Investment Spikes in Dutch Horticulture: An Analysis at Firm and Aggregate Firm Level Over the Period 1975-1999

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1. Introduction

Analysing farmers’ investment behaviour over time, one typically observes periods with little or no investment followed by periods with large investment activity. This phenomenon is found in firm level investment data in many different countries such as the USA (Caballero and Engel, 1999, Cooper et al., 1999), Norway (Nilsen and Schiantarelli, 2003), and Colombia (Hugget and Ospina, 2001).

In the literature, intermittent investments have been explained by the indivisibility and irreversibility of investments, the presence of fixed or non-convex adjustment costs, and the option value of waiting till more information or better technologies are available. Indivisibility of investment refers to a situation where firms, when switching to new technologies, need to install a set of related capital goods, preventing smooth investments, creating investment spikes in particular years (Jovanovic, 1998). When investments are irreversible, firms usually cannot disinvest without large costs, affecting their decision about the timing of investment. Nilsen and Schiantareli (2003) conclude that irreversibility increases the likelihood of intermittent patterns of investments. The impact of non-convexities on investments was discussed by Davidson and Harris (1981). The widely used explanation of periods with zero investment, alternating with periods of positive investment, is the presence of a fixed adjustment cost (Abel and Eberly, 1997, Caballero and Engel, 1999). Cooper et al. (2002) find that a model which includes both convex and non-convex adjustment costs with irreversibility fits the data best. Uncertainty about returns on invested capital also explains intermittent investment patterns. Dixit and Pindyck (1994) conclude that uncertainty has a negative effect on investments, although Abel (1995) shows that increasing uncertainty increases the level of expected long-run capital.
Empirical contributions considering time spells between investment spikes is rather scarce. The paper of Cooper et al. (1999) is one of the few that analyzed the spells between machinery replacements for US manufacturing industry. After the prior spike, they find the increasing probability of another investment spike. Nilsen and Schiantarelli (2003), analyzing Norwegian manufacturing plants, confirmed the importance of irreversibilities and non-convexities at the micro level. For investment behaviour in agriculture, systematic analyses of the spells between investment spikes are completely absent.

The aim of this paper is to identify the factors which can explain intermittent and lumpy pattern of investments. An additional aim is to apply to the Dutch horticulture sector relatively new duration analysis, which focuses on the timing of investments.

The paper proceeds as follows: Section 2 provides the theoretical background of this paper, Section 3 describes the data and the empirical model, Section 4 presents the estimation results and Section 5 gives conclusions.

2. Theoretical framework

The theoretical framework starts from a firm that generates profit, and in which over time, the producer invests so as to maximise the discounted present value of profits. Utilising a dynamic approach (Bellman, 1957), we can write the value of the firm \( V \) dependent on a vector of state variables \( X \) and time \( t \) as:

\[
V(X,t) = \max_i \prod(X,t) - C(I,X,t) + \alpha E V(X',t'|X)
\]

with unprimed variables indicating current values and primed ones indicating future values of variables in time \( t' \). \( \prod(X,t) \) denotes the profit flow, \( I \) investment, \( C(I,X,t) \) the adjustment cost function, and \( \alpha \) the discount rate.

The adjustment cost function \( C(I,X,t) \) includes both convex and non-convex costs components, which result in a pattern of periods of investment inactivity punctuated by lumps of investments (Cooper, 2002). From the theoretical framework of Cooper et al. (1999), the
profit function $P(X,t)$ depends on capital ($K$), a profitability shock ($A$) and other state variables representing firm-specific characteristics ($x$). We define a profitability shock as changes in profits that are not due to changes in the level of capital. $A$ plays two roles in investment decision-making problems: first it has a direct impact on current productivity, and second it is informative about future opportunities to invest.

Following Dixit and Pindyck (1994), at every instant, a firm can either continue its current firm operation and get a profit flow, or stop and get a termination payoff. Both the profit flow and the termination payoff depend on a vector of state variables $X$ and on time $t$. This problem can be characterised as a dynamic, stochastic discrete choice problem. The optimal stopping problem can be translated into an optimal investment decision making problem by defining continuation as waiting with an investment, and stopping as investing in new capital.

In case the firm operator waits with new investments, the value function ($V^W$) is given by:

$$V^W(A, K, x, t) = \prod(A, K, x, t) + aE[V(A', K', x', t'| x)]$$

(2)

whereas, in case the firm operator decides to invest, the optimal value function ($V^I$) becomes:

$$V^I(A, K, x, t) = \max_i \prod(A, K, x, t) - C(I, A, K, x, t) + aE[V(A', K', x', t'| x)]$$

(3)

where $K' = f(K, I)$ is the capital accumulation equation. The Bellman equation is then written as:

$$V(A, K, x, t) = \max[V^W(A, K, x, t), V^I(A, K, x, t)]$$

(4)

The outcome of the optimisation in (4) provides information on whether a firm invests. From this we can compute the expected time $T$ between investments:

$$E[T] = \begin{cases} T & \text{if } V^I > V^W \text{ invest} \\ >T & \text{if } V^I < V^W \text{ not invest} \end{cases}$$

(5)
The solution to (4) entails investments in period $T$ if $V^d > V^w$, given the state vector $(A, K, x, t)$. We characterise this solution by a hazard function $\theta(A, K, x)$ which is the probability that a firm (that did not invest until $T=t$) invests in the short interval of time after $t$.

The influence of the profitability shock $A$ on $\theta(A, K, x)$ depends on the nature of adjustment costs and the distribution of profitability shocks. Following Cooper et al. (1999) or Dixit and Pindyck (1994), we expect that $\theta(A, K, x)$ is decreasing in $K$, that is, the lower the level of capital (mostly due to the depreciation), the more likely an investment spike.

### 3. Data and Empirical model

#### 3.1. Data

The empirical application is based on panel data of greenhouse firms over the period 1975-1999. Data come from a stratified sample of Dutch greenhouse firms keeping accounts on behalf of the LEI accounting system. The firms rotate in and out of the sample to avoid attrition bias; and they usually remain in the panel for about five to seven years. The original sample used in the analysis had 6915 observations on 1505 firms. For empirical analysis, we construct two data sets: firm- and aggregated-level.

The firm-level sample, which we used for the duration analysis, consists of 2320 observations of 692 firms. All left-censoring observations were deleted to overcome the initial conditions problem. To analyse lumpiness of investments, we define an investment spike if the investment rate exceeds 20 percent of the value of installed capital. A dummy variable represents an occurrence of large investments. For the duration analysis we use “spell”, which is the time spent from the last investment spike until the next investment spike ($T$), or until a firm

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1 The reasons to use a rotating sample can be found in Hsiao, C., P. Hammond, and A. Holly. *Analysis of Panel Data*: Cambridge University Press, 2002.

is dropped from the observation. In the first case we have completed spell (419 spells in our data) and the second case is a right-censored spell (578). In the model we include interval-specific duration dummy variables (*Durat1-Durat10*) to define the spell-duration. The estimation of these dummies will give a specification for the baseline hazard. *Capital* (as well as all monetary variables) is measured at constant 1985-year prices in Euro and is valued at replacement costs. **Profitability shock**, calculated as the residuals of a Least Squares regression of revenue on capital, shows considerable variation across firms. The residuals obtained from the model\(^3\) represent changes in profit that are not due to changes in the level of capital and can also be interpreted as lower or higher return than expected on installed capital. Variable *Debt* is included because we assume that firms often attract external financing for large investments. *Successor* is included as a measure of the firm-operator’s planning horizon, positively affecting the occurrence of investment spikes. The WIR-law (Wet Investeringsregelingen, 1988) was in force between 1978 and 1988 and firms could get a subsidy in case of significant investments. The announcement in advance about the revocation of this law could stimulate firms to invest. We include the variable *WIR-received* and also dummy variable *WIR* for 1988, the year when the subsidy was removed.

In order to assess the nature of fluctuations of investment patterns, we consider (Figure 1) the distribution of the investment rates that is highly peaked and skewed, with a long right-hand tail. The major part of observations (36%) has investment rates between 0 and 5% and can be characterised as replacement investment. For the replacement investment, adjustment costs are close to zero and this may explain the high frequency of investments around zero. The observations of 0-investments account for about 16.6% of investments. Negative investments are rare (1.6% of observations) in the period under investigation and they are caused by retirement of capital. Although only 17.8% of firms experience an investment spike with an investment rate more than 20%, they account for 67.7% of total investments.

\(^3\) We used fixed-effect model due to Hausman test result of fixed-effect model vs. random-effect model (chi
Figure 1. Distribution of investment rates

Notes:

* Each bar represents the percentage of observations with the depicted investment ratio
** The far right bar includes all observations with an investment ratio greater than 0.98, the maximum equals 7.18.

The aggregated-level data set is calculated for 10 groups of horticulture firms which differ in size. The average size (DSU⁴) of every group is given in Figure 2.

Figure 2. Occurrence of investment spikes from 1978 – 1999 by 10 groups

Due to aggregation an investment spike is defined at 0.126-level that is the mean of ratios of investments to installed capital. The distribution of occurrence of investments

2(1)=1260.9). Both terms of capital in OLS are significant and R² for model is 0.65.
³ Dutch Size Units (DSU) describes the economic size of agriculture firms and calculated by Agricultural Economic Research Institute LEI, http://www.lei.wag-ur.nl/
spikes among the groups is represented in Figure 2 and shows for larger firms that it is more probable to observe investment spikes.

### 3.2 Empirical Model

The hazard function is the probability that a firm, which did not invest until time $t$, invests in the short interval of length $\Delta t$ after $t$. Let $T_i$ be the length of the spell between investment spikes for firm $i$. Then the hazard rate $\theta_i$ for firm $i$ at time $t$ is an average probability ($P$) of an investment spike per unit of duration in the small time interval (Lancaster, 1990)

$$\theta_i(t) = \lim_{\Delta t \to 0} \frac{P[t + \Delta t > T_i \geq t | T_i \geq t]}{\Delta t}$$

(6)

For the proportional hazard model a hazard is specified as:

$$\theta_i(t|x(t)) = \theta_0(t) \cdot \exp(x_i(t)'\beta),$$

(7)

where $\theta_0(t)$ is the baseline hazard at time $t$, $x$–vector of covariates, and $\beta$–vector of unknown parameters.

Following the (Meyer)(1990) derivation, the likelihood function is:

$$L(\gamma, \beta) = \prod_{i=1}^{N} L_i(k_i, d_i | \gamma, \beta) = \prod_{i=1}^{N} \left[1 - \exp[\gamma(k_i) + x_i(k_i)'\beta]\right]^{d_i} \times \prod_{i=1}^{N} \left[\exp[-\sum_{j=1}^{k_i-1} \exp[\gamma(t) + x_i(t)'\beta]]\right]$$

(8)

where $TC_i$ is the censoring time and $d_i=1$ if $T_i \leq TC_i$ and 0 otherwise, and $k_i = \min(\text{int}(T_i), TC_i)$. Estimation of this specification for a given choice of discrete intervals yields a nonparametric estimate of the baseline hazard, but does not control for unobserved heterogeneity. Unobserved heterogeneity refers to differences between firms that can appear due to omitted or unobserved variables. Literature on duration analysis (Neumann, 1997, Van den Berg, 2001) shows that unobservable heterogeneity will generally bias the estimated hazard rates downward. Accordingly, we proceed with an estimation strategy to control for unobservable heterogeneity. We use a semiparametric specification to estimate the hazard from the distribution of durations between spikes (Meyer, (1990)):
with estimated parameter vector \((\sigma^2, \beta)\). The proportional hazard model \((9)\) incorporates a gamma distributed random variable \(\varepsilon\) with mean 1 and variance \(\sigma^2\) to describe unobserved (or omitted) heterogeneity among firms. The main argument for choosing a gamma distribution for heterogeneity is that the distribution of the heterogeneity converges to gamma distribution. The convergence for hazard models was proven by Abbring and Van den Berg (2003).

\[
\theta_i(t | x(t), \varepsilon_i) = \theta_0(t) \cdot \exp(x_i(t)' \beta + \varepsilon_i)
\]

\((9)\)

4. Results

We estimated two proportional hazard models\(^6\) with different specifications that allow for firm specific fixed effects. Because the data are intrinsically discrete, we apply a discrete time duration model. Maximum Likelihood estimation results are presented in Table 2. Both models are jointly significant and useful in explaining variation in investment spells across firms. The Log-Likelihood of the second model is higher. The main difference between these models is the specification. Model 1 is based on the theoretical model and includes only profitability shock and capital. Model 2 contains additional variables.

Profitability shock has a positive effect on the probability of an investment spike. From a theoretical point of view, this effect is not clear ex ante. On the one hand, firms would like to replace machines at times when the opportunity costs of lost output are small. On the other hand, firms are encouraged to introduce new machines and increase productivity when returns are high (Nilsen and Schiantarelli, 2003). The estimation results suggest that the latter factor is dominant. Other findings in the literature considering investment decisions of Dutch horticulture also find a positive effect of profitability and other financial factors on the probability of investment (Elhorst, 1993). In line with prior expectations, current capital has a

\(^5\) For our data we estimated also a Proportional Hazard model with normally distributed heterogeneity. This specification led to lower log-likelihood than the model with Gamma distributed heterogeneity. The value of Log-Likelihood was almost the same as for model without taking into account heterogeneity. It confirmed the theoretical findings.

negative impact on the probability of observing an investment spike that can be explained by irreversibility of capital investments. Moreover, with vintage of capital (and consequently with decreasing of level), a firm will be more inclined to invest. In Model 2, the effect of capital has larger magnitude. A similar effect of capital on investments was found in energy installations for the Dutch glasshouse industry (Oude Lansink and Pietola, 2003).

Table 2. Estimation results of the Proportional Hazard Models of Investment

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>St. Errors</th>
<th>Coefficient</th>
<th>St. Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durat1</td>
<td>-3.296*</td>
<td>0.262</td>
<td>-5.146*</td>
<td>0.660</td>
</tr>
<tr>
<td>Durat2</td>
<td>-2.839*</td>
<td>0.248</td>
<td>-4.594*</td>
<td>0.607</td>
</tr>
<tr>
<td>Durat3</td>
<td>-2.299*</td>
<td>0.269</td>
<td>-3.967*</td>
<td>0.559</td>
</tr>
<tr>
<td>Durat4</td>
<td>-2.186*</td>
<td>0.365</td>
<td>-3.891*</td>
<td>0.554</td>
</tr>
<tr>
<td>Durat5</td>
<td>-2.377*</td>
<td>0.519</td>
<td>-3.961*</td>
<td>0.623</td>
</tr>
<tr>
<td>Durat6</td>
<td>-1.839*</td>
<td>0.638</td>
<td>-3.358*</td>
<td>0.698</td>
</tr>
<tr>
<td>Durat7</td>
<td>-1.308***</td>
<td>0.821</td>
<td>-2.384*</td>
<td>0.826</td>
</tr>
<tr>
<td>Durat8-Durat10</td>
<td>-2.568*</td>
<td>1.257</td>
<td>-3.496*</td>
<td>1.250</td>
</tr>
<tr>
<td>Profitability Shock</td>
<td>0.0008*</td>
<td>0.0004</td>
<td>0.0008***</td>
<td>0.0004</td>
</tr>
<tr>
<td>Capital</td>
<td>-0.0006***</td>
<td>0.0003</td>
<td>-0.0015*</td>
<td>0.0004</td>
</tr>
<tr>
<td>WIR received</td>
<td></td>
<td></td>
<td>0.045*</td>
<td>0.015</td>
</tr>
<tr>
<td>WIR</td>
<td></td>
<td></td>
<td>1.898*</td>
<td>0.390</td>
</tr>
<tr>
<td>Debt</td>
<td></td>
<td></td>
<td>0.001*</td>
<td>0.0003</td>
</tr>
<tr>
<td>Successor</td>
<td></td>
<td></td>
<td>0.651*</td>
<td>0.216</td>
</tr>
<tr>
<td>$\sigma^2$</td>
<td>0.448</td>
<td>0.993</td>
<td>0.863</td>
<td>0.595</td>
</tr>
<tr>
<td>Log Likelihood (^1)</td>
<td>-445.2</td>
<td></td>
<td>-421.5</td>
<td></td>
</tr>
<tr>
<td>LR-statistic (^2)</td>
<td>1300.6</td>
<td></td>
<td>1305.8</td>
<td></td>
</tr>
</tbody>
</table>

\(^*\); \(^**\); \(^***\) 1%, 5%, 10%-level significance

\(^1\) Log Likelihood for intercept only model = -1095.7

\(^2\) Model without heterogeneity vs. Model with gamma-distributed heterogeneity

The possibility of getting a WIR-subsidy influenced positively, and it is important to include this variable because by receiving compensation, firms could lower the actual price of installed capital. Another variable related to WIR that is represented by 1988-year dummy captures the effect of the announcement about its revocation in 1988. We explain this phenomenon by the fact that firms which had an intention to invest preferred to do it earlier and get the subsidy before the WIR-law was repealed. Another of the reasons as well can be an uncertainty: after
1988 firms would be more uncertain about future regulation of investments by Dutch government. In this case, uncertainty has a positive influence on a decision to invest.

The significant and positive effect of debt on occurrence of investment spikes may be due to the better investment opportunities proxied by the debt. The use of external financing may signal stronger entrepreneurship and liability of business. It also gives some insight into the planning horizon of a head of firm, but this effect can be better indicated by the presence of a successor. The availability of a successor influences the probability of investing positively.

Both models were estimated taking into account gamma-distributed heterogeneity. The estimation of a variance due to heterogeneity has a positive sign and is significant at 15%-level; the LR-statistic (1300.6 and 1305.8 respectively) proves that models give better estimations, and underlines an importance to correct a model by including heterogeneity.

An additional issue of the comparison between the models is the baseline hazards which represent changes in the probability of observing an investment spike for all firms, given that other variables have no effect. Two baseline hazards are presented in Figure 3. One of the conclusions is that Model 1 overestimates the hazard ratios and the difference in coefficients become larger with an increase of the length of the duration between spikes. In Model 2 the probability of having an investment spike is increasing in the time after the initial fall, and in the seventh year there is a high probability of observing another spike. A similar shape is found by Cooper et al. (1999) and by Meyer (1990). U-shaped hazard was also found by Nilsen and Schiantareli (2003). The shape of the hazard supports an assumption about the presence of fixed adjustment costs that can explain lumpiness of investments.

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7 Hazard ratios are equal to \( \exp(\beta) \)
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Figure 3. Baseline hazards for models with different specification

The high probability of an investment spike in the seventh year of duration, common for all firms, leads to a suggestion that on aggregate level it can be revealed by the seven year cycle of investment activities of firms.

Aggregated data are used to observe investment spells over a longer period. Figure 4 presents the baseline hazards that were estimated for 10 groups of firms. For estimation dummies of spell duration were used as well as firm characteristics (capital, profitability shock, WIR-received, debt, income of farm). All variables (except one dummy for the first year) were significant on 1%-level. Due to insignificance the first year of a spell was not included. A general tendency is a decrease in the level of hazard ratio, but few spikes are observed. They are in the 7\textsuperscript{th}, 11\textsuperscript{th} and 14\textsuperscript{th} year.

The seventh- and fourteenth-year spikes are consistent with our results from individual-level data. Additionally, although magnitudes are very small, it is also possible to see an increase in the 21\textsuperscript{st} - 22\textsuperscript{nd} year. In the aggregated data, the first year of a spell corresponds to 1978. Then we can also assume that year-effect plays a role in estimation of the baseline hazard. Due to this fact, the 11\textsuperscript{th} year investment spike corresponds to 1988. A specific year-effect is consistent with previous individual-firm level results.
An intermittent and lumpy pattern of investments is observed in the Dutch horticulture sector: only 17.8% of firms experience an investment spike, but they account for 67.7% of total investment. These facts determine the importance of understanding this phenomenon.

Duration analysis has been used to investigate the factors that determine variation in timing between investment spikes. Two specifications of model were estimated by the proportional hazard model that controls unobserved heterogeneity. The results at firm-level demonstrate a U-shaped baseline hazard: the lowest probability of investing is just after an investment spike, followed by a small growth with a sharp increase in the seventh year. This supports the evidence of presence of irreversibility and fixed costs that can cause lumpiness of investments.

The firm-specific variables were included. This generates some important results, i.e. the positive impact of a profitability shock and the negative impact of the level of capital on the probability of observing an investment spike. In the second specification of the model that outperformed the first one, the effects of debt, investment subsidies (WIR) and the presence of a successor are also estimated. These insights can contribute to understanding determinants of investment decision making. One of the results is that the inclusion of gamma-distributed
heterogeneity yields significant increase in the log-likelihood and a quite different pattern of baseline hazards. Even though the Dutch horticulture sector has some specific characteristics compared to manufacturing sectors in previous studies, the baseline hazard exhibits a similar shape. Thus, the data and results of the present research can be used for further studying of investment patterns.

Our results at aggregate level confirm the firm-level results. Aggregate data exhibits 7-year periods of investment activities, the same as is found for individual firms. The effect of the announcement of the revocation of the investment subsidy law (WIR) in 1988 is reflected by a higher hazard ratio of aggregated baseline hazard.

The present study has shown a relevance of duration analysis in improvement of our knowledge of the investment behaviour. Conventional statistical approaches are not able to capture the effects of time-varying determinants and length of time-span between investment spikes (or it would require prohibitively complex statistical techniques).

The next result can give a direction for future research. The dummy for 1988 can indicate uncertainty for farmers about future regulations after 1988, and has shown the highly positive impact on probability of observing an investment spike. It is commonly assumed that uncertainty influences investment negatively. Here, however, the uncertainty relates to the years after 1988. The WIR coefficients capture the positive effect of an investment subsidy on the probability of investing. To extend our knowledge it seems useful to estimate models for different types of capital goods separately. Considering these sources of heterogeneity may provide a better understanding of investment behaviour. Regarding the econometric technique, we can propose to use an indirect inference procedure to solve the initial-conditions problem that can substantially improve performance of the duration model.
References


