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How limiting is finance for Dutch dairy farms? A dynamic profit analysis

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Abstract

Accessibility to financial resources is considered a prevalent problem in the agricultural sector. We develop an approach to quantify the long-term opportunity costs of financial constraints in relation to peers who do not face any financial constraints. Using data on past financial performance, we assess creditworthiness and the size of an additional accessible bank loan to farmers. Combining this with data on reported expenditure, we determine the accessible finance. We quantify the opportunity cost as the forgone dynamic profit (intertemporal profit in current-value terms) from financial constraints. Using data envelopment analysis, we apply our approach to 264 specialised Dutch dairy farms for the years 2006–2017 and explore the potential impact of changes in finance provision for several scenarios. Our results show an increasing gap between frontrunners and other farmers, as the latter generate progressively less dynamic profit in comparison to their best peers. The gap between the dynamic profit of the average farm and that of its best peers from their production and investment decisions made over the span of 1 year grew from €40,040 in 2009 to €114,548 in 2017. However, the growth is not driven by insufficient access to finance. Financial constraints can only explain 6% of the forgone dynamic profit in 2009 and as little as 1% for 2017. The number of farms classified as financially constrained in comparison to their peers decreases in our sample from 44% in 2009 to 8% in 2017. This suggests that non-financial factors are driving the growing gap.

KEYWORDS

dairy farms, efficiency, farm management, finance and credit, Netherlands

JEL CLASSIFICATION
D22, M21, Q12, Q14

1 | INTRODUCTION

Financial services are essential for agricultural production by enabling farmers to invest and to bridge periods with lower earnings. To increase productivity and stay competitive, farmers need to make investments to mechanise and modernise farm operations (Barry & Robison, 2002). Between 2009 and 2019, farms in the European Union reinvested on average 25% of their gross farm income, which led to an increase of 41% in the value of farm buildings, machinery, livestock, and permanent crops (own calculations; European Commission, 2022). Failure to buy costly inputs and make investment can suppress farm profits in the short and long run (World Bank, 2008) and thus threaten their economic viability. Financial constraints that limit farmers' ability to purchase costly inputs and make investments comparable to their peers can make their farms uncompetitive in the long run.

A study by the European Commission and European Investment Bank revealed that in 2017, 10.4% of surveyed farms in the European Union experienced difficulties in accessing finance for working capital, while 12% encountered challenges accessing finance for investment (Fi-compass, 2020a). In the Netherlands, these figures were even higher, with 12% of farms struggling to access finance for working capital and 15% facing difficulty accessing finance for investment (Fi-compass, 2020b). Compared to greenhouse horticulture businesses and pig and poultry farms, Dutch dairy farms generally have more land, which can serve as collateral for accessing finance. This increased collateral potentially places them in a better position to access finance.

Bank loans are the most important source of finance for Dutch farmers (Fi-compass, 2020b). Family loans, equity financing, and leasing are less common, but are still used by some farmers. Multiple factors make it difficult for Dutch dairy farmers to access finance. A considerable proportion of dairy farm households earn less than the national low-income threshold (from farm business and other non-farming activities). In 2019, 2020 and 2021, 25%, 37% and 30% of households respectively fell below this threshold (ca. €27,000), indicating a challenging economic situation for many in the sector (Wageningen Economic Research, 2022). As a result, finance providers may not be confident that these farms will be able to repay any loans, though the collateral of the herd, and in some cases the land may have offset these low earnings in the past.

Additionally, in the years leading up to and following the abolition of milk quotas, some farmers made significant investments to expand production. With a high proportion of earnings committed to repaying old loans, farmers have less cash flow available to repay new loans. Furthermore, the Basel III and upcoming IV regulations are changing the way creditworthiness of farms is assessed (Basel Committee on Banking Supervision, 2017). Basel III and IV are a set of regulatory standards that aim to strengthen the banking sector's resilience and risk management following the 2008 financial crisis. Instead of relying on sufficient collateral, the emphasis changed towards profitability and liquidity (van der Meulen et al., 2020). For the agricultural sector, this is challenging due to tight and fluctuating profit margins and policy uncertainty. Loans to dairy farms are classified as 'risky' despite the herd and the land that can serve as collateral (van der Meulen et al., 2020). Additionally, banks are reducing the maturity period of loans, which increases the risk for farmers as they need to refinance their loans at the end of the maturity period (van der Meulen et al., 2020). The Dutch banking association stated in a letter to parliament that the stricter banking regulations will make it difficult for Dutch farmers to access finance (NVB, 2020).

In this context, we develop a method to determine to what extent lack of access to finance limits production and profit in the Dutch dairy sector. Our objective is to quantify the financial constraints of Dutch dairy farms and their potential impact on profit in the long run.

Past research has focused on the potential short-run impact of insufficient finance to purchase variable inputs (e.g., Ciaian et al., 2012; Fletschner et al., 2010; Kumbhakar & Bokusheva, 2009; Smith et al., 2011). Färe et al. (1990) determined the opportunity costs in terms of forgone *static* profit from financial constraints by benchmarking farms using a frontier approach. The optimal levels of input use and resulting static profit are determined for each farm with and without a finance constraint, with the difference between the two representing the opportunity cost of the financial constraint. This method assumes that farmers intend to maximise static profit in a given time period, but that insufficient accessible finance limits their ability to purchase variable inputs. Inputs are categorised as variable (instantly adjustable) or fixed (not adjustable within the time period). The crucial limitation of the static approach is that it ignores the intertemporal linkages of farmers' decisions to maximise long-term profit and the adjustment costs associated with investments. A more realistic assumption is that farmers intend to maximise profits over time, and while they make production and investment decisions in a given time period, they will do so with a long-term perspective.

In the *dynamic* approach, some inputs are additionally categorised as quasi-fixed (that is, adjustable through investment).[1] According to adjustment-cost theory, investments in quasi-fixed inputs increase future productivity and profitability but are associated with adjustment costs. Variable inputs that could otherwise be used for production are diverted towards investments, for example in training, reorganisation of production processes, administration, procurement, and installation (Dakpo & Oude Lansink, 2019). Additionally, inventory, permanent vegetation and animal herd size are sluggishly adjusted over time leading to lower investment returns in the short run. Finally, farmers experience a learning curve (as found by Geylani & Stefanou, 2013). In order to be consistent, we henceforth use the term 'dynamic profit' to describe the intertemporal profit in current-value terms.

Estimating accessible finance is difficult because of the various sources of equity and debt finance available to farmers (Blancard et al., 2006). Briggeman et al. (2009) and Fletschner et al. (2010) surveyed farmers and asked them to estimate the level of accessible finance. Surveying farmers at a large scale is costly and time intensive. Additionally, this approach is more suitable in a context where farmers' sole accessible finance is their savings, and they cannot borrow from the banks. Farmers themselves are likely not fully informed about their total accessible bank loans unless they have immediate plans to invest and apply for loans. They may thus not be able to provide accurate estimates for a survey. Ciaian et al. (2012) used reported liquidity and Blancard et al. (2006) used reported expenditure to approximate accessible finance. These indicators neglect the fact that farmers may have access to more financial resources, but underspend from a perspective of dynamic profit maximisation. Possible reasons include risk aversion, expectations for market or policy developments, market distortions or following other economic and non-economic production objectives.

We make three contributions. First, we assess how limited access to finance affects profit from a dynamic perspective. We do so by extending the static approach of Färe et al. (1990) to the dynamic context of Ang and Oude Lansink (2018) and Silva et al. (2020). In contrast to the static approach, the dynamic approach appropriately considers the limiting factor of finance on investment decisions, the intertemporal linkages of production and investment decisions, and adjustment costs, assuming dynamic profit-maximising behaviour. Second, we develop a method to estimate accessible finance to farms that reflects the famers' ability to take out bank loans and borrow money from friends and family, which recognises that farmers may underspend. We estimate the accessible finance to farms by combining reported expenditures and data on past financial performance from accountancy data. Third, we apply this approach under multiple scenarios.

[1]We follow the terminology used in efficiency literature, which deviates from the terminology used in accounting literature.

2 | MODEL

Our model builds on Färe et al. (1990), in which profit is maximised subject to a technology with and without a financial constraint. The opportunity cost of the added constraint is the difference in profit levels. We extend their static approach to the dynamic context and determine the maximum dynamic profit for a technology with and without a financial constraint.

We develop a dynamic financial inefficiency model rooted in adjustment-cost theory. We start by introducing the adjustment-cost technology $\mathcal{T}_t$, as defined by Ang and Oude Lansink (2018) and Silva et al. (2020). Let $\boldsymbol{x}_t \in \mathbb{R}_+^m$, $\boldsymbol{K}_t \in \mathbb{R}_+^n$ and $\boldsymbol{L}_t \in \mathbb{R}_+^o$ be, respectively, a vector of variable, quasi-fixed and fixed inputs that are used to produce a vector of outputs $\boldsymbol{y}_t \in \mathbb{R}_+^q$ at time t. The level of variable inputs can be changed instantaneously. The level of quasi-fixed inputs can be changed through investments $\boldsymbol{I}_t \in \mathbb{R}_+^n$, while the level of fixed inputs $\boldsymbol{L}_t$ cannot be changed in a given period. The adjustment-cost technology is defined as follows:

$$\mathcal{T}_t = \left\{ \left(\boldsymbol{x}_t, \boldsymbol{I}_t, \boldsymbol{y}_t \right) \in \mathbb{R}_+^{m+n+q} \mid \left(\boldsymbol{x}_t, \boldsymbol{I}_t \right) \text{ can produce } \boldsymbol{y}_t \text{ given } \left(\boldsymbol{K}_t, \boldsymbol{L}_t \right) \right\} \tag{1}$$

$\mathcal{T}_t$ is assumed to be a closed, non-empty, bounded, and convex set, satisfying free disposability of variable inputs, quasi-fixed inputs and corresponding investments, fixed inputs, and outputs.

Next, we introduce the *financially constrained* adjustment-cost technology. Whereas Färe et al. (1990) only considered the impact of the financial constraint on the cash expenditure on variable inputs, we extend it to the cash expenditures on variable inputs, fixed inputs and investments. The sum of all cash outflows must be smaller than or equal to the accessible finance. Let $\boldsymbol{w}_t^x \in \mathbb{R}_+^m$ be the price of the variable inputs, $\boldsymbol{w}_t^L \in \mathbb{R}_+^o$ the rental price of the fixed inputs, $\boldsymbol{w}_t^I \in \mathbb{R}_+^n$ the (unit) price of investments and AF_t the accessible finance. The financially constrained adjustment-cost technology is defined as follows:

$$\mathcal{T}_t^c = \left\{ \left(\boldsymbol{x}_t, \boldsymbol{I}_t, \boldsymbol{y}_t \right) \in \mathcal{T}_t, \boldsymbol{w}_t^{x\prime} \boldsymbol{x}_t + \boldsymbol{w}_t^{L\prime} \boldsymbol{L}_t \boldsymbol{w}_t^{I\prime} \boldsymbol{I}_t \leq AF_t \right\} \tag{2}$$

Note that $\mathcal{T}_t^c \subseteq \mathcal{T}_t$, which makes the limiting impact of lack of accessible finance explicit. Following adjustment-cost theory, farmers make production plans to maximise dynamic profit. Investments decrease profit in the short run but increase it in the long run. Farmers weigh the initial adjustment costs against the discounted future returns on investment. Financially constrained farmers additionally weigh the returns from spending on variable inputs to produce more in time t against spending on investments to earn more in the future. We assume that the farmers are price-takers, facing competitive input, output and capital markets. Lastly, we assume static expectations on discount and depreciation rates.

The maximum dynamic profit subject to the adjustment-cost technology and equation of motion (that is, that changes in capital are equal to the sum of net investments minus depreciation) can be calculated as the solution to:

$$W\left(\mathcal{T}_t\right) = \max_{\boldsymbol{y}_t, \boldsymbol{x}_t, \boldsymbol{I}_t} e^{-rt} \int_t^{\infty} \left[\boldsymbol{p}_t{}' \boldsymbol{y}_t - \boldsymbol{w}_t^{x\prime} \boldsymbol{x}_t - \boldsymbol{c}_t{}' \boldsymbol{K}_t - \boldsymbol{w}_t^{L\prime} \boldsymbol{L}_t \right] \mathrm{d}t \tag{3a}$$

s.t.

$$\frac{\mathrm{d}\boldsymbol{K}_t}{\mathrm{d}t} = \boldsymbol{I}_t - \boldsymbol{\delta}' \boldsymbol{K}_t \tag{3b}$$

$$\left(\boldsymbol{x}_t, \boldsymbol{y}_t, \boldsymbol{I}_t \right) \in \mathcal{T}_t \tag{3c}$$

where W is the dynamic profit function, r the discounting rate, $\boldsymbol{p}_t$ the vector of output prices, $\boldsymbol{y}_t$ the vector of output quantities, $\boldsymbol{w}_t^x$ the vector of variable input prices and $\boldsymbol{x}_t$ the vector of input quantities. Further, $\boldsymbol{c}_t$ is the rental price of quasi-fixed inputs, $\boldsymbol{K}_t$ a vector of quasi-fixed inputs, $\boldsymbol{w}_t^L$ a vector of rental prices of fixed inputs, $\boldsymbol{L}_t$ a vector of fixed inputs and finally δ is the vector of depreciation rates of the quasi-fixed inputs. The change in the stock of quasi-fixed inputs $\boldsymbol{K}_t$, is composed of the investments $\boldsymbol{I}_t$ minus the depreciation $\boldsymbol{\delta K}_t$.

The production and investment decisions of farmers at time t are represented by the choice variables $\boldsymbol{y}_t$, $\boldsymbol{x}_t$ and $\boldsymbol{I}_t$. The marginal increase in dynamic profit through one unit increase in quasi-fixed inputs $\boldsymbol{K}$ is specified by the shadow price of the investments.

The current-value formulation of Equation (3) is:

$$rW(.\,|\mathcal{T}_t) = \max_{\boldsymbol{y}_t, \boldsymbol{x}_t, \boldsymbol{I}_t} \left\{ \boldsymbol{p}_t{}' \boldsymbol{y}_t - \boldsymbol{w}_t^{x}{}' \boldsymbol{x}_t - \boldsymbol{c}_t{}' \boldsymbol{K}_t - \boldsymbol{w}_t^{L}{}' \boldsymbol{L}_t + \boldsymbol{W}_t^K(.)' \left(\boldsymbol{I}_t^K - \boldsymbol{\delta K}_t \right) \right\} \tag{4a}$$

s.t.

$$\left(\boldsymbol{x}_t, \boldsymbol{y}_t, \boldsymbol{I}_t \right) \in \mathcal{T}_t \tag{4b}$$

where rW is the dynamic profit of time t and $\boldsymbol{W}_t^K(.)$ is the vector of the shadow prices of capital. Dynamic profit inefficiency is computed as the difference between maximum and observed dynamic profit. It is the forgone dynamic profit from suboptimal production and investment decisions and reflects the forgone profit from production at time t and the forgone discounted future profit from investments made at time t.

$$PI(.\,|\mathcal{T}_t) = rW(.\,|\mathcal{T}_t) - \left[\boldsymbol{p}_t{}' \boldsymbol{y}_t - \boldsymbol{w}_t^{x}{}' \boldsymbol{x}_t - \boldsymbol{c}_t{}' \boldsymbol{K}_t - \boldsymbol{w}_t^{L}{}' \boldsymbol{L}_t + \boldsymbol{W}_t^K(.)' \left(\boldsymbol{I}_t^K - \boldsymbol{\delta K}_t \right) \right] \tag{5}$$

Without loss of generality, Equations (3)–(5) can also be established subject to the adjustment-cost technology with a financial constraint. Dynamic financial inefficiency is computed as the maximum dynamic profit subject to the technology *without* a financial constraint minus the maximum constrained dynamic profit subject to the technology *with* a financial constraint. It is the forgone dynamic profit from suboptimal production and investment decisions in time t due to financial constraint. Again, it reflects the forgone profit from production in time t and the forgone discounted future profit from investments made in time t.

$$FI = rW(.\,|\,\mathcal{T}_t) - rW(.\,|\,\mathcal{T}_t^c) \tag{6}$$

An illustrative example of the concept of dynamic financial inefficiency is shown in Figure 1. Figure 1a shows the concept for the static context of Färe et al. (1990), which is also consistent with the dynamic context. We further expand the Figure 1b,c to illustrate the dynamic context. Suppose that there are six observations of farms *A, B*, *C*, *D*, *E* and *F*. Farms *A*, *B*, *C*, *D* and *E* indicate the outer bounds of the adjustment-cost technology, while production of farm *F* lies within the frontier. The lines *h*, *i* and *j* are the dynamic iso-profit lines of different profit levels. To maximise dynamic profit, farm *F* should produce at point *D* to generate dynamic profit *h*. When introducing a limit in accessible finance, farm *F* can only produce at point *C* and thus only generate dynamic profit *i*. The difference in dynamic profit between point *F* and point *C* is the opportunity cost of the financial constraint, in other words the dynamic financial inefficiency. All farms use the same production technology, but because of the financial constraint farm F can only access a subset of production (shaded area) as opposed to its peers.

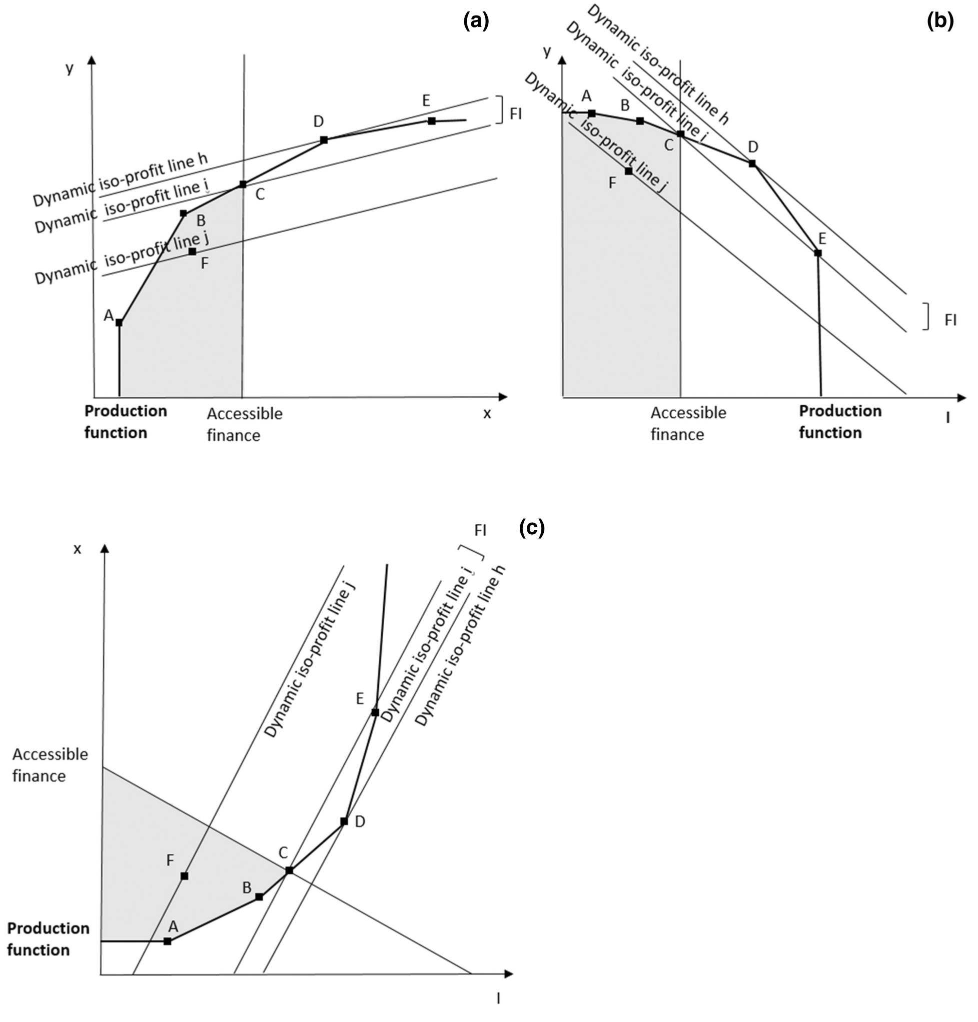

FIGURE 1 An illustration of dynamic profit inefficiency and dynamic financial inefficiency. The shaded area shows the attainable production possibility set with a financial constraint. Dynamic profit is maximised where the dynamic iso-profit line is tangent to the production possibility set. (a) illustrates this for the input–output dimension, (b) for the investment-output dimension and (c) for the output-investment dimension.

3 | EMPIRICAL APPROACH

3.1 | Data

From the Farm Accountancy Data Network, we obtained unbalanced yet stratified data of 264 conventional, specialised dairy farms in the Netherlands covering the time period 2006 to 2017. The dataset contains farm-level financial data (total agricultural income, value of farm business, solvency and investments) and physical production data (quantities of inputs and outputs). Inputs and outputs are aggregated using chained Törnqvist price indices with 2006 as base year. We distinguish between fixed inputs (treated as constant over the time span of 1 year), quasi-fixed inputs (levels can be changed through investments and disinvestments but with associated adjustment costs) and variable inputs (levels can easily be changed without adjustment costs). As most labour on Dutch dairy farms is either done by the family and long-term employees or outsourced, we consider family and hired labour as fixed and contract work as variable input. Farmers generally breed their own milking cows and do not purchase animals and thus progressively adjust their herd size over the span of several years. We therefore treat animals as a fixed input. The adjustment costs associated with expanding or decreasing the herd size are captured in the adjustment costs of the buildings and the milk quota. We treat buildings, machinery and land as quasi-fixed inputs and milk quota as a constraint, which can be increased through investment. We aggregate several variable inputs by purchase value: seeds and planting materials, purchased feed, pesticides, fertiliser, energy, veterinary costs, contract work and costs of renting machinery. We aggregate the quasi-fixed inputs of buildings and machinery by their economic value. The outputs are milk, constrained by the milk quota, the sale of cattle, and the sale of other agricultural outputs (this includes crops, vegetables, flowers and bulbs, eggs, poultry, sheep and pigs aggregated by purchase value). We distinguish three fixed inputs (family labour, hired labour and number of cows), two quasi-fixed inputs with corresponding investments (land and an aggregate value of buildings and machinery), one variable input and three outputs (milk, sold cattle, other). For the period of 2009–2014, we include milk quota.

Prices, price indices and interest rates are drawn from the Eurostat database (Eurostat, 2019) and the Agrimatie database (Wageningen Economic Research, 2020). Information on the average annual Dutch household expenditure is drawn from the Eurostat database (Eurostat, 2019); average wage costs are drawn from Statline (Centraal Bureau voor de Statistiek, 2021). Using the fat percentage per kilogramme of milk obtained from the *Kwantitatieve Informatie Veehouderij* (Blanken et al., 2016), we convert quota prices expressed per kilogramme of milk fat to prices per kilogramme of raw milk. Table 1 provides the summary statistics of the data.

3.2 | Estimating dynamic profit inefficiency and dynamic financial inefficiency

Dynamic profit inefficiency is calculated as the difference between maximum and observed dynamic profit subject to the same adjustment technology. Dynamic financial inefficiency is calculated as the difference in maximum dynamic profit computed subject to the same adjustment technology, with and without a financial constraint.

We operationalise our theoretical model employing Data Envelopment Analysis (DEA). To account for interannual changes in weather, technology, and policy and market environment, we run the DEA for each year. The dynamic profit inefficiency and dynamic financial inefficiency respectively represent the dynamic profit forgone from suboptimal production within a given year, as well as discounted future profit forgone from missed investments in that year. To account for structural differences across farms that affect the maximum dynamic profit generated in a given year, we hold some variables fixed and quasi-fixed. The milk quota system has been operational until 2015. Therefore, we included an output constraint for the years until 2015. The production model and classification into variable, fixed and quasi-fixed inputs, outputs investments and constraints is illustrated in Figure 2.

We employ a restricted dynamic profit function, in which fixed input costs are deducted from the total dynamic profit function. This does not affect the optimal values of the choice variables. The maximum dynamic profit and allocation of inputs, outputs and investment with a financial constraint for farm j belonging to the sample of $i = 1, \ldots, N$ farms for year t is computed by solving the following linear programming problem:

TABLE 1 Descriptive statistics.

Variable (measured annually)	Unit	Sample averages in 2009	Average annual growth rate
Total agricultural income	Euro	13,858	61.8%[a]
Value of farm business	Euro	3,598,680	4.5%
Solvency	Percentage	61	0.6%
Investment in buildings and machinery[b]	Euro	92,665	0.5%
Investment in land[b]	Hectare	1.33	12.3%
Investment in milk quota[b]	Kg	31,283	−14.4% (until 2015)
Family labour	Hours	3618	1.6%
Hired labour	Hours	189	19.3%
Number of cows	Livestock unit[c]	137	4.2%
Land used	Hectare	60	3.5%
Value of buildings and machinery	Euro	451,520	5.8%
Variable input use	Euro	107,812	6.7%
Milk production	Kg	824,510	7.0%
Revenues of selling cattle	Euro	23,370	10.9%
Revenues of other agricultural activities	Euro	7904	9.7%
Inflation-adjusted price index of buildings and machinery	-	1.1	1.1%
Inflation-adjusted price of land	Euro/Hectare	47,051	4.6%
Inflation-adjusted price of milk quota	Euro/Kg	0.84	−19.8%
Inflation-adjusted wage costs	Euro/Hours	20	1.8%
Inflation-adjusted milk price	Euro/Kg	0.28	5.6%
Inflation-adjusted price index of variable inputs	-	1.1	1.4%
Inflation-adjusted price index selling cattle	-	0.9	2.0%
Inflation-adjusted price index of other agricultural activities	-	0.9	4,2%
Inflation-adjusted interest rate	-	0.04	−14.2%

[a]The high annual growth rate of the agricultural income is driven by an exceptionally low income in 2009 and exceptionally high income in 2017.

[b]Cash outflows of purchase corrected for sales. Investments plus disinvestments.

[c]Livestock unit is a reference system to aggregate livestock of different categories and age based on feeding requirements. Milking cows are equal to 1.0 unit, heifers above the age of 2 are equal to 0.7 unit, those under the age of 2 are equal to 0.5 unit and calves are equal to 0.3 unit.

$$r_t W_{jt} = \underbrace{Max}_{y^1_{jt}, \boldsymbol{y}^2_{jt}, x^O_{jt}, I^K_{jt}, I^Q_{jt}, I^L_{jt}, \lambda_{it}} \quad p^1_t y^1_{jt} + \boldsymbol{p}^{2\prime}_t \boldsymbol{y}^2_{jt} - w^O_t x^O_{jt} + W^K_{jt}(.)\left(I^K_{jt}\right) + W^L_{jt}(.)\left(I^L_{jt}\right) + W^Q_{jt}(.)\left(I^Q_{jt}\right) - \sigma_{jt} \tag{7a}$$

s.t.

$$\sum_{i=1}^{N} \lambda_{it} y^1_{it} \geq y^1_{jt} \tag{7b}$$

$$\sum_{i=1}^{N} \lambda_{it} \boldsymbol{y}^2_{it} \geq \boldsymbol{y}^2_{jt} \tag{7c}$$

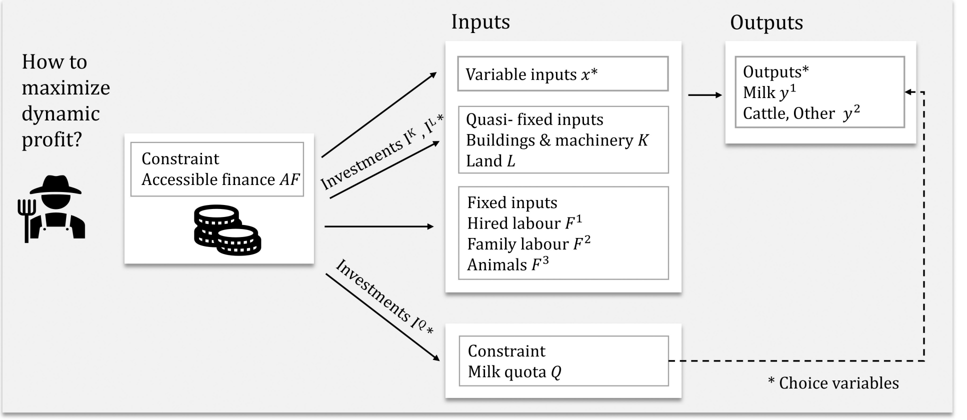

FIGURE 2 Objective function and production and investment decisions embedded in the empirical model.

$$\sum_{i=1}^{N} \lambda_{it} x_{it}^{O} \leq x_{jt}^{O} \tag{7d}$$

$$\sum_{i=1}^{N} \lambda_{it} L_{it} \leq L_{jt} \tag{7e}$$

$$\sum_{i=1}^{N} \lambda_{it} K_{it} \leq K_{jt} \tag{7f}$$

$$\sum_{i=1}^{N} \lambda_{it} F_{it}^{1} \leq F_{jt}^{1} \tag{7g}$$

$$\sum_{i=1}^{N} \lambda_{it} F_{it}^{2} \leq F_{jt}^{2} \tag{7h}$$

$$\sum_{i=1}^{N} \lambda_{it} F_{it}^{3} \leq F_{jt}^{3} \tag{7i}$$

$$\sum_{i=1}^{N} \lambda_{it} I_{it}^{K} \geq I_{jt}^{K} \tag{7j}$$

$$\sum_{i=1}^{N} \lambda_{it} I_{it}^{Q} \geq I_{jt}^{Q} \tag{7k}$$

$$\sum_{i=1}^{N} \lambda_{it} I_{it}^{L} \geq I_{jt}^{L} \tag{7l}$$

$$Q_{jt} + I_{jt}^{Q} \geq y1_{jt} \tag{7m}$$

$$w_t^{IK} \times I_{jt}^{K} + w_t^{IQ} \times I_{jt}^{Q} + w_t^{IL} \times I_{jt}^{L} + w_t^{O} x_{jt}^{O} + w_t^{F1} F_{jt}^{1} \leq AF_{jt} \tag{7n}$$

$$\sum_{i=1}^{N} \lambda_{it} = 1 \tag{7o}$$

$$\lambda_{it} \geq 0 \tag{7p}$$

where the variables are defined as in Table 2. Figure 2 shows that the choice variables are variable inputs, outputs and investments in quasi-fixed inputs and milk quota. We distinguish between quasi-fixed inputs that depreciate (buildings and machinery labelled K in Figure 2; Equation 7) and that do not depreciate (land labelled L in Figure 2; Equation 7). We further distinguish fixed inputs *with* a cash outflow (wages of hired workers labelled F^1 in Figure 2; Equation 7) and *without* a cash outflow that do not draw on the accessible finances (family labour labelled F^2 and animals labelled F^3 in Figure 2; Equation 7). The constraints (7b)–(7k) determine the adjustment-cost technology. The constraint (7l) ensures that optimised milk production does not exceed the limitations set by the milk quota rights. Constraint (7n) ensures that all expenditures for optimised levels of variable inputs, fixed inputs and investments do not exceed the level of accessible finance.

Equation (8) shows that the fixed costs are: (a) depreciation of machinery and buildings, and milk quota; (b) opportunity costs of holding onto the assets machinery and buildings, milk quota, land and animals; (c) the depreciation of net investment into machinery and buildings, and milk quota; and (d) the opportunity costs of family labour as well as the costs of hiring labour. We determine the shadow prices for net investment in machinery and buildings, and milk quota and therefore subtract as a lump sum the shadow price multiplied by the depreciation after optimisation of investments. Here, δ is the depreciation rate and r is the discounting rate, equal to the interest rate that farmers would receive from banks if they sold their assets and stored the money in their bank accounts. Buildings and machinery depreciate as their functionality wears off with use and better technology becomes available over time. Milk quota also depreciates due to a drop in the market price in anticipation of the abolishment of the milk quota system.

$$\begin{aligned}\sigma_{jt} = &\left(\delta^{K} + r_t\right) c_t^{K} K_{jt} + \left(\delta^{Q} + r_t\right) c_t^{Q} Q_{jt} + r_t c_t^{L} L_{jt} + r_t\, c_t^{F3} F_{jt}^{3} \\ &+ W_{jt}^{K}(.)\left(\delta^{K} K_{jt}\right) + W_{jt}^{Q}(.)\left(\delta^{Q} Q_{jt}\right) + w_t^{F1} F_{jt}^{1} + w_t^{F2} F_{jt}^{2}\end{aligned} \tag{8}$$

3.3 | Estimating accessible finance to farms

So far, we have not elaborated on the determination of the accessible finance, defined in Equation (7m). Finance accessible to farms consists of liquid assets, loans from banks and loans

TABLE 2 Variables used in the empirical model.

Variable	Explanation
r	Discounting rate
W	Dynamic profit
y^1	Milk
p^1	Milk price
y^2	Cattle for sale, aggregation of other agricultural output
p^2	Unit price for cattle and aggregated unit price of other agricultural output
x^O	Variable input
w^O	Unit price of aggregated input
I^K	Investment in capital
$W^K(.)$	Shadow price of net investment in capital
I^L	Investment in land
$W^L(.)$	Shadow price of investment in land
I^Q	Investment in quota
$W^Q(.)$	Shadow price of net investment in quota
σ	Fixed costs
L	Land
K	Capital
F^1	Hired labour
F^2	Family labour
F^3	Number of animals
Q	Quota
w^{IK}	Unit price of investment in capital
w^{IQ}	Unit price of investment in quota
w^{IL}	Unit price of investment in land
λ	Intensity weight
δ^K	Depreciation rate of capital
c^K	Capital rental rate
δ^Q	Depreciation rate of quota
c^Q	Quota rental rate
c^L	Land rental rate
c^{F2}	Wages and unit price of animals
w^{F1}	Wages

from family members and friends. We use a mixed approach that combines information on the size of accessible bank loans with information on reported expenditures. Our approach is illustrated in Figure 3. We simulate creditworthiness assessments to estimate the size of the accessible bank loan. We employ two criteria: (1) the loan cannot exceed the anticipated ability to repay, and (2) the solvency cannot drop below 30%. The solvency is the ratio of equity to the value of the farm:

$$Solvency_t = \frac{E_t}{A_t} \tag{9}$$

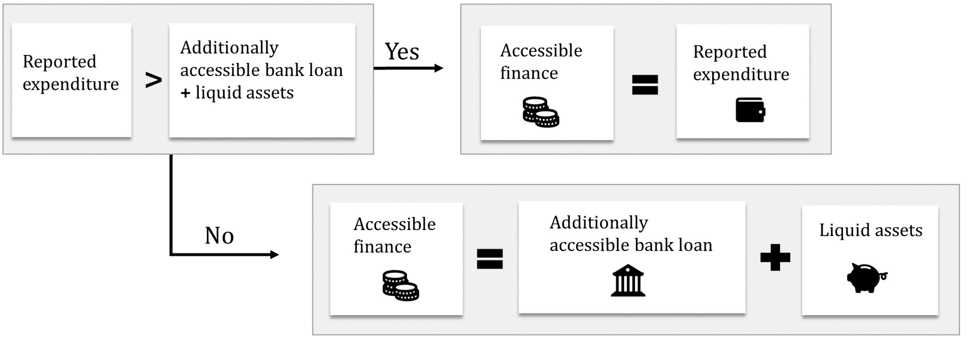

FIGURE 3 Illustration of the base model to estimate accessible finance to farms.

where E_t is the value of equity and A_t the value of total assets, both at time t. The anticipated ability to repay is computed for an annuity payment scheme taking into consideration historic net cash flow from on-farm and off-farm activities, household expenditure, the loan maturity period and interest rate.

$$\begin{aligned} Net\ cash\ flow_t = {} & total\ income_t + depreciation_t - taxes_t - household\ expenditure_t \\ & * number\ of\ households_t - loan\ repayment_t \end{aligned} \tag{10}$$

where $loan\ repayment_t$ is calculated as 8% of long-term debts at time t.

$$Ability\ to\ repay = \frac{\frac{1}{3} * \left(Net\ cash\ flow_{t-1} + Net\ cash\ flow_{t-2} + Net\ cash\ flow_{t-3} \right)}{Annuity\ factor} \tag{11}$$

We apply a loan maturity period of 20 years and interest rates set at the long-term government bond rate.

$$Annuity\ factor = \frac{r}{1 - (1 + r)^{-t}} \tag{12}$$

where r is the interest rate and t the number of years.

We also use data on reported expenditures to account for loans that farmers take out with family and friends. Farm accountancy data do not reveal information on the opportunities to make loans. We employ the reported expenditures as proxies for the loans taken out from family and friends. This is followed by an estimation of the total accessible finance as the larger number of the two (that is, bank loan plus liquid assets *or* reported expenditure).

The method illustrated in Figure 3 serves as the base model. We further estimate the accessible finance using only reported expenditure as a proxy to show the added value of our mixed approach, making adjustments to the base model to simulate scenarios. We simulate three scenarios that affect the level of the finance accessible to farms. The *Basel IV scenario* simulates the introduction of stricter conditions on bank loans to farms, similar to what might happen when Basel IV becomes operational in 2023. We make two adjustments to the method of the base model. First, we reduce the maturity period from 20 to 15 years, and second, we make a more risk-averse estimation of the ability to repay. We multiply the historic three-year average of on- and off-farm income by the factor 0.8 to simulate how banks hedge against future market and production risks.

The *Only on-farm net cash flow scenario* investigates the dependence of farm businesses on off-farm income from family members. Although not necessarily simulating potential future developments, this represents a situation in which banks only consider on-farm net cash flow in their assessment of creditworthiness. Adjusting the method of the base model, we exclude off-farm income in the estimation of the ability to repay.

Lastly, the *Low interest rate scenario* simulates a policy intervention that reduces interest rates for farms in order to increase their accessible finance. The real interest rate has changed from 4% in 2009 to 0.5% in 2017. We adjust the method of our base model by reducing the interest rate to 0.5% for the overall time period.

3.4 | Estimating shadow prices of quasi-fixed inputs

The shadow prices of the quasi-fixed inputs reflect the increase in dynamic profit by a unit increase in quasi-fixed inputs. To estimate the shadow prices, we approximate a production frontier through frontrunner farms (the best peers according to a set of benchmarking constraints). Assuming those best peers produce at the point of dynamic profit maximisation subject to the adjustment-cost technology, we can determine the shadow prices knowing the quantities y and price p of outputs and quantities of net investments NI. Using a linear programming procedure in line with Aigner and Chu (1968), we approximate a dynamic directional distance function by a quadratic functional form. Following Ang and Kerstens (2023), we adapt the approximation of the static directional distance function (see, for example, Färe et al., 2005 and Ang & Kerstens, 2020) to the dynamic context. The shadow prices are determined by exploiting the dual relationship between the dynamic directional distance function and the dynamic profit function. The estimated dynamic directional distance function represents the same adjustment-cost technology as in the dynamic profit maximisation function in Equation (7), except that we aggregate several variables to avoid dimensionality issues. The directional vectors g^x, g^y and $\boldsymbol{g^I}$ are equal to average sample quantities of variable inputs x, outputs y, and of gross investments $\boldsymbol{I}$, respectively. We introduce a time trend to account for technical change.

The quadratic functional form of farm j belonging to the sample of $i=1, \ldots, N$ farms for time t is:

$$D_t\left(x_{jt}, y_{jt}, L_{jt}, \boldsymbol{NI}_{jt}; \left(g^x, g^y, 0, \boldsymbol{g^I}\right)\right) = a^0 + a x_{jt} + b y_{jt} + c L_{jt} + \sum_{f=1}^{3} d^f NI_{jt}^f + \frac{1}{2}\alpha x_{jt}^2 + \frac{1}{2}\beta y_{jt}^2 + \frac{1}{2}\gamma L_{jt}^2 + \frac{1}{2}\sum_{f=1}^{3}\sum_{g=1}^{3}\delta^{fg} NI_{jt}^f NI_{jt}^g + \varepsilon x_{jt} y_{jt} + \theta x_{jt} L_{jt} + \sum_{f=1}^{3}\vartheta^f x_{jt} NI_{jt}^f + \mu y_{jt} L_{jt} + \sum_{f=1}^{3}\pi^f y_{jt} NI_{jt}^f + \sum_{f=1}^{3}\rho^f L_{jt} NI_{jt}^f + a^{time}(t-2009) \tag{13}$$

which is solved by the following linear programming problem:

$$\min_{e_{kt}\geq 0, a^0, a, b, c, d, \alpha, \beta, \gamma, \delta, \varepsilon, \theta, \vartheta, \mu, \pi, \rho} \sum_{k=1}^{K} e_{jt} \tag{14a}$$

s.t.

$$e_{jt} = (13)\forall j = 1, \ldots J \tag{14b}$$

$$\delta^{fg} = \delta^{gf} \tag{14c}$$

$$b g^y + d g^I - a g^x = -1 \tag{14d}$$

$$-\alpha g^{x}+\varepsilon g^{y}+\vartheta g^{I}=0 \tag{14e}$$

$$\beta g^{y}-\pi g^{I}-\varepsilon g^{x}=0 \tag{14f}$$

$$\delta g^{I}-\pi g^{y}-\vartheta g^{x}=0 \tag{14g}$$

$$\frac{\partial D_t\left(x_{jt},y_{jt},L_{jt},NI_{jt};\left(g^{x},g^{y},0,g^{I}\right)\right)}{\partial x_{jt}}\geq 0 \quad \forall j=1,\ \dots ,J \tag{14h}$$

$$\frac{\partial D_t\left(x_{jt},y_{jt},L_{jt},NI_{jt};\left(g^{x},g^{y},0,g^{I}\right)\right)}{\partial y_{jt}}\leq 0 \quad \forall j=1,\ \dots ,J \tag{14i}$$

$$\frac{\partial D_t\left(x_{jt},y_{jt},L_{jt},NI_{jt};\left(g^{x},g^{y},0,g^{I}\right)\right)}{\partial L_{jt}}\geq 0 \quad \forall j=1,\ \dots ,J \tag{14j}$$

$$\frac{\partial D_t\left(x_{jt},y_{jt},L_{jt},NI_{jt};\left(g^{x},g^{y},0,g^{I}\right)\right)}{\partial I_{jt}}\leq 0 \quad \forall j=1,\ \dots ,J \quad \forall I=1,\ \dots ,3 \tag{14k}$$

Using Equations (14i) and (14k), we determine the farm-specific shadow prices of the net investments in the fth quasi-fixed input $\nabla_{NIt}\ W_{jt}^{f}(.)$:

$$\nabla_{I_{jt}}\ W_{jt}^{f}(.)=p\ \frac{d^{f}+\sum_{f=1}^{3}\delta^{fg}NI_{jt}{}^{g}+\vartheta^{f}x_{jt}+\pi^{f}y_{jt}+\rho^{f}L_{jt}}{b+\beta y_{jt}+\varepsilon x_{jt}+\sum_{f=1}^{3}\pi^{f}NI_{jt}{}^{f}+\mu L_{jt}} \tag{15}$$

This estimation assumes Hicks-neutral technical change. Moreover, the computed Hessian matrix is not negative semi-definite, which indicates the potential violation of the convexity assumption on the adjustment-cost technology. The shadow prices could result in non-optimal allocations of inputs, outputs and investments that do not maximise dynamic profits. In the robustness check, we re-estimate the quadratic dynamic directional distance function per year. In this way, we account for non-Hicks-neutral technical change. An added benefit is that we obtain a Hessian matrix per year. This permits us to check the overall robustness of the results, also for the years that indicate non-convexity of the adjustment-cost technology.

4 | RESULTS

4.1 | Dynamic profit inefficiency is increasing over time

We find a progressively increasing gap in dynamic profit amongst peers. The average dynamic profit inefficiency increases in absolute values over time: in real constant 2009 terms

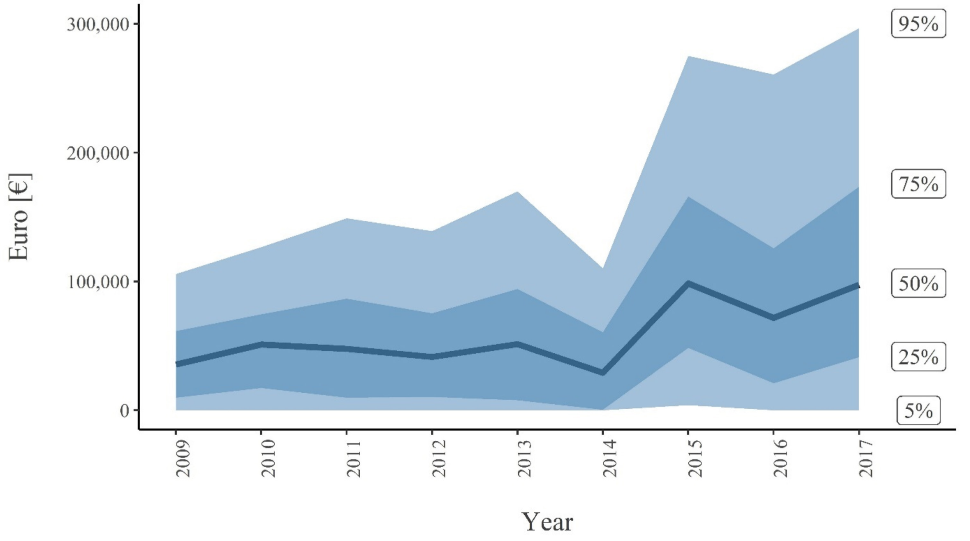

FIGURE 4 Dynamic profit inefficiencies of 264 Dutch dairy farms from 2009 to 2017. The dark line indicates the median farm, the darker shaded area the 25 to 75 percentile range and the lighter shaded area the 5 to 95 percentile range.

from €40,040 in 2009 to €114,547 in 2017, as shown in Figure 4. This trend is more pronounced for the laggards falling furthest behind. The dynamic profit forgone by the 25% least efficient farms increases from a minimum of €61,575 in 2009 to a minimum of €173,705 in 2017. For the 5% least efficient farms, the dynamic profit forgone increases from a minimum of €105,909 in 2009 to a minimum of €296,700 in 2017. In relative terms, the average dynamic profit inefficiency decreases from 2010 onwards (the average dynamic profit in 2009 was negative, making it not possible to express the average dynamic profit inefficiency in 2009 in percentage terms). The average observed dynamic profit of the sample farms is €21,831 in 2010 and €274,787 in 2017. Respectively, the average forgone dynamic profit is 70% and 29% of the maximum attainable dynamic profit (see also Tables A4 and A5 in the Appendix S1).

4.2 | Dynamic financial inefficiency plays only a minor role

Focusing on the share of profit inefficiency that can be ascribed to finance constraints, we find that dynamic financial inefficiency for the full sample is decreasing over time. *Financially constrained* farms have insufficient accessible finance to make the production and investment decisions that maximise dynamic profit given the adjustment-cost technology. Figure 5 shows the average dynamic financial inefficiency for the full sample and for the affected subsample of farms that are financially constrained. It also shows the share of farms classified as financially constrained each year. Average dynamic financial inefficiency across all farms and years is €1964 with a downward trend (€2311 in 2009 and €681 in 2017). The reduction is driven by a decreasing number of farms experiencing financial constraint. The number of such farms decreases from 71 (44%) in 2009 to 12 (8%) in 2017. The average dynamic financial inefficiency across the constrained farms is €6985. This is minor in comparison to the average dynamic profit inefficiency across all farms (€68,136). More detailed results are included in the Appendix S1.

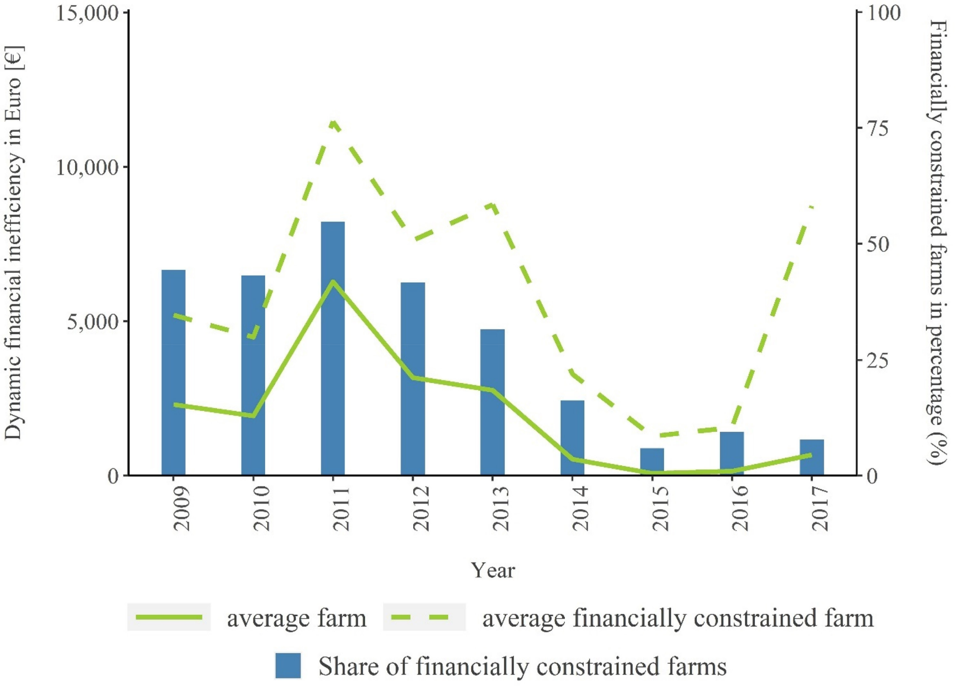

FIGURE 5 Average dynamic financial inefficiency averaged over all farms and over financially constrained farms, and the percentage of farms classified as financially constrained compared to their best peers.

4.3 | Net cash flow is hampering creditworthiness

We find that fewer than half of the farms (42%) in our sample are creditworthy, meaning that they can make additional bank loans. The numbers fluctuate over time without a clear trend. Table 3 provides an overview of financial indicators linked to accessible finance and expenditures. The average net cash flow during the studied period is negative, which puts a major constraint on the size of the bank loans that farms can access. For only 1.2% of farm observations is solvency the constraining factor. By definition, the average accessible finance is larger than the additionally accessible bank loan as farms can also use their savings or borrow money from friends and family. The estimated average accessible finance of farms in our sample is €975,221 between 2009 and 2017; the observed average expenditure is €667,474. The difference between the two parameters, that is, the finance oversupply, fluctuates, but does not follow a clear trend over time.

4.4 | Different scenarios have little impact on share of farmers becoming financially constrained

We estimate the dynamic financial inefficiency, using different methodologies to estimate the accessible finance. All effects are in line with our expectations. In absolute terms, the effect of using reported expenditure as a proxy for accessible finance is large, while the effect of the three scenarios is modest. The results are presented in Table 4. Using reported expenditure as a proxy for accessible finance, as used in several earlier studies on the impact of financial constraints in agriculture, leads to a significant larger share of farms classified as financially constrained (38.4% instead of 28.1% in our base model). Stricter banking regulations after

TABLE 3 Financial indicators linked to accessible finance and expenditure.

Indicators	Averages across the sample/ subsample, measured over the span of one year and averaged for 2009 to 2017
Average net cash flow	–€15.270
Average accessible finance	€975,221
Average additional accessible bank loan (for creditworthy farm)	€794,815
Share of farms creditworthy	42%
Solvency as constraining factor	1.2%
Average finance oversupply	€307,746
Average expenditure	€667,474
Average expenditure on financial obligations	€114,241
Average expenditure on financial obligations as share of overall spending	17%
Average expenditure of farms not deemed creditworthy	€385,620
Share of farms spending more than accessible through banks and savings	24.8%

TABLE 4 Average dynamic financial inefficiency and share of farms classified as financially constrained using different methods to estimate the accessible finance to farms.

Cases	Average dynamic financial inefficiency	Share of farms classified as not creditworthy (%)	Share of farms classified as financially constrained compared to peers (%)
Base model	€1964	57.8	28.1
Reported expenditure	€2757	–	38.4
Basel IV scenario	€2096	57.8	31.0
Only on-farm net cash flow scenario	€1978	58.8	28.5
Low interest rate scenario	€1913	57.8	27.4

the implementation of *Basel IV* will lead to slightly more farms being financially constrained (31.0%) and larger opportunity costs at the sector level. Considering *only on-farm net cash flow* in determining creditworthiness leads to a reduction in accessible finance, a higher average dynamic financial inefficiency and a slight increase in the share of farmers classified as financially constrained compared to their peers (28.5%). The *low interest rate scenario* leads to fewer farms becoming financially constrained (27.4%).

4.5 | Robustness test of shadow prices

The average shadow price of net investment into capital is €0.078 per €1 of value of capital stock, of investment into land is €1816 per hectare of land and of net investment into milk quota is €0.004 per kg of milk quota. As a robustness test of the Hicks neutrality assumption, we also run the quadratic dynamic directional distance function for each year separately and compare outcomes. We should note that this relaxation comes at a cost, as in this case there are fewer observations to span the frontier compared to the number of observations, which may lead to computational problems. We are able to estimate the quadratic dynamic directional distance function with corresponding shadow prices and Hessian matrix for years 2009–2016, but not for year 2017. The Appendix S1, include the full set of results for completeness. In contrast to our main specification, the associated Hessian matrix is negative semi-definite in some years. In all years, the results are quantitatively and qualitatively similar, notwithstanding the semi-definiteness of Hessian matrix. Through the robustness test we are confident in the robustness in the results.

5 | DISCUSSION

Our analysis reveals that Dutch dairy farmers experienced an average dynamic profit inefficiency of €68,136, equal to 40.5%, between 2009 and 2017. Dynamic profit inefficiency is measured as the forgone dynamic profit from suboptimal production and investment decisions with reference to the best peers in the sample. A study conducted by Ang and Oude Lansink (2018) on Belgian dairy farms finds a similar average dynamic profit inefficiency of 40% during the period preceding our study, from 1996 to 2008. However, it is important to note that their model only considered capital investments, whereas our model also covered investments in land and milk quota. By employing a static approach to analyse Dutch dairy farmers within a similar timeframe, Lamkowsky et al. (2021) find a static profit inefficiency of 34% between 2006 and 2017. Although the sample is not exactly the same, there is a strong overlap. The difference between the findings could imply that part of the dynamic profit inefficiency relates to investments. In comparison, Dakpo et al. (2019) identify a higher output inefficiency of 69% amongst French beef farms between 2002 and 2015 using a static approach that considered all inputs as variable. Their study focused on output inefficiency rather than dynamic profit inefficiency.

We further find that the average financial inefficiency of the sample farms between 2009 and 2017 is €2081 or 1.2% of the maximum attainable dynamic profit. In 2009, 44% of the Dutch dairy farms in the sample are financially constrained compared to their best peers, but this number decreases to 8% in 2017. In a similar vein, several previous studies have examined static financial inefficiency in different agricultural contexts. Blancard et al. (2006) find that 67% of 178 French arable farms in a time period of 1994 and 2001 were financially constrained in the short run (financial inefficiency of 8%), while 99.7% are constrained in the long run (financial inefficiency of 49%). Briggeman et al. (2009) find that 5.5% of 5411 US farms are financially constrained in 2005, corresponding to an output loss of 3% of national production. Fletschner et al. (2010) find that 28% of 372 crop farms in Peru are financially constrained in 2003 and 2004, with financial inefficiency scores between 17% and 27%. Kumbhakar and Bokusheva (2009) find that 95% of 73 Russian farms between 1999 and 2003 are financially constrained, which corresponds with an output loss of 20%. Finally, Smith et al. (2011) find that 28% of 226 Indian subsistence farmers in 1998 are financially constrained.

We find that solvency is rarely limiting farmers' ability to take out bank loans. This makes sense as most Dutch dairy farms are rich in land, which provides banks the confidence that they will be able to recover their finance, even in cases of default. In almost all cases the farm net cash flow limits farmers' ability to repay new loans. This is why stricter banking regulations focusing on business liquidity and profitability could have a severe impact on agricultural businesses (NVB, 2020). van der Meulen et al. (2020) has similarly observed that Dutch dairy farms' solvency was high, with an average solvency of 74% in 2018, and that profitable business models are the key to helping farmers access more finance. In practice, the age of the farmer and presence of a successor and also the economic and political environment will have an impact on the banks' willingness to provide loans.

Our study suggests that a large share of our sample farms is not creditworthy (not eligible to borrow additional money from the bank). The share is much higher than the share of financially constrained farms (financially limited in their production and investment choices to optimise dynamic profit). One reason for the discrepancy is that our estimation of creditworthiness is conservative, with the stringent condition that past net cash flow should exceed the annuity payment of a new loan. In the past, Dutch banks might have been more forthcoming to provide loans thanks to the high solvency rates of dairy farms. The upcoming Basel IV regulations will lead to more stringent loan provision. A second reason is that Dutch dairy farmers also borrow money from family and friends, albeit to a smaller extent (Fi-compass, 2020b). Lastly, investments usually occur in discrete steps. The expenditures of the best peers will be lower in some years and higher in others, and therefore at times stay within reach for the laggards with less accessible finance. Even with a more conservative estimate of creditworthiness and using reported expenditure to estimate the lower limit of loans from family and friends, not knowing the upper limit, we find that farms have not spent all their accessible finance. When we run our model using reported expenditure as a proxy for accessible finance, we find that many more farms would be classified as financially constrained. This suggests that the true accessible finance of farms exceeds the reported expenditure by a substantial margin.

Financial constraints only play a minor role in our study. We may conjecture about more important determinants in terms of internal and external factors. Internal factors include differences in objectives, risk attitudes and managerial abilities. Dynamic profit inefficiency may partially be attributed to non-economic objectives such as animal welfare (Hansson et al., 2018) and lifestyle (Barnes et al., 2015). Farmers may diversify production to mitigate risk (Hardaker et al., 2015; Meuwissen et al., 2019). Lamkowsky et al. (2021) suggest that the Dutch dairy farms in their sample may lack awareness of the upward potential to increase profit and knowledge about managerial practices. External factors include differences in the local production environment, and broader structural changes. Our specification assumes one common, attainable technology, which may mask unobserved heterogeneity in the production environment, such as varying conditions of weather and soils. Nevertheless, the effect of unobserved heterogeneity is expected to be small, as our sample consists of a relatively homogeneous group of dairy farms in a small geographical location. The studied period is characterised by structural changes, plausibly triggered by the liberalisation of the Common Agricultural Policy. Direct subsidies were decoupled in 2013 and the milk quota system was abolished in 2015. This liberalisation may have increased average dynamic profit inefficiency, which is consistent with the structural changes of exploitation of economies of scale and consolidation. Regarding the exploitation of economies of scale, between 1975 and 2022, the average size of dairy farms has grown significantly, with an increase from 24 cows per hectare of land at an intensity of 1.62 in 1975 (Van Everdingen, 1993) to 110 cows per hectare at an intensity of 1.84 in 2022 (CBS, 2022). Farmers have made large investments in land and capital to upscale production, as reflected in Table 1. They built larger animal housings and adopted new technologies such as improved milking or feeding systems. Consequently, farmers have high financial obligations to pay back outstanding bank loans. In our sample, 17% of income is used to pay back these obligations. The large financial obligations and dynamic profit inefficiencies contribute to the on-average negative net cash flow. A long-run negative net cash flow means that farmers drain their savings or cut back on household spendings, which jeopardises their ability to meet financial obligations. As mentioned in the introduction, a large share of dairy farming households earn less than the national low-income threshold through both farming and non-farming activities. Regarding consolidation, the Dutch dairy sector has experienced a substantial decline in the number of dairy farms over the years, dropping from more than 91,560 in 1975 to a mere 14,700 in 2022. This ongoing trend can be attributed, in part, to increasing economic pressure faced by farmers (Van Everdingen, 1993; ZuivelNL, 2023).

The classification of farms as financially constrained is determined with respect to the production and investment decisions of their best peers. The dynamic profit should be interpreted as the expected discounted profit from production and investment decisions, as the estimation of the shadow prices of investments are based on the expectations of the frontrunners. Therefore, factors suppressing the spending of the best peers, such as policy uncertainty and not finding a successor, increase the ability of laggards to match the spendings of their peers and decrease their likelihood of being classified as financially constrained. At the sector level, dairy farms have made large investments in 2013 and 2014 in expectation of the end of the milk quota system, but we do not observe a strong increase in financial inefficiency. Theoretically, a situation is possible in which the best peers are also faced with financial constraints, impeding investment. Yet, in our study, a large share of farms has access to more finance than they actually spend.

Lastly, this study generates useful insights, but the findings should not be interpreted as representative of the entire Dutch dairy sector. Although the original dataset of the Farm Accountancy Data Network is considered representative, we only analysed the dynamic financial inefficiency of farms that are represented in the sample for at least 4 years, which skews the final sample towards larger farms. Larger dynamic financial inefficiency may prevail in smaller farms.

6 | CONCLUSION

We benchmark Dutch dairy farms to determine the extent to which farms are limited by their accessible finance in making decisions on input use, output production and investments to maximise dynamic profit. In addition, we quantify the impact in terms of potential forgone dynamic profit. To this end, we extend the static approach of Färe et al. (1990) to the dynamic context of Ang and Oude Lansink (2018) and Silva et al. (2020). We estimate the accessible finance to farms using accountancy data, and by combining information of reported expenditures with information of past financial performance. The latter impacts a farm's creditworthiness with banks and thus its ability to take out additional bank loans. We also run multiple scenarios to provide further insights into the implications of the current provision of agricultural financial services and impact of potential future developments.

The results show that laggards are falling further and further behind their best peers in terms of dynamic profit, but that financial constraints are not driving this trend. The average dynamic profit inefficiency increases from €40,040 in 2009 to €114,548 in 2017. At the same time, the dynamic financial inefficiency decreases from €2311 in 2009 to €681 in 2017. The number of farms being classified as financially constrained compared to their peers falls from 44% in 2009 to 8% in 2017.

That laggards are increasingly losing out of potential dynamic profit generated by their best peers could endanger their financial viability in the long run. This is not a structural problem, in the sense of certain farm types becoming financially unviable or having insufficient accessible finances to make investments. Further research about the drivers of the growing gap amongst peers would yield useful insights. In line with Lamkowsky et al. (2021), the results suggest that policy-makers should focus on improving farm management and peer learning. Suitable instruments could entail advocacy for the economic gains of better farm management, information exchange, training, advice and platforms for peer learning.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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