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RESEARCH ARTICLE

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Anticipate, wait or don't invest? The strategic net present value approach to study expansion decisions under policy uncertainty

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Abstract

Dutch dairy farmers used different investment strategies in their production capacity in the periods around the abolishment of the European Union milk quota. Some farmers anticipated and expanded their production, others waited till expected policies were implemented or did not change their production. We develop a theoretical framework that integrates investment strategies—anticipating, waiting, or not investing—in the presence of policy uncertainty. We provide a numerical illustration of the framework to a typical Dutch dairy farm considering to expand the milk production. Results show that farmers would anticipate when they expect that the right system will be implemented with delay and will have low financial consequences. A low risk aversion reinforces the adoption of the anticipation strategy. The implications for policy and practice are discussed [EconLit Citatons: D22, Q00, Q18].

KEYWORDS

dairy farming, investment decisions, policy uncertainty, real options theory, risk attitude, strategic net present value

Abbreviations: CBS, Centraal Bureau Statistiek (Central Bureau for Statistics); EU, European Union; KWIN, Kwalitatieve Informatie Nederlandse Veehouderij; NPV, net present value; SNPV, strategic net present value; ROA, real options approach.

1 | INTRODUCTION

In the years before and after the abolition of the milk quota in April 2015, the uncertainty about future government policy has been a key factor in investment decision-making for Dutch dairy farmers. In 2003, the European Commission announced a gradual increase of milk quota per 2008, and the abolishment of the milk quota system per 2015 (European Commission, 2015). This gradual increase and eventual abolition of the milk quota gave dairy farmers new opportunities to expand their milk production by investing in additional production capacity. However, dairy farmers also operate in an environment that is characterized by uncertainty about future policies and their expectations may also be determined by their past experiences. For example, in the period following the abolition of the dairy quota, farmers may have expected the government to choose for emission grandfathering in the future. Emission grandfathering is the distribution of emission entitlements or production rights based on historical production levels and is used in a large part of actual emission control frameworks (Knight, 2013). Grandfathering was also used to distribute milk quota in the 1980s. If farmers expect the government to use emission grandfathering, then they will have an incentive to expand their production earlier, at least before a date used to determine historical production levels. As such, it is reasonable to assume farmers may consider an anticipation strategy, where they invest early with the expectation of getting more production rights or emission entitlements in case the government introduces new restrictive policies.

As a result of the investments in the expansion of production, the total milk production increased by 26.6% between 2008 and 2017 (CBS, 2018). Worse, this increase in milk production caused an exceedance of the enforced agricultural phosphate production ceiling (Jongeneel et al., 2017). By mid-2015, in response to the observed increase in phosphate emissions, the Dutch government announced the intention to introduce a phosphate right system, without further specification of how this system would be implemented (European Commission, 2017). As of January 2018, farmers were allocated tradable phosphate emission rights. The government used emission grandfathering and distributed production rights based on the farms herd size on July 2, 2015. Farmers who invested in the expansion of production after this reference date were forced to acquire additional phosphate rights or reduce their herd size. The initial uncertainty about the introduction of the phosphate right system may have influenced farmers investment decisions.

How do farmers cope with uncertainty about future government actions according to investment theory? The net present value (NPV) present value rule only considers the option to invest now, or not at all. The real options approach (ROA), as opposed to the (NPV) rule, considers the option strategically postpone the investment until more information is available (Trigeorgis, 1993). The strategic net present value (SNPV) rule allows both the option to strategically postpone and an option to strategically anticipate the behavior of others by investing early (Smit & Trigeorgis, 2017). Most applications of ROA in the context of dairy farming have focused on production (technical) and market (price) uncertainty (Engel & Hyde, 2003; Odening et al., 2005; Rutten et al., 2018). As shown in the review of Komarek et al. (2020), policy uncertainty is less commonly studied, possibly because probability distributions of policy uncertainty are not easily established in empirical studies, which usually take the frequentist view on probabilities.

A few studies in an agricultural context used the ROA to study the impact of policy uncertainty on farmers' investments (Floridi et al., 2013; Linnerud et al., 2014; Purvis et al., 1995). For example, Floridi et al. (2013) studied investment decisions under policy and technological uncertainty using a two-period model. In the first period, the farmer chooses whether to invest now or postpone the decision. In the second period, the farmer who chose to invest is “locked in” whereas the farmer who postponed can still decide to invest and has more information about some uncertain variables. They modeled policy uncertainty with a stochastic variable, which influences the cash flow, and found that farmers are likely to postpone their investments when faced with uncertainty.

Hence, previous studies have investigated the effect of policy uncertainty on investment decisions by including the option to postpone the investment decision. However, the observation of Dutch dairy farmers anticipating the instalment of new restrictive policies suggests the relevance of anticipation next to postponing an investment decision as a response to policy uncertainty. To our knowledge, no study has investigated the possibility of anticipation in the context of policy uncertainty. In the context of the dairy quota abolition, farmers may have expected that, considering the full lifetime of an investment, they are financially better off when anticipating.

The SNPV approach, developed by Smit and Trigeorgis (2017), includes both the anticipating and waiting strategy in investment decision making and compares these with not investing. In the context of corporate firms, the benefit from the anticipation strategy may materialize, for example, through a larger market share, when one firm invests before other firms enter the market (Smit & Trigeorgis, 2017). If neither waiting nor anticipating are considered profitable, the investors can choose not to invest. The authors developed a tool, called "option games," to quantify the value of anticipation and waiting based on ROA and game theory. Option games are suited mostly for analyzing investment decision-making in capital-intensive, oligopolistic markets facing demand volatility. The Dutch dairy sector exhibits an atomistic market structure characterized by a large number of producers (mostly family farms) on the supply side. Nevertheless, the value of the investment can still be affected by others, as investing before the implementation of future policies can be beneficial. The idea that investing early can be valuable, as described in the SNPV may thus apply here, as dairy farmers may also have strategic considerations to anticipate an investment in relation to what they expect the government to do. For example, the experience that manure and dairy market regulations that were implemented in the past in the Netherlands were usually based on grandfathering (using historical production levels) implies that investors would be better off investing early.

In this article, we develop a theoretical framework to study farmers' investment behavior in the presence of policy uncertainty. The theoretical framework can reflect three investment strategies—anticipating, waiting, or not investing as special cases. We apply this framework to a typical Dutch farm considering an investment in production expansion in the presence of policy uncertainty about the timing of a phosphate right system. The outcomes of the numerical illustration show under which conditions the farmer chooses which strategy, and as such, they also provide an explanation of the observed investment behavior of farmers before and after the abolition of the milk quota in 2015.

Apart from developing a theoretical framework for modeling farmers' investment decisions under policy uncertainty, our paper also contributes to the literature by providing valuable insights into the role of policy uncertainty and economic conditions in farmer investment decisions These insights are relevant for policy and practice to help farmers avoiding situations of financial distress as a result of an improper risk assessment.

2 | THEORETICAL FRAMEWORK

In this section, we describe the theoretical framework that was developed to study the effect of policy uncertainty on investment strategies. The model is inspired by the SNPV as it was developed by Smit and Trigeorgis (2017). The advantage of the SNPV over the ROA is that it considers the strategic anticipation option, whereas the ROA only considers the strategic option to postpone the investment. However, the SNPV is in principle an expansion of the ROA that provides more flexibility and therefore can be applied to markets with specific dynamics. In our paper, these dynamics are the anticipation of farmers that new policies will be implemented and the potential benefit of investing early. In the ROA, these potential benefits are not taken into consideration. As such, the SNPV has the same merits as the ROA, only it adds in additional flexibility. A disadvantage of the SNPV in comparison to the ROA may be the increased modeling complexity.

Let us consider a decision-maker, considering to invest in an expansion that requires an initial investment I and which generates a yearly future cash flow CF_h. The NPV of the investment is given by

$$\mathrm{NPV} = \max\left(0, -I + \sum_{t=1}^{T} \frac{\mathrm{CF}_h}{(1 + r)^t}\right), \tag{1}$$

where t is the period, T is the useful life of the investment, and r is the risk-adjusted discount rate. The risk-adjusted discount rate is given by $r = i + k$, where i is the risk-free discount rate and k is the risk premium. The risk premium represents the riskiness of the project and the risk attitude of the decision-maker (Finger, 2016; Hillier et al., 2016).

A higher risk premium reflects a riskier project and/or a more risk-averse decision-maker. The maximization operand in (1) reflects that the decision-maker only invests if the project is "in the money," that is, in case $-I + \sum_{t=1}^{T} \frac{CF_h}{(1+r)^t} > 0$.

The NPV in Equation (1) assumes a constant cash flow over the entire project period. We now extend this NPV by introducing a negative shock S that arrives at time $t - S$, and which results in a yearly cash flow CF_l, where $CF_l < CF_h$:

$$NPV_l = \max\left(0, -I + \sum_{t=1}^{S} \frac{CF_h}{(1+r)^t} + \sum_{t=S+1}^{T} \frac{CF_l}{(1+r)^t}\right). \quad (2)$$

Next, we introduce uncertainty about *whether* the shock will occur through a probability p, reflecting the decision maker's perception of the probability that the shock occurs at time $t = S$. Hence, Equation (2) is rewritten to reflect the NPV of our base situation (NPV_b):

$$NPV_b = \max\left(0, -I + \sum_{t=1}^{S} \frac{CF_h}{(1+r)^t} + (1-p)\sum_{t=S+1}^{T} \frac{CF_h}{(1+r)^t} + p\sum_{t=S+1}^{T} \frac{CF_l}{(1+r)^t}\right). \quad (3)$$

We next present two potential strategies for the decision-maker and show how the NPV can be calculated in each situation. In the first strategy, the decision maker may choose to wait till period $t = S$ to invest. The waiting strategy results in new information to arrive at $t = S$, that is, *whether* the negative shock occurs. In case a negative shock does occur, then the decision-maker adjusts the investment downward to I in line with the lower yearly cash flow (CF_l) after $t = S$; if the negative shock does not occur, the higher investment level I_h associated with the high cash flow CF_h is chosen. The NPV in case of waiting (NPV_w) is calculated as

$$NPV_w = p\max\left(0, \frac{-I_l}{(1+r)^S} + \sum_{t=S+1}^{T+S} \frac{CF_l}{(1+r)^t}\right) + (1-p)\max\left(0, \frac{-I_h}{(1+r)^S} + \sum_{t=S+1}^{T+S} \frac{CF_h}{(1+r)^t} +\right). \quad (4)$$

Note that the investment costs I_l and I_h are discounted because the decision maker invests in period $t = S$. Since the total investment life differs across the different strategies We now use the equivalent annualized annuity[1] of the NPV_w to determine the optimal investment decision (Hillier et al., 2016). The value of the option to wait with the investment (WV) until new information has arrived is calculated as

$$WV = \max(0, NPV_w - NPV_b). \quad (5)$$

The second potential strategy for the decision maker is the option to anticipate the shock and invest early. A decision-maker who anticipates the shock and invests early believes there is a specific advantage of investing before the potential arrival of the shock. The advantage of anticipating materializes through a cash flow CF_a after the shock has occurred. Hence, the investor expects that anticipation generates an advantage that comes through a cash flow that is higher after the shock has occurred than the cash flow would have been if the investor had not invested early.

Using (3), the NPV of anticipation (NPV_a) is calculated as

$$NPV_a = \max\left(0, -I + \sum_{t=1}^{S} \frac{CF_h}{(1+r)^t} + (1-p)\sum_{t=S+1}^{T} \frac{CF_h}{(1+r)^t} + p\sum_{t=S+1}^{T} \frac{CF_a}{(1+r)^t}\right). \quad (6)$$

[1]The equivalent annualized annuity (EAA) cashflow is calculated as $EAA_j = \frac{r \times NPV_j}{1-(1+r)^{-(T+\alpha S)}}$ Here r is risk free discount rate, k is the risk loading and T is the total number of periods. In the anticipation strategy, the investment life is T years, and in the waiting strategy, it is $T + S$ years. Remember α is 1 in the case of waiting, and 0 in the base case and anticipation strategy.

The value of the option to anticipate (AV) is given by

$$AV = \max(0, NPV_a - (NPV)_b). \tag{7}$$

The different investment strategies, that is, no investment, anticipating, and waiting can be combined into a theoretical framework, which computes the SNPV:

$$\begin{aligned} SNPV = \max_{\alpha,\beta} \Bigg[& \alpha \max\left(0, -I + \sum_{t=1}^{S} \frac{CF_h}{(1+r)^t} + (1-p) \sum_{t=S+1}^{T} \frac{CF_h}{(1+r)^t} \right. \\ & \left. + p(1-\beta) \sum_{t=S+1}^{T} \frac{CF_l}{(1+r)^t} + p\beta \sum_{t=S+1}^{T} \frac{CF_a}{(1+r)^t} \right) \\ & + (1-\alpha)p \max\left(0, \frac{-I_l}{(1+r)^S} + \sum_{t=S+1}^{T+S} \frac{CF_l}{(1+r)^t}\right) \\ & + (1-\alpha)(1-p) \max\left(0, \frac{-I_h}{(1+r)^S} + \sum_{t=S+1}^{T+S} \frac{CF_h}{(1+r)^t}\right) \Bigg]. \end{aligned} \tag{8}$$

The maximization problem in Equation (8) solves for the values of α and β that maximize the SNPV. α and β are dummy variables that take the value of either 0 or 1. It can be easily verified that the NPV_b from Equation (3) results if α and β are 0. If both α and β are 1, then the anticipation strategy, with the net present value given by NPV_a in Equation (6), is optimal. Finally, if α is 0 and β takes the value of either 0 or 1, then the waiting strategy, with the net present value given by NPV_w in (4), is optimal.

The optimal investment decision—anticipating, waiting, or not investing at all—as the outcome of Equation (8) can be further simplified as

$$SNPV = NPV_b + \max(AV, WV). \tag{9}$$

Note that both AV and WV are non-negative. Hence, the decision-maker should anticipate, that is, invest early, if the SNPV > 0 and AV > WV. The investment should be postponed if the SNPV > 0 and WV > AV. The decision-maker should not invest if the SNPV = 0. In that case, there is no value in anticipating nor postponing the investment.

The SNPV as we have developed it here based on the idea that investors have strategic considerations when deciding the timing of their investment in production capacity. This is in line with the ideas based on which Smit and Trigeorgis (2017) developed their SNPV framework. However, since the market conditions and the Dutch dairy sector are different from the intended application of Smit and Trigeorgis (2017), our model is quite different. Besides that, we look at an interaction between the investor and the government whereas Smit and Trigeorgis (2017) study the interaction between investors.

3 | NUMERICAL ILLUSTRATION

The SNPV framework is applied to an investment in the expansion of the barn capacity and herd size of a typical Dutch dairy farm. To do so we use a numerical example. The farmer makes the investment decision in the presence of uncertainty about a future policy. This policy, the "shock" in the theoretical framework, may reduce the number of cows the farmer is allowed to keep on the farm. The total reduction depends on the number of cows the farmer owns on a specific date. Thus, there may be a value of anticipating as the farmer can keep more cows at the future reference date. However, postponing the investment may also be beneficial as this will give the farmer full knowledge of whether the investment will be profitable.

We assume the farmer currently operates a farm with 100 cows. The investment in production expansion will let the farm size increase to 180 cows. The initial farm size is close to the average number of cows held on Dutch dairy farms in 2017. The farm size after the expansion is large but realistic; about 13% of the dairy farms had more than 150 cows in 2017 (BINternet, 2020). It is further assumed that the farmer faces no other capacity restrictions.

The investment I is an initial cash outflow, which is expected to generate a cash inflow (IF) and cash outflow (OF) stream. The cash outflows are split up into a variable cash outflow OF_{var} and a fixed cash outflow OF_{fix}. The cash flows I and OF_{fix} correspond with the concept of sunk or committed cost[2] and do not change with the farm size.

In the NPV calculations without the strategy considerations, two cash flow streams apply:

$$\mathrm{CF}_h = IF - OF_{var} - OF_{fix}, \tag{10}$$

$$\mathrm{CF}_l = (1 - f)(IF - OF_{var}) - OF_{fix}, \tag{11}$$

where CF_h corresponds with the (high) cash flow before the shock, CF_l is the (low) cash flow received after the shock, and f is the expected consequence of the shock in terms of a reduction in the number of cows the farmer is allowed to keep on the farm.

To include the strategic considerations in the NPV calculations, two additional cash flow streams are received after the shock apply. The cash flow corresponding with the waiting strategy is

$$\mathrm{CF}_w = (1 - f)(IF - OF_{var} - OF_{fix}). \tag{12}$$

The farmer now has full knowledge of the cash flow outlay and will avoid the burden of committed costs. This also means that the initial cash outflow (i.e., the investment) will be adjusted to the allowable number of cows (referred to as I_l) in Equations (4) and (8).

The cash flow corresponding with the anticipation strategy is

$$\mathrm{CF}_a = (1 - g)(IF - OF_{var}) - OF_{fix}. \tag{13}$$

Compared to the cash flow in (11), the change is g instead of f. So g as before represents the expected consequence of the shock in terms of a reduction in the number of cows the farmer is allowed to keep on the farm, but $f > g$.

Table 1 summarizes the default parameter values used in the numerical illustration to show under which conditions the farmer should anticipate, wait or not invest. The investment and cash flow parameters used in this numerical illustration are taken from a commonly used reference guide (known as KWIN) for the Dutch dairy sector that contains all sorts of quantitative base values that advisors, farmers, students, or researchers use to perform financial analyses (Blanken et al., 2018). As such, our numerical illustration is based on the indicators from this reference guide and not on real data from dairy farms. The cash inflow IF is based on a constant milk price of €35.5 per 100 kg milk and an average milk production of 8500 kg per cow (Blanken et al., 2018). The variable cash outflow OF_{var} includes expenditures for feeding, animal health and reproduction, cow replacement, soil fertilization, and so forth. It also included expenditure for cow replacement, assuming the farmer replaces 20% of the herd per year. The fixed cash outflow OF_{fix} includes interest and maintenance expenditures. For a more detailed description of all inflow and outflow items for a typical Dutch dairy farm, we refer to the KWIN reference guide.

In the analyses that will follow, we vary the policy uncertainty and risk attitude parameters in different configurations. These parameters are subjective in nature (Hardaker & Lien, 2010) and reflect a range of beliefs of

[2]"A committed cost is an investment that a business entity has already made and cannot recover by any means, as well as obligations already made that the business cannot get out of" (accountingtools.com).

TABLE 1 Parameter values or ranges

Category	Symbol	Description	Unit	Value or range	Based on
Cash flow	I	Initial investment outlay	€	394,240	Blanken et al. (2018)
	IF	Yearly cash inflow[a]	€	241,440	
	OF_{var}	Yearly variable cash outflow	€	158,960	
	OF_{fix}	Yearly fixed cash outflow	€	17,742	
Policy uncertainty	S	Perceived timing when the phosphate right system is introduced	year	1–10	-
	p	Perceived probability that the phosphate right system is introduced	%	0–100	-
	f	Expected consequence in terms of a reduction in the number of cows (for NPV_b and NPV_w)	%	30	-
	g	Expected consequence in terms of a reduction in the number of cows (for NPV_a)	%	20	-
Risk attitude	i	Risk-free discount rate	%	5	Schulte et al. (2018)
	k	Risk premium	%	0–12	

[a]Based on a milk price of € 35.5 per 100 kg of milk and an average milk production of 8500 kg per cow.

the farmers concerning the uncertainty they experience. To explore the robustness of our results to price changes, the optimal investment decision will also be analyzed for a range of possible milk prices.

4 | RESULTS

We begin by showing in Figures 1 and 2 the results of the joint impact of risk attitude and perceived probability of the introduction of the phosphate right system on the optimal investment decision. We vary k and p while keeping s constant, the perceived timing when the policy is introduced, at 3 years, and all other parameters at their default value (Table 1). In Figure 1, we report the absolute values of the NPV of the two strategies, waiting (NPV_w) and anticipation (NPV_a) for a range of values of p and k. Figure 2 presents the results in a complementary way by showing the optimal investment strategy for each combination of p and k.

The value of both investment strategies in Figure 1 decreases when p increases. The NPV of the anticipation strategy reduces more quickly and has a steeper slope than the NPV of the waiting strategy. The intersections in Figure 1 indicate when the waiting and anticipation strategies are equally attractive. When the risk premium increases, the $NPV_w = NPV_a$ intersect is at a lower value of p, meaning that risk-averse farmers are more likely to postpone the investment.

The three investment strategies—anticipating, waiting, or not investing, are represented in Figure 2 by the white, dotted, striped, and black areas. For highly risk-averse farmers ($k \geq 10.5\%$) it is optimal not to invest, even when they do not expect the introduction of the phosphate right system (black area). The remaining three areas show when the two other investment strategies are optimal for different combinations of k and p. In the dotted area, the value of waiting is positive but the value of anticipation exceeds this value. At very low levels of risk aversion ($k < 3\%$), the anticipation strategy is always optimal to take. Presumably, k and p go hand in hand as more

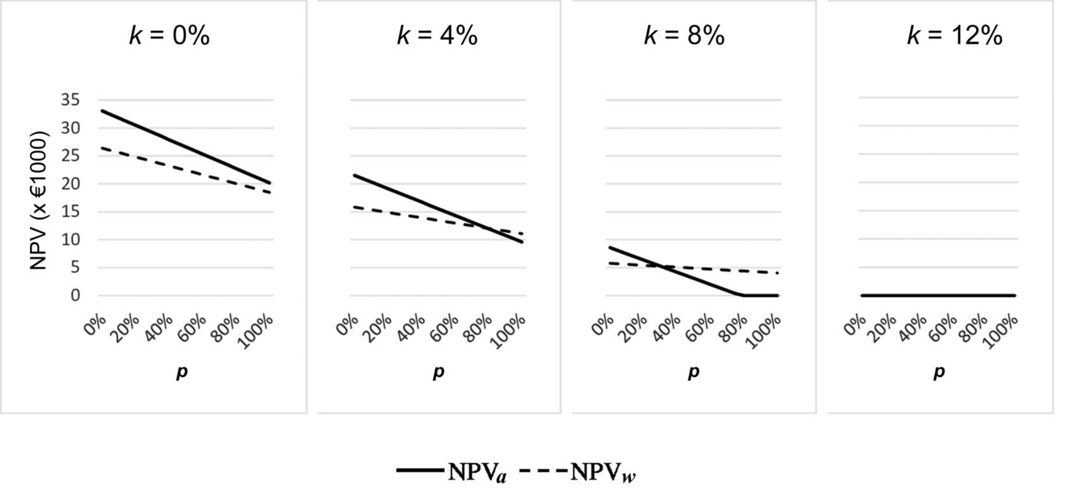

FIGURE 1 The net present value (NPV) of the anticipation (*a*) and waiting (*w*) strategy for different risk premia (*k*), and varying the perceived probability that the phosphate right system is introduced (*p*). The timing of the shock is $S = 3$ and all other parameters are kept constant at the value reported in Table 1.

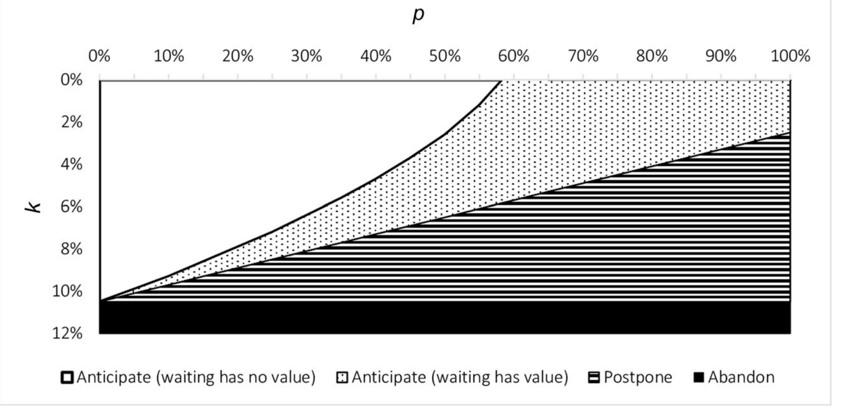

FIGURE 2 The optimal investment strategy while varying risk premium (*k*) and the perceived probability that the phosphate right system is introduced (*p*). The timing of the shock is $S = 3$ and all other parameters are kept constant at the value reported in Table 1.

risk-averse farmers more strongly expect a restrictive policy. Farmers who can be characterized by high-risk aversion likely adopt the waiting strategy to cope with policy uncertainty.

Next, we vary *k* and *s* in discrete steps while keeping *p*, the perceived probability that the policy is introduced, at 50%, and all other parameters at their default value (Table 1). Thus, we now look into the joint influence of risk attitude and the perceived timing of the introduction of the phosphate right system on the optimal investment decision. The results of this step are presented in Figures 3 and 4, in a comparable manner as in Figures 1 and 2 but in bar graphs given the discrete nature of the time unit used. The legend in Figure 4 is the same as in Figure 2.

While both investment strategies decrease in *p* (Figure 1), they have opposite effects in *s*. The value of anticipation increases with a delayed or late policy implementation because the farmer expects to receive the high

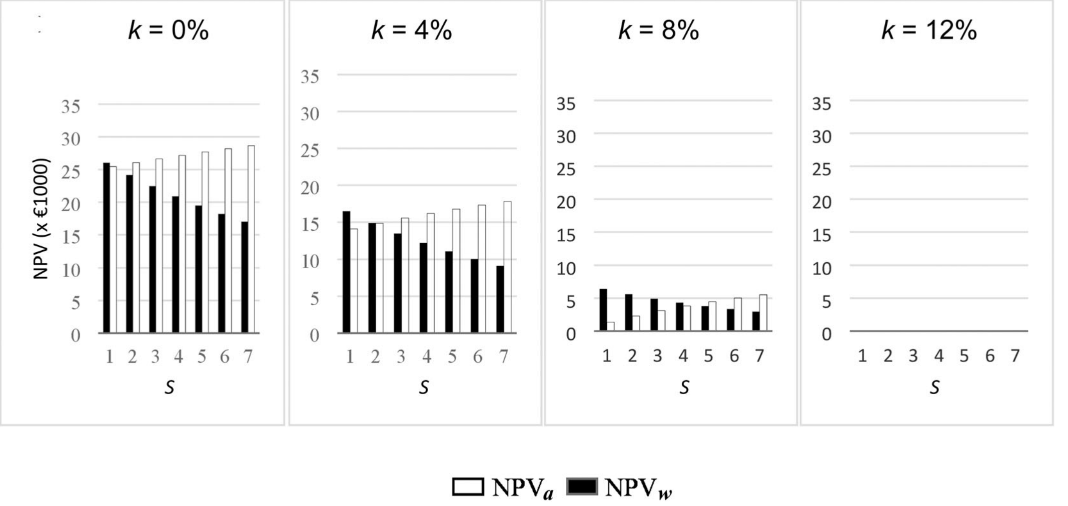

FIGURE 3 The net present value (NPV) of the anticipation (a) and waiting (w) strategy for different risk premia (k), and varying the perceived timing when the phosphate right system is introduced (S). The perceived probability of the shock is p = 50% and all other parameters are kept constant at the value reported in Table 1.

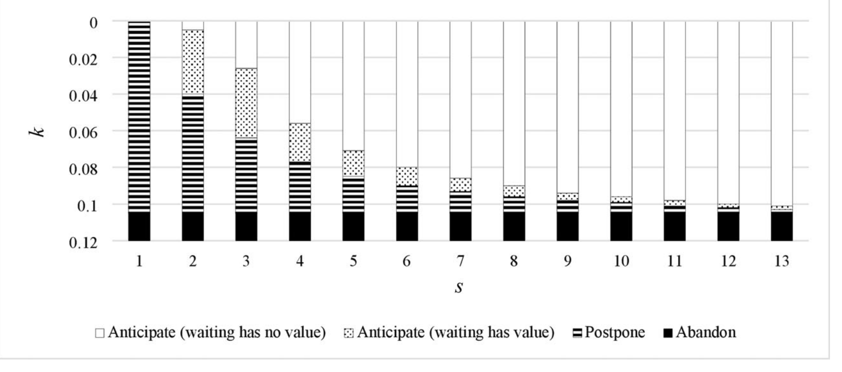

FIGURE 4 The optimal investment strategy while varying risk premium (k) and the perceived timing when the phosphate right system is introduced (S). The perceived probability of the shock is p = 50% and all other parameters are kept constant at the value reported in Table 1.

cash flow CF_h for a longer time (Figure 3). The value of waiting decreases because the farmer will receive the cash flow later in time, resulting in a lower present value. Figure 3 further shows that for higher levels of risk aversion the economic values of both strategies become more comparable. At k = 8%, switching strategies—from waiting to anticipation—occurs at s = 5 but the difference in net present value is limited.

For highly risk-averse farmers ($k \geq 10.5\%$) it is optimal not to invest for the full range of S (black bars in Figure 4). At very low levels of risk aversion ($k < 3\%$), the anticipation strategy is only disregarded when the farmer expects the introduction of the phosphate right system the year after the investment.

In the results presented so far, a milk price of €35.5 per 100 kg of milk was assumed (Table 1). To study the robustness of our results, we vary the milk price while s is at 3 years, p is at 50%, k is at 6%, and all other parameters are at their default value (Table 1). The optimal investment strategy is sensitive to milk price changes (Table 2). The strategic NPV (SNPV) is €9474 with an unchanged milk price. The anticipation value is

TABLE 2 The optimal investment decision at different values of the milk price.

Milk price change	−10%	−5%		+5%	+10%
Milk price per 100 kg	€32.0	€33.7	€35.5	€37.3	€39.1
NPV_b	0	0	6616	17,432	28,247
WV	0	1867	2477	0	0
AV	0	0	2857	3275	3694
SNPV	0	1867	9474	20,707	31,940
Optimal strategy:	No investment	Postpone	Anticipate →		

Note: All parameters, except milk price, are kept constant, $S = 3$, $p = 50\%$, and $k = 6\%$.

positive (€2857), the waiting value is 0, implying the farmer should anticipate. Milk price increases of 5% and 10% do not change the strategy; the anticipation value increases, and the waiting value decreases.

We varied the milk price to study the robustness of our results to changes in the milk price. When the milk price decreases by 5%, the anticipation value is 0, and the waiting value exceeds the anticipation value. If the farmer postpones the investment, a negative effect of a strict policy is avoided. However, if the farmer anticipates and the strict policy is implemented this would lead to a financial loss. The strategy of waiting has now become optimal. A further decrease in the milk price (−10%) causes the optimal investment decision to switch from postponing to not investing. The investment is no longer profitable and the farmer should choose not to invest. The SNPV cannot be less than 0 because both the NPV_b, the waiting value and the AV cannot be less than 0. Though the optimal investment strategies are affected by the milk price, the direction of the effect of policy uncertainty and risk attitude on the optimal investment strategy will not be affected by changes in the milk price.

5 | DISCUSSION

This section first discusses the main findings and this is followed by the policy implications.

5.1 | Discussion of the main findings

Our study was dedicated to the question of how farmers make investment decisions in the presence of policy uncertainty. This was stirred by the observation of many Dutch dairy farmers investing in the expansion before and after the abolition of the dairy quota system, while new restrictive policies to limit emissions could reasonably be expected. We developed a general framework that is capable of calculating the NPV of three investment strategies for production expansion in the presence of policy uncertainty: anticipate, wait, and not invest. The anticipation strategy provides an explanation for the observed investment behavior of dairy farmers. The outcomes of the numerical illustration showed under which conditions the farmer anticipates, waits, or chooses not to invest.

Apart from the main analysis on policy uncertainty, we analyzed the robustness of our results to changes in the milk price (while keeping policy uncertainty constant). However, in future analysis interested in studying price uncertainty, data could be used to study the effect of a dynamic milk price. In this paper, we did not include dynamic milk price as we were not interested in studying price uncertainty. We assumed the farmer only had to deal with one source of uncertainty at a time, that is easily defined and quantifiable using a single probability value. In practice, policy and price uncertainty can be interrelated, as the period before and after the abolishment of the milk quota has shown. A restrictive policy (a quota) affects the milk price (volatility) while increasing milk prices may trigger investments, which in turn will increase the production and simultaneously the level of emissions. To empirically quantify the effect of both uncertainties on investments, likely a combination of the frequentist and subjectivist views on probabilities has to be taken (Hardaker & Lien, 2010; Komarek et al., 2020). Due to the unavailability of data about policy uncertainty, a suitable approach may be to combine historical data about prices with expert judgments in a Bayesian network approach (Werner et al., 2017).

We highlighted the subjective nature of the parameters used in this study describing policy uncertainty and risk attitude in the framework. In the numerical illustration, these parameters were varied in a range of possible values to show which investment strategy is selected under which parameter settings. Constant risk and exponential time preferences were hereby assumed. The elicitation of risk and time preferences in a survey and experimental farmer behavior research is a current theme in the agricultural economics literature (e.g., Bocquého et al., 2013; Hermann & Musshoff, 2016). If farmers' time preferences are indeed (quasi-)hyperbolic instead of exponential, farmers would be present biased. This means that they perceive more utility from cash flows received in the present compared to cash flows received in the future. For present-biased farmers, the anticipating strategy is more attractive. Besides time preferences, farmers' risk preferences may be a time-variant personality trait (Guiso et al., 2018; Schulte et al., 2018). As such, the SNPV of a farmer today may need to be calculated with a different risk premium as the SNPV calculated 10 years from now. However, within one SNPV calculation, the same risk premium should be used as it should include the risk attitude of today to determine the SNPV of today. Moreover, the s-shaped utility function from cumulative prospect theory (Bocquého et al., 2013) indicates that different risk premia should be used depending on the current endowment of the farmer. More prosperous farmers may thus be willing to take more risks than less prosperous farmers.

Future research could extend our framework by allowing for flexibility in the risk and time preferences, possibly based on an empirical data collection of these preferences. The basic or extended SNPV could be taken as the presented maximization problem (see Section 2) to simulate decision problems under policy uncertainty, for example, the farmers' willingness to invest in farm technologies that are currently being proposed to reduce emissions and environmental harm. There will be a value of anticipation when an investment before new policies could lead to a benefit after policy implementation.

Furthermore, risk and time preferences have also been linked to personality psychology and entrepreneurial behavior (e.g., Borghans et al., 2008). It may well be that the entrepreneurial-oriented farmers more quickly adopt an anticipation strategy when considering to invest despite being surrounded by high policy uncertainty. In survey research on farmers' perceived obstacles for business development, it was found that extraversion and openness explain these perceptions (Hansson & Sok, 2021). Farmers who scored higher on these personality traits experienced fewer obstacles in developing their businesses. Both personality traits are associated with entrepreneurial behavior (Hao Zhao et al., 2010). Future research could be dedicated to finding explanations from entrepreneurial and personality psychology to understand investment decision-making in the presence of policy uncertainty.

5.2 | Policy implications

In our analyses, we studied a situation in which a dairy farmer wished to expand the farm but did not have full information about the introduction of the phosphate right system. The policy uncertainty was represented by a combination of parameters in the framework. These parameters captured expectations of the farmer about the likelihood (probability), timing, and expected financial consequences of the introduction of the phosphate right system. We showed for this particular case that an anticipation strategy is optimal when the farmer expects that the phosphate right system will be implemented with delay and will have low financial consequences. Thus, if policymakers communicate “uncertainty” about the timing of the implementation of restrictive policies and remain unclear about the financial implications, farmers may be more prompted to invest early. A low-risk aversion reinforces the adoption of this strategy under these circumstances.

The insights generated in this study emphasize the importance of understanding farmers' responses to government interventions. First of all, policymakers need to carefully estimate how farmers respond to either revealing or not revealing information about an intended action. While not formally taken into account in our framework and analyses, we recommend policymakers also take into consideration how the experiences of farmers with restrictive policies and regulations in the past affect expectations. Previous research has shown that past behavior can influence farmers' behavior (Cohen et al., 2008). Former manure and dairy market regulations were based on historical production levels (grandfathering). Farmers likely take these experiences into account in their investment decisions following a quota abolishment.

Also, farm advisors can play an important mediating role between policymakers and farmers in assuring proper communication of the risks and uncertainties and avoiding situations of financial distress. Farmers often act simultaneously as owners and as the main labor providers in (family) farm businesses. The operator or entrepreneur defines the goals at the strategic and tactical levels. Support from several "gatekeepers" for the provision of strategic information regarding, for example, policy developments is hereby indispensable. This information is often provided by advisors affiliated with bank and accountancy firms active in the agricultural sector (e.g., Hilkens et al., 2018). These advisors are key referents in the investment decision-making process. Moreover, previous research has shown that extension services can influence investment decisions (Nobre & Grable, 2015).

6 | CONCLUSION

In conclusion, we found that the anticipation strategy is optimal when the farmer expects that the policy will be implemented with delay and will have low financial consequences. A low-risk aversion reinforces the adoption of this strategy. As such, when the government communicates uncertainty about the timing of policy implementation, farmers may choose to invest early. We also saw that a higher milk price makes anticipation more valuable. These results imply the importance of understanding farmers' decision timing and investment strategies for policymakers.

DATA AVAILABILITY STATEMENT

All data used is publicly available in a handbook named KWIN.

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