price contract adoption in Ireland with results indicating that the number of children in the farm household could have a positive influence on adoption.

In the U.S., the most commonly used risk management tools in the agricultural sector are forward price contracts and insurances (Coffey and Schroeder, 2019). Many studies have evaluated the risks faced by farmers, the strategies which are formulated and implemented at farm level as well as the adoption of available risk management tools (Hadrich and Johnson, 2015; Prager et al., 2020). To adopt these tools, knowledge of management techniques is required, which can be acquired through the promotion of educational programmes. The adoption of price risk management tools in U.S. dairy sector was evaluated (Wolf, 2012, and Wolf and Widmar, 2014) to examine the extent and determinants of forward contract usage. These studies pointed out that the farmers adopting risk mitigating tools tend to be higher educated, younger in age, with larger herd size and farm size in terms of land area.

Crop insurance and livestock insurances are largely considered as risk reducing public policy mechanisms in the United States (Mahul and Stutley, 2010). As in the case of Europe, risk management tools in the United States are more established in the grain sector relative the dairy sector. Educational programs and agricultural training are found to contribute positively to the risk management adoption decisions in the U.S. grain sector (Goodwin and Schroeder, 1994). Farm size, contact with a market advisory service, and being a technology adopter are also found to be positively associated and particularly important factors in predicting risk management tool use by grain farmers in the Mid-West region of the United States (Coffey and Schroder, 2019).

2.4 Research Hypotheses

Summarising the above discussion, the selection of investigating variables are country specific and according to the typology of the region. We test the following hypotheses (Table 1) to examine the association between the selected explanatory variables and both the adoption decisions and farm investments in the dairy sector in Ireland. To test these hypotheses, we apply the 2SRI model to deal with the potential endogeneity of the FMC adoption variable. In this two stage model, the 1st stage estimates the probability of fixed milk price contract adoption by the dairy farms using a probit model and the 2nd Stage model estimates the impact of adoption of fixed milk price contracts on farm investments using a linear regression model.

Table 1. Hypotheses and expected relationships among the variables

	Models **Hypothesis**	**1st Stage** **Adoption of FMCs**	**2nd Stage** **Farm Investments**
H1	Adoption of Fixed Milk Price Contracts affects	N/A	(+)
H2	Milk Production affects	(+)	(+)
H3	Farm Operators Age affects	(+/-)	(+/-)
H4	Subsidies affect	(-)	(+)
H5	Number of Children affects	(+/-)	(+/-)
H6	Having High Agricultural Training affects	(+/-)	(+/-)

Note: The sign reported in the above table represents the expectation of positive (+) or negative (-) influence which the selected set of explanatory variables may have on the dependent variable. The authors expect possibility of double effect (+/-) in some specific variables.
Source: authors` own illustration

Hypothesis 1 - Adoption of fixed milk price contracts is a binary variable and is expected to have positive association with farm investments as fixing the proportion of milk production can stabilise milk revenue and reduce farm market risk and secondly, the adoption of this risk management tool may be a requirement from a financial institution prior to accessing loans which enable farm investments to take place (Goodwin, 1993; Du et al., 2017, and Wolf, 2012)

Hypothesis 2 - Total milk production per farm per year in litres which represents the size of farms in the analysis is expected to have a positive association with risk management tool adoption due to the findings of previous studies and the tendency for perceived risk to increase with farm size (Van Winsen et al., 2016). A positive association between the size variable and investments is expected as operators of larger farms may have a higher propensity to invest than smaller farms due to economies of scale (Aramyan and Cragg, 2007). As mentioned in 2.3, the relatively larger farms may have more resources available to spend time on risk management (Vigani and Kathage, 2019).

Hypothesis 3 - Farmers' age is selected to test whether the stage of the life-cycle may have an impact on investments (Calus et al., 2008). Farm operator's age is considered an important predictor of risk attitude and risk perception with older farmers tending to take fewer risks (risk attitude) and to perceive risks as being greater than is the case for younger farmers (risk perception) (van Winsen et al., 2016). Consistent with this understanding, Skevas et al., 2018, found that farmer's age has a negative effect on capital investments on farms. This literature points to a negative association between farmer age and investment decisions. We hypothesise that the association between farmer age and investment could be positive or negative given the possible role of experience in supporting investment decisions (Wolf, 2012). We hypothesise that farmer age could be positively or negatively related to the FMC adoption decision. Older farmers may be willing to take fewer risks and therefore seek to reduce the extent of price volatility through adopting a FMC contract. However, there is also the possibility that older farmers could be less inclined to take on new strategies including the FMC risk management tool.

Hypothesis 4 - Subsidies – as they are a relatively stable source of farmer's overall income (Špička et al, 2009). are expected to reduce the demand for price risk management tools and lead to an increase in investment (O'Toole and Hennessy, 2015).

Hypothesis 5 - Number of children in the household - where more children of a younger age might affect investments on farm in both possible directions - positive or negative. Positive because having a farm successor is associated with higher investments (Wright and Brown, 2019; Bertoni et al., 2023) but there might also be a negative association due to a higher cost of education if they are school or college going age, so farmer's might tend to invest less due to higher cost of living.

Hypothesis 6 - High agricultural training- this variable is binary and is selected to test whether farmers who have undertaken agriculture related trainings are better enabled to make investment decision on their farms. Farm owners who obtained agricultural training tend to have more knowledge of the risk management strategies and hence might have a higher probability to adopt the FMC contracts and invest more in their farms as compared to farm owners with low agricultural training. The precise definition of high agricultural training for the purpose of this study is provided at the end of Section 3.2.

3 Research Methodology and Data

3.1 Methodology

Previous literature has applied propensity score matching (PSM) methods to model the impact of risk management tool adoption decisions in agriculture (Hadrich and Johnson, 2015; Kuethe and Morehart, 2012; Ifft et al., 2015). This method can take into account both observed and unobserved heterogeneity, but relies on a relatively large sample size to accurately estimate the various parameters involved in the regressions for adopters and non-adopters (Ton et al., 2018).

The 2 stage residual inclusion model approach (2SRI) is used in health economics and agricultural economics research. The 2SRI model has been applied to identify and address unobserved heterogeneity in an agricultural economic setting (Ma and Zhu, 2020). Our research applies the 2SRI approach to address the association between risk management tool adoption and farm investment and focuses on the post quota years from 2016 to 2021. The 2SRI model is chosen over the fixed effects model (see Appendix Table A4) as the latter is based on within-farm variation in the explanatory variables. Many of the variables of interest in this research have limited variation over time.

The adoption of risk management tools such as FMC's is not randomized as it is a voluntary decision. The non-randomized nature of the data means that self-selection bias could be an issue. In this research, the unobserved heterogeneity may include risk aversion, the presence of off-farm income, family wealth, the use of risk management tools such as milkflex, income averaging for taxation purposes and unobserved household differences. We account for this unobserved heterogeneity using the 2SRI approach.

We use the availability of contracts at the processor level (only processors offering contracts included) as an instrument to identify the effect of adoption of contract on farm investments. The availability of contracts at the processor level (IV) is considered exogenous to an individual farm and does not have any direct effect on farm investments (though contract availability may indirectly affect investments by influencing the adoption of FMCs). This means that the IV variable is uncorrelated with unobserved factors that affects farm investments (Key and McBride, 2008:179).

The first stage model estimates the probability of the adoption of fixed milk price contracts by the dairy farms based on the following probit model. We test the hypotheses stated in Table 1 related to adoption of FMCs with Equation 1.

$$D^*_{it} = \alpha_{it}X_{it} + \beta_{it}I_{it} + \varepsilon_{it,} \quad (1)$$

where, D^*_i represents the adoption of fixed milk price contracts which is a binary variable (0 for non-adoption and 1 for adoption), Xi is a vector of explanatory variables and Ii represents the instrumental variable (IV). This IV variable is used in 2SRI models to address potential endogeneity. The α_i and β_i are estimation parameters, t refers to the time (year), i refers to the farm in each year and ε_i refers to the error term. The explanatory variables, milk production, subsidies, number of children and high training are potentially endogenous to adoption decision variable.

Instrumental variables have previously been used to explore the relationship between contract adoption and farm performance (Key and McBride, 2008). The IV is calculated for each processor based on the share of farms adopting a fixed milk price contract. The approach is therefore similar to Key and McBride, 2008, but the availability of contracts is based on processor rather than county level estimates. The validity of the IV has been checked by applying a Kendall's tau-b correlation test to test the correlation between the IV and the error term in the second stage. The Kendall's tau-b test is chosen due to the non-linearity of the IV variable. The results show that there is no correlation between the IV and the error term in the second stage. This satisfies the main assumption that the instrumental variable should be correlated with endogenous explanatory variable but uncorrelated with the error term (Cameron and Trivedi, 2005) (see Appendix Table A5).

The availability of FMC contracts positively influences the likelihood of an individual farmer adopting a contract but does not have a direct influence on the investment level. There is a weak positive correlation between the IV and the dependent variable (0.11) (Gogtay and Thatte, 2017). The absence of a correlation between the IV and the error term in the main equation supports the choice of the IV. There remain some limitations with the IV given that there is variation between processors in terms of the maximum share of production which can be allocated to a contract.

The second stage model estimates the impact of adoption of fixed milk price contracts on farm investments using a linear regression model presented as follows. We test the hypotheses stated in Table 1 related to net new investments with Equation (2).

$$Y^*_{it} = \gamma_{it}D_{it} + \delta_{it}X_{it} + \eta_{it}\, Xuhat_{it} + \varpi_{it} \quad (2)$$

where Y^*_i represents the net new investment per farm (€), Xi and D_i are explained in Equation (1), γ_i and δ_i are estimation parameters, $Xuhat_i$ is the estimated residual probability from Equation 1, t refers to the time (year) and ϖ_i refers to the error term in the 2nd stage. Note that the error term (ε_i) in the 1st stage equation and $Xuhat_i$ in the 2nd Stage are not identical (Terza 2018, Eq. 3).

Farm investment is a continuous dependent variable in the model. This dependent variable is converted using the inverse hyperbolic sine transformation (arcsinh) described in (Bellemare and Wichman, 2020). This transformation method has gained popularity recently in applied econometrics as it is similar to a natural logarithm conversion and retains the zero-valued and negative value observations in the data. The inverse hyperbolic sine transformation is useful when the data has negative values in a skewed distribution (Bellemare and Wichman, 2020). The dependent variable (***Y^*_{it}***) in the 2nd Stage which is Net New Investments (€) per farm per year is the only variable in the analysis which is transformed using the inverse hyperbolic sine transformation given in the Equations (3) and (4) below. These equations are only related to and used for converting the Y variable in the 2nd stage (Equation (2)).

The main challenge in such variable transformation involves interpretation of the coefficients of the dummy variables in semi-logarithmic regression equation format (Giles, 2011; Halvorsen and Palmquist, 1980). Bellemare and Wichman (2020) outline a series of equations that can be used to interpret the size of the coefficients in the following (Equations (3) and (4)). As in the case of Equation (2), the dummy independent variable is represented by ***D*** which take values of zero and one. Bellemare and Wichman, 2020, explain how the percentage change denoted by $\hat{p}$ is obtained in Eq. (3) under a change in the value of the dummy variable from D = 0 to D = 1. The symbol ^ (hat) indicates that the value of the coefficient is an estimated or predicted value for the population of dairy farmers in Ireland.

$$\frac{\hat{P}}{100} = \frac{\hat{y}\,(D=1) - \hat{y}\,(D=0)}{\hat{y}(D=0)} = \frac{\sinh(\hat{\alpha} + \hat{\beta} + \hat{\varepsilon}) - \sinh(\hat{\alpha} + \hat{\varepsilon})}{\sinh(\hat{\alpha} + \hat{\varepsilon})}$$

$$= \frac{\sinh(\hat{\alpha} + \hat{\beta} + \hat{\varepsilon})}{\sinh(\hat{\alpha} + \hat{\varepsilon})} - 1 \qquad (3)$$

The final logarithmic equation obtained is:

$$\frac{\hat{\hat{P}}}{100} \approx exp(\widehat{\beta}) - 1 \qquad (4)$$

The $\hat{\hat{P}}$, in Equation (4) denotes the percentage change in the dependent variable in response to the adoption of contracts.

3.2 Data Description

This study uses the Teagasc National Farm Survey Data for the empirical analysis. The National Farm Survey (NFS) has been conducted by Teagasc on an annual basis since 1972. Teagasc-the Agriculture and Food Development Authority is the national body which provides integrated research, training and advisory services in the agriculture and food sector in Ireland. Teagasc is designated as Ireland's Farm Accountancy Data Network (FADN) Liaison Agency. The Teagasc NFS survey is operated as part of the Farm Accountancy Data Network of the EU and fulfils Ireland's statutory obligation to provide data on farm output, costs and income to the European Commission. Farm-Level data and Stata codes are available in excel and stata format on request.

The Teagasc NFS is based on a process of stratified random sampling. Teagasc specifies to the Central Statistics Office (CSO) the number of farms it requires for the NFS according to the strata, which is based on farm system and size class. In response, the CSO supplies Teagasc with a random sample of farm holder names and addresses in encrypted format to enable the Teagasc NFS to take place. This data is available to the CSO via Census of Agriculture data and Farm Structures Survey data and administrative data provided by the Department of Agriculture, Food and the Marine (Basic Payment Scheme, Animal Identification and Movement System, Sheep and Goat Census, Corporate Client System). Teagasc farm recorders visit each selected farm and collect accountancy details as part of the Teagasc NFS (CSO, 2022). A unique code is used to identify each farm thus ensuring that data cannot be linked to a particular farm. Each farm is assigned a weighting factor so that the results of the survey are representative of the national population of farms. Annually, CSO provides a sample of 800-1000 random sample of farms which includes all type of farms (dairy, sheep, tillage and other mixed farming) to Teagasc. Margarian (2022) sets out a decision tree to guide researchers on the use of statistical hypothesis tests. The decision to use statistical hypotheses tests is supported by the use of the random sample available through the Teagasc NFS. Furthermore, the analysis can be repeated in the future with comparable samples from the same population.

The data for this research is taken from the Teagasc National Farm Surveys (NFS) database for the post quota period 2016 to 2021. The data consists of approximately 180 to 250 specialist dairy farms in each year including the adopters and non-adopters of the FMCs contracts (number of farms are different for each year). The weighted data is a representative sample of the population of dairy farmers in Ireland (see Appendix Table 1). According to the European Commission, the specialised dairy farms are defined as, the farms which have at least 2/3rd livestock on their farms and out of which at least 3/4th of the livestock are dairy cows.

Table 2 provides details of the entire Teagasc NFS sample of specialist dairy farms and the final sample count.

Table 2. Sample Size

Year	Number of specialist dairy farms	Number of dairy farms who did not respond to FMC Question	Number of remaining farms responding to the FMC Question	Farms which are attached to cooperatives which did not offer contracts	Number of dairy farm exits	Final sample size taken for analysis
2016	324	85	239	26	0	213
2017	309	85	224	22	3	199
2018	311	61	250	26	1	223
2019	312	40	272	26	0	246
2020	301	90	211	19	1	191
2021	287	78	209	24	0	185
Total	1,844	439	1,405	143	5	1,257

Source: Teagasc NFS (2016-2021)

The final sample of total 1,257 observations has been included in the analysis. The dependent variable in the study has some zero valued observations, which are meaningful. In the sample, some farms did not answer the FMC's question and so they were excluded in the final sample. There were five farms, which had cow inventories falling to zero by the end of some years. These farms are removed from our analysis as they may skew the results and probably relate to dairy farm exits. Every farm in the data is attached to one milk processor group in Ireland, and some of these processors did not offer any FMCs and hence these farms never had an opportunity to be an adopter of FMCs (Table 2, Loughrey et al., 2021). Such farms were also removed from the sample as these farms had no choice other than to be a non-adopter. The analysis was conducted using STATA 17 software.

Table 3 provides the list of the variables used in this study and their definition. The descriptive statistics (mean and standard deviation) based on the adoption of the contracts for the entire study period are presented in this table. Although the spot milk price is a possible influencer of adoption decisions, we do not include milk price in the list of variables. This is due to the tendency for standardised milk prices to be similar across farms and processors in Ireland at a given point in time.

The summary statistics show that adopters are larger in terms of milk production (631,700 versus 449,500 litres) and farm investments (37,860 versus 25,440 euro per farm). Subsidies received by the adopters are higher as compared to the non-adopters (24,700 versus 20,700 euro per farm). On average, the adopters have higher agricultural training than non-adopters and have more children below the age of 24 years.

Table 3. Variable Definitions and Descriptive Statistics

		Adopters (498)		**Non-Adopters (759)**	
Dependent Variable	*Variable Definition*	*Mean*	*Std Dev*	*Mean*	*Std Dev*
Net New Capital Investment (000' €)	Capital expenditure during the calendar year minus capital sales and capital grants. This includes major repairs to farm buildings and machinery, and land improvements.	37.86	60.01	25.44	40.66
Explanatory Variables					
Total Milk Production (000' ltr)	Total milk produced per farm for the particular year	631.7	409.5	449.5	296.2
Farmer's Age	Age of the farm operator in that year	54	11	53	10
Subsidies (000' €)	Total subsidies (€) which is calculated as sum of the basic farm payment and other subsidies.	24.7	15.2	20.7	12.5
No. of Children	Number of children in the family below age of 24 years	1.21	1.37	1.17	1.36
High Agricultural Training*	This variable is a binary variable and refers to the level of agricultural training undertaken by the farmer (1 = having taken high level training and 0 = not taken).	0.26	NA	0.18	NA
Adoption of Contract	Fixed price milk contracts adoption variable which is the binary treatment variable (1 = adoption and 0 = non-adoption)	1	NA	0	NA
IV	The availability of contracts at the processor level	0.50	0.16	0.33	0.20

*Note: The variable High Training is given value 1 if the farm holder has completed either one of these 1. Full-Time 3rd Level Agriculture related Course, 2. Farm Apprenticeship Scheme, 3. 1 year Agriculture College education and zero otherwise.
Source: author's own calculations based on Teagasc National Farm survey

4 Results and Discussion

Stata codes will be available on request.

Table 4 shows the 2SRI model results for the first and second stage regressions.

The first-stage results of the probit model show that the volume of milk production is strongly associated with the decision to adopt FMC's. The marginal effect analysis results depicted that a 10,000 increase in milk litres is associated with 2.9% increase in probability of adoption of FMCs. This concurs with the findings of other studies which indicate that variables representing the size of the farm are positively associated with risk management tool adoption (Wolf and Widmar, 2014). We have examined the potential for reverse causality by estimating the model with the lag of milk production included as an independent variable. This provides similar results. We also test separately using the one-year change in milk production as an independent variable. These results indicate that reverse causality is not an issue i.e. the adoption of a fixed milk price contract does not affect the annual change in milk production.

Farmer age and the number of children in the farm household are not found to have a statistically significant association with contract adoption. A z-test fails to reject the null hypothesis of a zero coefficient for the farmer's age and the number of children variables at the 5% level. The IV represents the availability of contracts at the processor level and is found to have a strong positive association with the adoption of FMCs. This reflects the fact that among those processors offering contracts, there is a strong disparity in the extent to which processors are active in offering FMCs (Loughrey et al., 2018). The probability of an individual farm choosing to adopt FMCs is closely connected to the relevant milk processor for that farm.

Table 4. 2SRI Estimation Results

Variables	**First Stage** Adoption of Contracts	95% CI or Compatibility Interval	**Second Stage** Net New Investment (€)	95% CI or Compatibility Interval
Adoption of Contracts			0.220 (0.576)	(-0.909, 1.349)
Farmer's Age	-0.015 (0.009)	(-0.034, 0.003)	0.003 (0.011)	(-0.018, 0.025)
Milk Production	0.013 (0.003)***	(0.004, 0.021)	0.028 (0.005)***	(0.001, 0.004)
Subsidy	-0.012 (0.008)	(-0.029, 0.004)	0.035 (0.013)***	(0.011, 0.061)
High Training	0.278 (0.262)	(-0.302, 0.858)	-0.365 (0.296)	(-0.946, 0.216)
Number of Children	0.052 (0.075)	(-0.105, 0.208)	0.222 (0.108)**	(0.010, 0.434)
Year 2017	-0.116 (0.187)	(-0.477, 0.245)	1.375 (0.374)***	(0.641, 2.108)
Year 2018	0.082 (0.191)	(-0.329, 0.493)	1.209 (0.379)***	(0.464, 1.953)
Year 2019	0.047 (0.187)	(-0.384, 0.477)	0.957 (0.408)***	(0.157, 1.756)
Year 2020	-0.061 (0.208)	(-0.516, 0.393)	1.250 (0.413)***	(0.441, 2.059)
Year 2021	-0.227 (0.222)	(-0.691, 0.236)	1.968 (0.426)***	(1.133, 2.803)
Residual			-0.453(0.606)	(-1.641, 0.735)
IV	5.287 (0.671)***	(3.959, 6.614)		(3.959, 6.614)
Observations	1,257		1,257	

Notes: ***p < 0.01, **p < 0.05, *p < 0.1.
Robust standard errors are presented in parentheses. The reference year is 2016.
Source: author's own calculation based on Teagasc NFS Data

In terms of the second-stage results, the residual term is found to be negative but statistically insignificant. A z-test fails to reject the null hypothesis of a zero coefficient for the residual term at the 5% level. This residual term represents the unobserved reasons involved in the FMCs adoption decision and may include risk aversion, the degree of trust of the farmer in the co-operative and the presence of off-farm income. The result means that we do not have evidence to support the conclusion that unobserved heterogeneity has an impact on the net new investment per farm. After controlling for these potential sources of endogeneity, the FMCs variable is found to be positive but statistically insignificant in terms of the association with Net New Investment per farm. A z-test fails to reject the null hypothesis of a zero coefficient for the FMC variable at the 5% level. There was an expectation of a positive relationship between the adoption of FMCs and farm investments. This expectation was partly due to the possibility that the access to bank loans could improve as a result of a decision to adopt a fixed milk price contract, which would reduce the income risk.

The statistical insignificance of the coefficient suggests that other factors could be more influential in affecting the level of investment on Irish dairy farms. However, this does not preclude us from discussing the economic relevance of the econometric results. Firstly, there is the potential for a type II error by concluding that no association exists between FMC adoption and farm investment when there could be a true association (Heckelei et al., 2023). The upper and lower limits of the “compatibility interval” (Amrhein et al., 2019), show the interval estimates which are compatible with the data and the model used for our analysis (Lindena and Hess, 2022). After accounting for a number of confounding variables, the results indicate that adopters have a 24% higher level of investment relative to non-adopters. This is based on the coefficient result and the application of Equation (4). However, the compatibility interval is very wide. An estimated 24% difference points to some economic relevance.

Both milk production and farm subsidies are statistically significantly associated with higher investment. In the case of both variables a z-test rejects the null hypothesis of a zero coefficient at the 1% level. The results are therefore in line with hypotheses of a positive association with p-values below 0.01 for both variables. For instance, the results indicate that a 10,000 litre increase in milk production is associated with a 2.8% increase in investment and a €1,000 increase in subsidies is associated with a 3.5% increase in investment. The latter result may be due to the tendency for farm subsidies to reduce risk. We also supported these results by using the lag of milk production instead of milk production to see if there exist any potential endogeneity between NNI and milk production. However, the results were similar to the result presented above. Also, there is no multicollinearity between investments and milk production or between subsidies and investments (see Appendix Table A6) as the Variance Inflation Factor (VIF) values are very low (below 10). In Ireland, the basic farm payment scheme is the largest contributor to overall subsidies. Farmers can avail of the basic farm payment scheme through which are they are entitled to get an income support through a one-time payment made per year on the basis of their land used for agricultural activities. There is also Targeted Agriculture Modernisation Schemes (TAMS) introduced in Ireland in 2015, which provides grants to the farmers for improvements and modernisation purpose (DAFM, Ireland, 2023). It is important to note that these grants are not included in the subsidies variable in the model. The model was also estimated using debt per cow as an explanatory variable, however, the results did not alter notably (see Appendix Table A7).

The result for the milk production variable could be due to the greater need for large dairy farms to replace or repair existing buildings and machinery or as a result of expansion. Other factors may also be influential, including environmental regulations and the adoption of labour-saving technologies. It is expected that the demand for labour-saving technologies is greater on large farms and the milk production variable may capture some differences in demand for these technologies. In a study of automation and efficiency on Irish dairy farms, Garcia-Covarrubias et al. (2023) conclude that ‘investing in labour-saving technologies’ could reduce ‘dairy farmers' workload related stress’ while increasing efficiency.

The findings also depict that the level of investments made in Irish dairy farms is also associated with the number of young children in the household. This supports the findings of previous research indicating that household composition and the presence of a farm successor are positively associated with investment (Wright and Brown, 2019; Bertoni et al., 2022). The year 2016 was particularly difficult in terms of milk price. Previous research found that the adoption of the FMCs reduced milk price volatility in 2016 (Loughrey et al., 2018: 34-38). The results indicate that farm investment was significantly higher (statistically) after 2016. The dummy variable for the year 2021 is associated with higher investment than for other years. This is the case despite the Covid-19 pandemic.

The overall impact of FMC adoption on farm investment decisions may therefore be limited as many adopting farmer’s commit only a minority of their production in the contracts. There is also the tendency for investment to be lumpy and concentrated in particular years for each farm. Formal agricultural training and farmer age are not associated with investment. The latter may appear surprising given the possible influence of the farm life-cycle in investment decisions (Calus et al., 2008). However, the presence of a chosen farm successor may be an important factor on decision-making on some farms.

We have tested the impact of replacing the volume of milk production with the number of dairy cows as the proxy variable for farm size and the results are similar in both the first and second stage (results available on request). The 2SRI modelling approach is a useful method to overcome potential problems with endogeneity but data on market risk perceptions and risk attitudes could be helpful in assessing the direct influence of these factors on adoption decisions.

Finally, we note some limitations of our study. Ideally, one could model the share of production committed to the fixed milk price contracts, but this data is not available in an accessible form. The choice of the 2SRI approach means that several potential sources of unobserved heterogeneity are bundled together including risk aversion, risk attitude and possibly wealth. The FMCs vary according to the processor in terms of price and duration. However, the data on the exact fixed milk price and the duration of the contracts are not available. In some FMCs, the fixed milk price is adjusted for fluctuations in price of particular inputs. These complexities are not taken into account and more detailed data could provide further insights

5 Conclusion

Since 2015, the Irish dairy sector has expanded dramatically due to the increase in the national herd size and milk production per farm and per cow (yield). The rate of increase in milk production is much greater than for other EU member states. The large expansion demanded large investments. Dairy farming is a risky business with farmers facing high volatility in output and input prices with consequences for income volatility. Thus, this study has analysed the relationship between the adoption of fixed milk price contracts which is one of the risk management tools available in the Irish dairy sector and farm investments using detailed farm-level microdata for farms in Ireland and by applying the 2SRI approach to address potential endogeneity.

Our econometric results indicate no statistically significant relationship between FMCs and Net New Investments. However, the particulars of investment mean that additional caution is required in interpreting the results. Farm-level investment is lumpy. This increases the uncertainty surrounding the estimates for individual parameters. We, therefore, place most of the emphasis on the size of the estimates with adopters of FMCs found to have a higher net new investment relative to non-adopters. The positive sign of the coefficient is expected although the magnitude of the estimates is lower than expected. The weak result for the adoption variable means that other factors may be more important in influencing the investment at farm level. Subsidies play an important role in the investment decision although they are a small proportion in the overall specialised dairy farm income and provide a relatively stable source of income in Ireland. This research highlights the continued role of subsidies, which are considered as a risk-free source of income (O'Toole and Hennessy, 2015). Despite the absence of a statistically significant finding, it is important not to ignore the potential importance of fixed milk price contracts when farmers are making investment decisions.

In Ireland, dairy farm investment varies between farms and this study highlights the importance of various factors including the subsidies provided by government. Recently, the subsidies provided to farmers in Ireland have begun to decrease in real terms due to inflation. This is expected to drive greater demand for risk management tools. In light of the increase in farm investments in a highly volatile environment, there are a few policy implications which we draw from this research. There is scope to improve the design of these FMCs in terms of protecting farmers from drastic margin volatility to increase the adoption rate. There is recent evidence that milk processors in Ireland are making such improvements (Tirlan Farm Life, 2022). The absence of a statistically significant result does not mean that we should dismiss the importance of this risk management tool for investment decisions.

The adoption of the FMCs can protect farmers from downward milk price volatility e.g. 2016. This tool is primarily targeting market risk. Farm investment is mainly related to financial risk and is another consideration. Farmers use this tool for potentially different reasons. Many farmers use this tool to reduce market risk. Other farmers may use this tool to access loans and manage financial risk. Currently, there is a limited suite of risk management tools available to Irish farmers to deal with market risks and fixed milk price contracts are among the few tools available (Loughrey et al., 2021). Hence, there is a need for developing new tools for managing dairy farm risks or enhancing the efficiency of current ones. These improvements could potentially alter the association between FMC adoption and investment decisions in the future.

In terms of risk management tool adoption, the U.S. is much further ahead relative to the EU. There is an extensive literature on risk management in the agricultural sector in the U.S. with studies focusing on risk management tools such as insurances, forward contracts and the use of derivative markets. The novelty of this research is that we evaluate the relationship between the adoption of fixed milk price contracts and farm investments using the actual adoption data. Future work could involve analysing this risk management tool from the farmer's perspective and seek to establish more information on aspects involved in the farm holder's decision making towards the adoption of FMCs and other risk management tools. There is scope for researchers in other EU member states to undertake similar research as similar tools become more common.

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Appendix

Table A1. Proportion of Farms classified by Farm Size (AAU)

Figures are in (%)							
Year 2016	**Farm size (AAU) - hectares**						**Total**
	< 10	**10 - < 20**	**20 - < 30**	**30 - < 50**	**50 - < 100**	**>=100**	
CSO	1	4	11	32	42	10	100
Data Used in Analysis	2	4	10	34	42	8	100
Overall NFS	1	4	11	33	42	10	100
Year 2020	**Farm size (AAU) - hectares**						**Total**
	< 10	**10 - 20**	**20 - 30**	**30 - 50**	**50 - 100**	**100 +**	
CSO Sample	0	4	9	29	44	14	100
Data Used in Analysis	0	4	8	29	45	14	100
Overall NFS	1	3	9	30	44	14	100

Source: author's own calculations, based on NFS data or using the NFS data

Table A2. Descriptive Statistics

YEAR	GROUPS	NNI (000'€)	FARMER AGE (YRS)	MILK PRODUC-TION (000'LT)	SUBSIDIES (000'€)
2016	Non-Adopters (n=125)	12.15 (20.21)	53 (10.7)	399.5 (251.79)	21.56 (14.77)
	Adopters (n=88)	23.34 (43.55)	51 (9.3)	520.9 (295.31)	23. 97 (14.85)
	Total (n=213)	16.77 (32.37)	52 (10.2)	450.65 (276.51)	22.55 (14.81)
2017	Non-Adopters (n=111)	24.64 (39.84)	52 (11.2)	443.40 (254.51)	20.64 (11.80)
	Adopters (n=88)	28.52 (43.65)	54 (9.6)	550.46 (307.18)	22.79 (14.07)
	Total (n=199)	26.36 (41.50)	53 (10.6)	490.74 (283.35)	21.59 (12.87)
2018	Non-Adopters (n=122)	23.61 (42.42)	53 (10.5)	409.61 (263.61)	20.58 (12.44)
	Adopters (n=101)	40.67 (65.47)	54 (9.9)	627.13 (408.70)	25.25 (13.63)
	Total (n=223)	31.34 (54.62)	53 (10.2)	508.12 (353.40)	22.69 (12.17)
2019	Non-Adopters (n=150)	28.78 (48.24)	54 (10.7)	468.27 (336.21)	21.20 (11.46)
	Adopters (n=96)	46.31 (82.99)	56 (9.9)	654.67 (472.47)	25.26 (19.50)
	Total (n=246)	35.62 (64.49)	55 (10.5)	541.01(404.48)	22.78 (15.20)
2020	Non-Adopters (n=124)	27.85 (37.32)	54 (11.49)	467.88 (308.25)	19.36 (11.22)
	Adopters (n=67)	38.85(43.92)	55 (13.79)	723.90 (460.40)	25.70 (15.12)
	Total (n=191)	31.71 (40.00)	54 (12.3)	557.69 (387.48)	21.58 (13.04)
2021	Non-Adopters (n=127)	34.65 (45.10)	54 (11)	502.30 (328.64)	21.20 (12.98)
	Adopters (n=58)	54.04 (59.13)	54 (15.2)	786.36 (458.31)	25.91 (12.19)
	Total (n=185)	40.73 (50.57)	54 (12.4)	591.36 (395.58)	22.68 (12.89)

Note: The above table displays averages for each group and standard deviations in parentheses.
Source: author's own calculations, based on NFS data or using the NFS data

Table A3. Yearly Mean Comparison Test between Adopters and Non-Adopters

Dependent Variable	2016	2017	2018	2019	2020	2021
NNI	2.52***	0.65	2.34***	2.09**	1.99**	2.58***
Independent Variables						
Total Production	3.22***	2.68***	4.80***	3.61***	4.96***	5.40***
High Agricultural Training	7.31*** (χ^2)	1.12 (χ^2)	1.50 (χ^2)	1.61 (χ^2)	2.26 (χ^2)	2.35 (χ^2)
Number of Children	1.69**	-0.14	0.49	-0.24	-1.02	0.61
Farmer's Age	-1.35	0.98	0.91	1.72**	0.78	0.38
Subsidies	1.17*	1.16	2.67***	2.05**	2.84***	2.21***

Note: Statistical tests based on t-tests for continuous variables and chi-square tests for binary variables (distinguished by a χ^2).
***, **, and * significant at the 1%, 5%, and 10% level, respectively
Source: author's own calculations, based on NFS data or using the NFS data

Table A4. Fixed Effect Estimation Results

VARIABLES	NET NEW INVESTMENT (€)
ADOPTION OF CONTRACTS	-0.289 (0.40)
MILK PRODUCTION	0.000 (0.00)
FARMER'S AGE	-0.001 (0.02)
HIGH TRAINING	0.381 (1.55)
SUBSIDY	0.000 (0.00)
NUMBER OF CHILDREN	-0.374 (0.24)*
YEAR 2017	1.255 (0.39)***
YEAR 2018	1.088 (0.40)***
YEAR 2019	0.718 (0.41)***
YEAR 2020	0.885 (0.45)***
YEAR 2021	1.485 (0.48)***
CONSTANT	6.716 (1.91)***
SIGMA_U	3.49
SIGMA_E	3.72
RHO	0.47
OBSERVATIONS	1257

Notes: ***p < 0.01, **p < 0.05, *p < 0.1.
Robust standard errors are presented in parentheses. The reference year is 2016.
Source: author's own calculations, based on NFS data or using the NFS data

Table A5. Kendall's Tau-b correlation coefficient analysis for testing the IV's validity

Instrumental Variable	Dependent Variable	Correlation Coefficient
IV	Adoption of FMCs	0.3333***
IV	Net New Investments	0.1072***
IV	Residual	0.0137

Source: author's own calculations, based on NFS data or using the NFS data

Table A6. Multicollinearity Test Results

Variable	VIF	1/VIF
Total Milk Production	1.80	0.556
Subsidies	1.80	0.556

Source: author's own calculations, based on NFS data or using the NFS data

Table A7. 2SRI Estimation Results including Debt per Cow

Variables	First Stage Adoption of Contracts	Second Stage Net New Investment (€)
Adoption of Contracts		0.385 (0.643)
Farmer's Age	-0.013 (0.009)	0.001 (0.014)
Milk Production	0.011 (0.004)***	0.029 (0.006)***
Subsidy	-0.010 (0.008)	0.033 (0.014)***
High Training	0.246 (0.268)	-0.306 (0.409)
Number of Children	0.045 (0.075)	0.218 (0.120)**
Debt per Cow	0.0005 (0.0004)	0.0003 (0.0001)
Year 2017	-0.135 (0.189)	1.350 (0.377)***
Year 2018	0.083 (0.195)	1.055 (0.377)***
Year 2019	0.057 (0.190)	0.871 (0.370)***
Year 2020	-0.077 (0.210)	1.275 (0.400)***
Year 2021	-0.221 (0.225)	1.927 (0.421)***
Residual		-0.482(0.665)
IV	5.294 (0.68)***	
Constant	-2.462 (0.607)***	4.468 (0.923)***
Observations	1214	1214

Notes: ***p < 0.01, **p < 0.05, *p < 0.1.
Robust standard errors are presented in parentheses. The reference year is 2016.
Source: author's own calculations, based on NFS data or using the NFS data