Investment patterns

in Dutch glasshouse horticulture

Promotor:

prof. dr. ir. A.J. Oskam Hoogleraar Agrarische Economie en Plattelandsbeleid

Promotiecommissie:

prof. dr. ir. R.B.M. Huirne Wageningen Universiteit

prof. dr. C.J.M. Kool Utrecht School of Economics

prof. dr. M.J.C.M. Verbeek Erasmus Universiteit Rotterdam

prof. dr. G. Pfann Universiteit Maastricht

dr. ir. W.E. Kuiper Wageningen Universiteit

Dit onderzoek is uitgevoerd binnen de *Mansholt Graduate School* of Social Sciences

Natalia V. Goncharova

Investment patterns in Dutch glasshouse horticulture

Proefschrift

ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit
Prof. Dr. M.J. Kropff
in het openbaar te verdedigen
op dinsdag 12 juni 2007
des namiddags te half twee in de Aula

Investment patterns in Dutch glasshouse horticulture

PhD thesis Wageningen University – With summaries in English and Dutch

Natalia V. Goncharova, 2007

ISBN: 978-90-8504-668-4

Keywords: investment, uncertainty, investment spikes, entry, exit, duration model, GMM dynamic panel data estimator, Negative Binomial model, Heckman selection model, moving window ARIMA, Principal Component analysis, horticulture

Abstract

This thesis focuses on the analysis of investment decision-making in order to better understand the variables that influence a firm's profit-maximizing strategy. The goal of a firm is to continue to exist, which can be achieved through the maximization of profit. Thus, the investment decision is considered as a realization of the firm's profit-maximizing objective.

To understand the investment decision, investments in fixed capital in Dutch glasshouse horticulture were studied. Because an investment decision is dynamic by nature, investment patterns were analysed during the period 1975-1999, thereby providing a longer term overview. The salient characteristic of Dutch glasshouse horticulture firms is that they remain small-scale family firms with respect to labour and land, but are highly capital-intensive. Moreover, in recent decades, the sector has experienced many transformations in the fields of evolution and adaptation to new technologies, consumer preferences, and market and environmental requirements. This makes the Dutch glasshouse horticulture sector an attractive case for studying investment patterns. This is done by considering an investment decision as having three components: decisions about participation, about level, and about time. These components are a tangible part of investment decision-making; they reflect the latent factors of: investment thresholds, adjustment costs, irreversibility, and risk and uncertainty, all of which predetermine investments.

Results from this research show the relevance of separating the participation and level decisions since the set of significant variables differ (e.g. energy- and land prices are not significant for the level decision), and some of the variables exhibited contrasting signs (e.g. debts, revenue, labour cost). The impact of thresholds is tested on different types of entry and exit, which are considered as investment or disinvestment decisions. The raising of a threshold discourages firms from action; they prefer to delay any decision that can be related to the irreversibility of an investment. The results of this study do not provide strong support for the Real Option theory, which postulates that the effect of the uncertainty can be observed through the changes in investment threshold. While the model based on Marshallian trigger points, which suggests the direct impact of the sector-characterizing variables (such as expectation of output prices, interest rate and uncertainty), explains the participation investment decision better.

A phenomenon that has not been studied in any depth is the effect of uncertainty on investment, which is considered in many studies as ambiguous. This study argues that risk and uncertainty should be distinguished from each other. The estimation leads to the conclusion concerning the difference in their effects on the level of investment, which sometimes contrast with each other. Moreover, the asymmetry in the effect of uncertainty is confirmed.

The timing of investment addresses the phenomenon of lumpy and intermittent patterns of investment, as estimated by a duration model. The timing of investments can be explained by the irreversibility of investment, with the lumpiness suggesting the fixed component in adjustment costs. A 6-year investment cycle was revealed at firm level and confirmed at average level. This implies that new policy instruments for increasing the adoption of new technologies will not necessarily lead to an immediate increase in investments, but will depend on, amongst others, factors associated with the degree of vintage of the installed technologies.

Preface

"Our deepest fear is not that we are inadequate. Our deepest fear is that we are powerful beyond measure. It is our light, not our darkness that most frightens us. We ask ourselves, Who am I to be brilliant, gorgeous, talented, fabulous?

Actually, who are you not to be? You are a child of God. Your playing small does not serve the world. There is nothing enlightened about shrinking so that other people won't feel insecure around you. We are all meant to shine, as children do. We were born to make manifest the glory of God that is within us.

It's not just in some of us; it's in everyone. And as we let our own light shine, we unconsciously give other people permission to do the same. As we are liberated from our own fear, our presence automatically liberates others."

Marianne Williamson

I am an extremely privileged person. Privileged because I have met a lot of people who were not afraid to shine and who, through their light, evoked light in me. Now is my chance to reflect on what I have received from these people and to express my deepest gratitude.

A dissertation is more than a scientific work. It signifies working on my own development as a person. Thank you all very much for giving me lessons in life, for guiding me in my development.

I would like to convey my deepest gratitude to my supervisor Arie Oskam. Thank you for your trust and belief in me; thank you for challenging me, demanding more because you were convinced I could do more; thank you for giving me the feeling that you care about me and my professional and personal development. I am thankful for your critical comments on my thoughts and doubts; you enabled me to make mistakes and to learn from them; and for the meetings I had with you, often transforming into inspiring discussions! I would like also to thank your wife Miriam for her warm hospitality and kindness.

Often, people helped me without knowing it and now this is my chance to tell them how important it was for me. Gregori Ingram, you were not to know that your support of my research in Russia in 1998 was the first step on my way to this PhD thesis. Thank you for opening the door to the new world for me, for showing me perspective, for changing my life without even being aware of it.

Dear Bill, thank you so much for your sincere friendship over the years. You always could find honest and kind words to support me, especially important for me because you are a very intelligent and thought-provoking person.

I am very glad that in difficult moments in my life I was able to receive wise advice from Arie Kuyevenhoven, who contributed vividly to my PhD trajectory. I remember well your philosophical expression about winning a battle, which I repeated to myself many times.

My special gratitude goes out to Jos Verstegen. Thank you Jos for being honest and following your convictions even if it was not easy for you; it was very relevant for me. I am also grateful to you for sharing your expertise and responding to my numerous questions regarding Dutch glasshouse horticulture.

Thank you to my “old” friend Lusine for your understanding, and for sharing my ups and downs. We met within months of my arriving in the Netherlands and we went through many stages of our lives together. I had a wonderful time with you and Jos, celebrating our steps towards promotion, discussing our likes and dislikes, laughing together and making plans for the future.

It was very unexpected, but I am sure it was written somewhere in the book of life that I would meet Laura, first as a room-mate and later as a close and sincere friend. Laura, with your presence in my life I feel I got the sister I never had. Being from different continents, countries and cultures, we discover how much we have and feel in common so when we talk it isn't even necessary to finish the sentence to understand each other. Thank you Laura, Trevor and Lilly, for your unqualified trust and for allowing me to share with you Eva's entry into this world.

Dear Nicole, when I started Dutch lessons with you, I never expected that you would play a crucial role in my life. I read once: "If student is ready, teacher is appearing". Nicole, through your example, just through your presence, you challenge me. You helped me find the most concealed way, the way to myself. I have already learned a lot from you, but I want to learn more. Nicole and Jan, I enjoyed your intellectual company, your knowledge and your warm and wonderful house.

My very special words to Eugenia V. Serova, who encouraged me to start my second PhD. You have the most amazing ability to inspire people!

I would like to thank the rector of Stavropol State Agrarian University Vladimir I. Truhachev for accepting my choice and always welcoming me at my Alma Mater.

I am indebted to numerous academics who have provided help or advice along the way, including Spiro Stefanou, Alastair Hall, Erno Kuiper, Gerard Pfann, Clemens Kool and Guiseppe Bertola. My earnest gratitude goes to Ruud Huirne for introducing me to the Wageningen University and inspiring me to start my PhD. I have also benefited immensely from the insightful comments and inspiring discussions with Ruben Echeverria, William Meyers and Brian Hardaker; thank you Brian for your Australian hospitality. I thank LEI for providing me data for my research, and my special thanks extend to Jacob Jager, who was always willing to help with my queries regarding the data.

The Agricultural Economics and Rural Policy group of WUR has provided an excellent, stimulating environment that has been invaluable to my research. I would like to thank all my colleagues for the intellectual discussions and enjoyable coffee breaks. I have greatly benefited from the econometric lessons and high expertise of Allison Burel and Koos Garderbroek; thank you Daan, Aimee, Gerte, Axel, Zenebe, Nazneen and Moti for sharing the troubles and experience of PhD life; thank you Karen, Dineke and Wilbert for providing not only assistance, but also cooperation in solving many everyday problems.

I would like to express my gratitude to my colleagues from the Business Economics group who helped me settle in the Netherlands in those early years. Thank you Martin for your “big shoulders” and ability to listen. Thank you Christien, Claas Jan, Miranda, Ilya, Guan, Sveta, Oxana, Bouda for being supportive when I needed your help. My special thanks to Irina for your valuable advice and your part in my life. Thank you Marian for your excellent organizational support.

This list would not be complete without mentioning James, who radiates a cheery mood, optimism, and is full of stories that made me laugh.

Thank you Nelly for helping me to fight the threat of RSI. With your care I did not miss such valuable hours of work on my thesis.

I would also like to thank Ronald for his care and support and especially for his gentle teasing about my worries.

Thank you Kumar, for your professional editing of the thesis.

It is a great pleasure to thank Paula and Klazina for providing me with the opportunity to accomplish my childhood dream of riding a horse. It was the only time I could stop thinking about my thesis. The lessons were particularly enjoyable through the participation of people from the course, to whom I am thankful for the pleasant atmosphere.

My particular thanks go to the team of the Montessori school, to Bob, Helma, Monique, Karen and Ria, for supporting me in bringing up my daughter, for introducing her to the Dutch culture and language. Pascal and Jan-Willem, thank you for ensuring that after-school time for Darya was educational and fun. You all greatly contributed to completing my thesis.

Dear Eleonora, thank you for taking from my shoulders the responsibility to teach my daughter not only to speak Russian but also to write in Russian. Thank you Antonina Philippovna, for giving Darya lessons during our visits to Russia, in spite of your holidays. This made it possible for Darya to continue her Russian school education successfully from a distance, and that makes me feel really proud of her!

I am in debt to my aunts Nadya and Raya, my cousins Ira, Galya and Anya, and my friends Marina and Narina from Russia, who always give me that special feeling of connection with my country, my city. Thank you for accepting my not very regular telephone calls, my infrequent post, my short visits; thank you for your warm words and support.

Dear Valery, I enjoyed spending the time we spent together, our long discussions and your supportive and challenging words, which helped me find my way!

Dear Tamara Jakovlevna, thank you for being my great Teacher, not only in developing me as a scientist but also as a person.

Frank, thank you for your sincere love, constant encouragement and unconditional belief in me. This provided me with the confidence and conviction to achieve my goals. And thank you too for being not only next to, but also with me, in all my moments of frustration, doubt, happiness and joy. I am very thankful to your parents, Pauline and Jacques, and all your relatives, who made me feel part of the big family, which I missed here so much.

Of course, the greatest thanks go to my parents, without whose support I could not have completed the thesis. Dear Mama and Papa, Maria and Vladimir, thank you for your infinite love that has surrounded me throughout my life. You are always with me, in my thoughts, in my feelings. I was granted by God to grow up with the love of my grandparents. My dear Shura, Kolya, Dusya and Grisha, thank you for being the cornerstone of my life; I find it very difficult to accept that the two of you cannot share this achievement with me.

My first PhD thesis was dedicated to my mother, my second is dedicated to my daughter, Darya. My lovely Dareshka, without the happiness that you bring into my life it would never have been possible to reach this point. I am glad that you cannot fully understand what you have done for me, that you cannot understand how bitter the first year of the PhD was for me, so far away from you. Thank you for showing the courage to go with me to an alien country, to study other languages, to feel "responsible" for me, and for the sparkling colours of your paintings. As a message to you, I would like to say that my strong belief and additional proposition of this book is:

"Goodness is the only investment that never fails"

Natalia Goncharova

21 March 2007

Wageningen

Table of contents

Chapter 1

Introduction

“When economists reach agreement on the theory of capital they will shortly reach agreement on everything else. Happily, for those who enjoy a diversity of views and beliefs, there is very little danger of this outcome.”

Christopher J. Bliss,

Capital Theory and the Distribution of Income, 1975

1.1. Investment and investment theories at micro level

Investments play a prominent role in increasing the productivity and efficiency of a firm, as well as contributing to economic growth.

An investment can be broadly defined as an outlay of cash in exchange for expected future cash returns (Barry *et al.*, 2000 : p.84) and it is possible to distinguish between capital investments and financial investments. The former is the purchase of capital goods (such as a machine or buildings) in order to produce goods for future consumption. The latter is the purchase of assets (such as securities, bank deposits) with a primary view to their financial return, either as income or capital gain; this form represents a means of saving. In this thesis we focus on the capital (or real) investment. The main purpose of this study is to explain firms' investment behaviour. The most widespread theories that explain investment decisions are the management theory of capital budgeting, the neo-classical adjustment cost theory, and the real option value theory.

1.1.1. Management theory of capital budgeting

A procedure that evaluates the effects of a firm manager's investment choice on a firm's profitability, risk, and liquidity is called capital budgeting. The management theory of capital budgeting is founded on present value models, which provide decision-makers with the information needed to make investment decisions by converting future cash flows to their present cash equivalent. The main models for evaluating and ranking alternative investment choices are the Net Present Value (NPV), the Internal Rate-of-Return Model (IRR), and the Maximum-Bid and Minimum-Sell models. According to the NPV rule, managers invest in a project that has a positive net present value (Barry *et al.*, 2000). The important elements of Present Value (PV) models are the effects of the timing of cash flows and opportunity costs of the investment decision. Time is introduced into PV models in two ways: first, by discounting the future value of cash flows at a discount rate and second, by introducing the firm's planning horizon as a function of decisions concerning production, marketing, finance, and tax management.

The further developments of PV models are models that take into account opportunity costs and the possibility of reinvesting. Modified Internal Rate-of-Return Models (MIRR) allow for cash flows received in each period to be reinvested at the calculated IRR for that investment. The opportunity cost can be defined as the advantage foregone as the result of the acceptance of an alternative. Based on the opportunity cost conception, two approaches can be distinguished: Returns-to-Assets (RTA) and Returns-to-Equity (RTE). The RTA approach focuses on returns associated with the total assets invested regardless of whether they are financed by debt or equity. Thus the opportunity cost of capital is a function of the ratio of initial debt to initial equity. The alternative approach (RTE) assumes that marginal debt and equity opportunity costs depend on the debt and equity levels, rather than the debt-to-equity ratio.

One of the most important extensions of the Present Value models concerns models that introduce the effects of risk. As summarised by Robinson and Barry (1996), this can be done by (1) adding a risk premium to the discount rate to reflect the risks associated with investment; or (2) adjusting the series of risky cash flows so that they represent a series of "certainty equivalent" returns. Other approaches may involve Monte Carlo simulation, decision trees, or sensitivity analysis.

The two basic assumptions of the NPV principle i.e. that the investment is reversible or that, if the investment is irreversible, it is a now-or-never proposition (Dixit and Pindyck, 2001), are highly criticised in the literature. From managerial data it is known that firms often do not invest despite a positive NPV, or firms often have a policy decision rule that only a project with an expected NPV in excess of 20 percent of the investment can be undertaken.

1.1.2. Adjustment Cost Theory

A prominent concept in the neoclassical literature on investments (Eisner and Strolz, 1963; Epstein, 1981) is that of adjustment costs. "Adjustment costs are costs associated with the sale, purchase or productive implementation of capital goods over and above the basic price of this goods" (Nickell, 1978). Eisner and Strolz (1963), Lucas (1967), and Gould (1968) established the adjustment cost theory and confirmed that it is costly for producers to adjust the quantity of capital goods. The assumption of adjustment costs hypothesizes the idea that the average economic price of capital goods increases if the rate of investment increases. There are several specifications of adjustment cost function, the most popular being the symmetric quadratic, which implies strictly convex adjustment costs. According to this concept, investments are spread over a number of years in order to prevent high adjustment costs associated with investments. But this specification cannot explain lumpiness and zero investments adequately. In later research, more general specifications of the adjustment costs function can be found. The asymmetric adjustment costs function for quasi-fixed factors is used in articles by Pietola and Myers (2000), Oude Lansink and Stefanou (1997), Hsu and Chang (1990). Cooper and Haltiwanger (2006) tested a richer specification of capital adjustment costs and found that a model that mixes both convex and non-convex adjustment costs fits the data best. In the thesis of Gardebroek (2004), the more flexible (cubic) specification of adjustment cost function is tested, which allowed non-convexity in an initial part of the adjustment cost function, followed by a strictly convex part. Kort (1987) examined the effects of a concave adjustment cost function to explain the observed stepwise investment expenditures instead of the continuous investments predicted by theory. One of the extensions of the discussion on non-convexities is the discussion on the assumption of the presence of fixed adjustment cost (Caballero and Leahy, 1996, Gelos and Isgut, 2001, Abel and Eberly, 2002). Traditionally, adjustment costs are proportional – to investment with an increasing (for convex), or decreasing (for concave) pattern.

The study of investment patterns of firms reveals that investments are not spread over a number of years. Rather, investments are concentrated in some years, followed by some years in which no significant investment activity takes place (Nilsen and Schiantarelli, 2003, Cooper *et al.*, 1999). The estimation results also show that investment patterns differ between capital goods, e.g. for machines and buildings, Gardebroek (2004) and for buildings and equipment, Nilsen and Schiantarelli (2003).

1.1.3. Option Value Theory

The Net Present Value (NPV) principle and its associated adjustment cost concept are criticized for the fact that they ignore the possibility of delaying investment (Dixit and Pindyck, 1994) until more information (e.g. about prices or government policy) or better technologies (Grenadier and Weiss, 1997) are available. Triggering an investment if entrepreneurs have the option to wait involves a cost from the perspective of the entrepreneur in the form of a lost option value (Dixit and Pindyck, 1994). The NPV rule can be modified and applied such that it capitalizes on favourable future opportunities and reacts to mitigate losses (Trigeorgis, 1997). These modifications of the NPV rule are most often referred to as “real options theory”.

Real options theory, by including the option to wait, might better explain the existing investment patterns of zero and non-zero investments. This theory has its origin in the seventies and has more recently been developed for applications in investment decisions (see Dixit and Pindyck, 1994 for an overview). The theory has been successfully applied in normative models of investment (i.e. dynamic programming models with known parameters), but examples of positive modelling based on real options theory are still scarce to date (Tauer, 2006, Purvis *et al.*, 1995, Ostbye, 1997) and are often based on the implicit modelling of real options theory (Pietola and Myers, 2000, Richards, 1996).

Another important distinct assumption of the Real Option Theory is that the investments are irreversible. "When a company exercises its option by making an irreversible investment, it effectively 'kills' the option" (Dixit and Pindyck, 1994). In this case, an opportunity cost in Present Value models should include the lost option value. It should be noted that the option value of an investment is positive for risk-neutral and risk-averse firm operators, implying that both risk-neutral and risk-averse firm operators invest less than optimally according to NPV levels.

The Real Option Theory underlines the crucial role of uncertainty in the timing of capital investment decisions. If in the PV value models, systemic (common to all firms) and non-systemic (firm-specific) risks are added onto the discount rate to compute NPV, then taking into account uncertainty – for estimating the value of the opportunity – can lead managers to delay investments. Thus, in the option view of investment, uncertainty is "far more important and fundamental" (Dixit and Pindyck, 2001). In the same article, the authors write that uncertainty, at the same time, can prompt managers to accelerate other investments. Due to the non-unambiguous effect of uncertainty on investment decisions, researchers are confronted with two problems: first, classifying different types of uncertainty and second, measuring that uncertainty.

1.2. History of Dutch horticulture sector and the main challenges of future

Dutch horticulture is a very attractive case for exploring the investment behaviour of firms. This is a capital-intensive sector with high investments (about 400 million euros annually and 7 billion euros of total invested capital). High levels of inputs in the form of capital, energy, (skilled) labour, and nutrients, have resulted in the highest output levels of glasshouse products in the world. About 80% of Dutch horticulture products are exported around the world; that is 14% of the world export of horticultural products. In this sector, government policy, prices, and technological change are causes of considerable uncertainty, and this has affected investment patterns.

Dutch glasshouse horticulture has a long history[1], from the primitive constructions of wood, or iron and glass, to fully automated constructions including climate control. The second half of the 20th century saw many innovations take place, and these are still continuing. We can divide the development of horticulture into the following areas:

[1] A detailed overview of the history of Dutch greenhouse horticulture can be found in: Nicholson (1994); Plantenberg (1987, in Dutch).

technology improvement, changes due to market requirements, and changes in management and logistics.

The changes in technology aimed at improving light transmission, more economical use of energy, and the minimisation of emissions. To raise efficiency and also to meet requirements of consumers, firms became highly specialised, e.g. in the Netherlands more than 140 different products of vegetables, fruits and mushrooms were cultivated[2]. A classification of specialisation in horticulture can be made into the following groups: cut flowers, pot plants, vegetables and propagations (laboratories). One of the results of recent decades has been a substantial increase (50-100%) in production per square meter. The third area of development in Dutch horticulture sector has its historical roots in 1887, when the first auction in the horticulture sector was held in Holland. At the beginning of 20th century there were more than 150 auctions in operation, and by the end of the century this number had been drastically reduced, primarily through mergers[3]. The auctions and the leading role of Holland as exporter of horticulture production have triggered the development of transport and logistic systems.

All these developments contributed to structural changes in Dutch glasshouse horticulture: the area under glass is steadily increasing (a 32.6% increase in 2004 compared to the level of 1976), while the number of firms is decreasing (a 42.4% decrease in 2004 compare to the level of 1976). This resulted in a growth in the size of firms, on average 229% in 2004 compared to 1976. The smaller firms are leaving the sector; at the same time the number of big firms (≥ 2 ha) increased substantially: from 327 in 1976 to 1,551 firms in 2004. These developments observed within the sector are in the line with the expectations of the future of the Dutch horticulture: that the narrow specialised, bigger-scale firms will be able to compete and survive in future markets.

To maintain its competitive position, the Dutch greenhouse sector has to continuously adapt to new market circumstances and societal demands. The formation of the EU, liberalisation of world trade (WTO), and societal demands with respect to sustainable agriculture create a constant external pressure for change. An important part of this is to encourage investments in glasshouses that comply with the "ecolabel requirements". Careful use of fossil energy and the reduction of glasshouse gas emissions (as agreed upon in the Kyoto protocol) are becoming increasingly important arguments for government intervention. The Dutch government has put pressure on the glasshouse sector to lower the use of fossil energy. In 1997, the Dutch government and the greenhouse sector signed an agreement to reduce the use of energy per unit of production by 65 percent between 1980 and 2010. In

---

[2] www.thegreenery.com

[3] For vegetables, fruits and mushrooms there is a sales company the Greenery (www.thegreenery.com). The most important auctions for flowers and pot plants are Auction Aalsmeer (www.aalsmeer.com) and Flora Holland (www.bvh.nl).

2002, the government assigned a maximum amount of fossil energy use per square meter to horticultural firms. An important way for individual horticultural growers to respond to these government interventions is to invest in energy-saving technology. A better understanding of when horticultural growers decide to do so is valuable to policy-makers when designing intervention strategies.

All challenging opportunities that are linked with uncertainty require investments that will result in an increase in a firm's scale, in restructuring of glasshouses, and automation of processes. Improvement of the environmental performance can be achieved by investments in new technologies. Insight into the effect of firm financial factors, firm characteristics and uncertainty on the timing and size of investments in Dutch glasshouse horticulture is relevant for understanding investment behaviour and the elaboration of strategy of horticulture firms.

1.3. The objective of the thesis, and the related research questions

This thesis tries to rethink the traditional approach of analysing investment behaviour by achieving the four-fold goal:

1) to identify and introduce investment theories that focus on relevant aspects of investment behaviour;

2) to apply the theory to the glasshouse horticultural firms in the Netherlands;

3) to derive which empirically applicable approaches of investment theory function the best; this then gives the opportunity to reflect on investment theory;

4) to see if a new paradigm for analysing investment behaviour is empirically applicable.

Therefore, the focus of this thesis is both on theory and on application. In the subsequent four chapters, specific research questions are defined and worked out, which comprise theoretical and empirical aspects.

1. What are the factors underlying investment decision? What are the effects of these factors on the firm's decision to invest and on the decision of how much to invest? What are dynamic changes and the main characteristics of the Dutch glasshouse horticulture sector, which influence investments?

2. Does investment in the Dutch glasshouse horticulture sector reveal a smooth or a lumpy pattern? How can the lumpy and intermittent pattern of investment be explained? What defines the time duration between investment spikes? What is the time duration for Dutch glasshouse horticulture?

3. What is risk and what is uncertainty in relation to investments? How can risk and uncertainty be incorporated in a theoretical model of investment behaviour in relation to input demand and output supply? What is the effect of risk and uncertainty on investment?
4. What is the link between investment pattern and change in the number of operating firms in horticulture? What is the classification of entry and exit as an investment decision? What is the level of investment trigger points that a firm should overcome for entry and exit? What is the impact of changes in trigger points on the number of entry and exit firms? What is the effect of the uncertainty on the number of entry and exit firms?

1.4. Data used in the thesis

The models in this thesis are estimated on data of Dutch glasshouse horticulture firms over the period 1975-1999. For the research, three data sets were used. The main data set is FADN (Farm Accountancy Data Network). The data of macro-variables were exploited through all chapters of the thesis. “Meitelling” data that provide information on all firms in agriculture, including horticulture, were important for the last empirical chapter.

The period of FADN data is limited by 1999 because changes in the data system occurred in 2000. Due to these changes, 2000-year data is lacking and a combination of later than 2000-year data raises additional problems. Because of this FADN data restriction, two other data sets are used for the same 26 year-period.

Data on glasshouse firms come from a stratified sample of Dutch glasshouse horticulture firms (FADN data) keeping account on behalf of the LEI. The firms rotate in and out of the sample to avoid a selection bias. On average, firms stay under observation for 3-5 years. The data include firms specialised in the production of vegetables, pot plants and cut flowers. Individual firm characteristics include information about the age of the head of firms, the presence of a successor, year in which the firm was taken over, province where the firm is located. One output and seven inputs are distinguished (energy, materials, quasi-fixed inputs). Quasi-fixed inputs are land, buildings, machinery, installations and labour. Capital in buildings, machinery and installations is measured at constant 1985 prices and is valued in replacement costs. Labour is measured in quality-corrected man-years, and includes family as well as hired labour.

The objectives of Chapter 5 require additional information on entry and exit firms. This information is obtained from “Meitelling” data provided by LEI. These data cover the period from 1975 till 2004 and provide information on the full set of firms in glasshouse horticulture, but the list of variables is limited. Due to this problem, the "Meitelling" data are combined with the FADN data.

Besides firm-level variables, some macro-level variables are used in the thesis. They are obtained from the Dutch Central Bureau of Statistics, but required additional processing for reaching the adequate level of aggregation.

1.5. Outline of the thesis

This section presents the main contents of Chapters 2-6.

Chapter 2 starts with the descriptive analysis of investment patterns in Dutch glasshouse horticulture. In this chapter the data of Dutch glasshouse horticulture firms were analysed by Principal Component Analysis. This approach allows exploring the structure of the interrelationships among variables and revealing the most important variables for further analyses of investments. The investment decision can be divided into two steps, first, the decision about the necessity and the possibility of investments is made; second, the decision about the level of investments is made. A Heckman selection model is used for estimation due to the best reflection of this two-steps decision. This model estimates the investment participation decision on the whole sample of firms and then, using a sub-sample of investing firms, the investment level is estimated.

Chapter 3 focuses on the time patterns of investments by investigating the spells between investment spikes in a discrete-time proportional hazard framework. Two duration models were estimated on a stratified sample of Dutch glasshouse firms over the period 1975-1999, which were augmented with a Gamma distribution to account for unobserved heterogeneity among firms. One of the models includes only theoretically-grounded variables; another specification is extended by empirically-grounded variables.

Chapter 4 introduces risk and uncertainty in the analysis of level of investments in Dutch glasshouse horticulture. First, three measures for output-, input- and capital goods-price risk and uncertainty are constructed. If risk is defined as price variability, then uncertainty represents outcomes in the tails of distributions and is calculated as a distance (discrepancy) between expected interval estimation of prices and the realised prices. Second, the influence of risk and uncertainty on investments in Dutch horticulture is estimated. The investments were estimated as an equation of the system, which involves complex decision-making about the production process in a firm, through the 3SLS estimator. Taking into account the dynamic nature of investment decision-making, the single equation of investments was estimated by the Arellano-Bond GMM-estimator of dynamic panel data. The asymmetry of the effect of uncertainty on investments is tested.

In the final, empirical, Chapter 5, the participation investment decision in entry or in exit was considered. On the basis of the description of observed entry and exit investment decisions, the theoretical classification of entry and exit and their empirical implementation were proposed. The thresholds of entry and exit within the framework of Dixit (1989) were calculated for different types of entry and exit in Dutch glasshouse horticulture. Numbers of entering and exiting firms were modelled as a Poisson process that allows the determining of the effects of these thresholds on the entry-exit decision. To achieve the goal of the chapter, two data sets were combined.

Chapter 6 synthesises the results of the various chapters into a proposed paradigm for analysing investment behaviour. The general conclusions provide for the better explanation of the different aspects of the investment decision by summarising findings on underlying investment decision concepts. The coherence of the results is analysed and discussed. Finally, recommendations for future research are made.

Chapter 2

Empirical Analysis of Investments in Dutch Glasshouse Horticulture

Natalia V. Goncharova, Arie J. Oskam, Jos A.A.M.Verstegen

"If only we knew more about the determinants of investment! But, unfortunately, our knowledge in this direction is still very meagre."

Trygve Haavelmo,
Study in the Theory of Investment, 1961

2.1. Introduction

Insight into the investment pattern in Dutch glasshouse horticulture is important because investments are the engine that drives the changes in this highly capital-intensive sector. Glasshouse horticulture is experiencing big changes because of societal demands, while at the same time it is trying to retain its competitive position. The Ministry of Agriculture, Nature and Food Quality of the Netherlands (MLNV) expects future growth and is discussing possible strategies for the developments of agriculture up to 2015. The prospects for the agriculture firms can be most favourable if "they are able to modernise their relationship with the market, the environment in which they operate, and the public" (MLNV, 2005 : p.84). This vision is based on a study by LEI (2005) that provides the prognosis that the glasshouse sector has the highest potential growth of all agricultural sectors. Its value added in constant prices is expected to increase from 3,237 million euros in 2003 to 4,125 million euros in 2015.

Due to the concentration of international trade flows in the country and the innovative character of the sector, the Netherlands can be considered as a trendsetter for glasshouse horticulture. The contribution of the glasshouse horticulture complex (which includes ancillary supplying and processing industry, transport and trade) in the Dutch agro-complex is 20 percent (LEI, 2004). Production efficiency has increased considerably, e.g. the production under glass per m^2 (in constant prices of 1980) grew from €20.9 in 1980 to €41.2 in 2003 (Van der Knijff *et al.*, 2006: p. 10). One of the factors behind the success of the Dutch glasshouse horticulture is the continuous process of increase in intensity of capital use, supplemented by development in technology, mechanisation, and automation. The changes in the level of capital are, however, not uniform over time. This is closely related to an observed investment pattern, with high investment activity during some years intermitted with a low level of investment.

Because of the importance of future changes in Dutch glasshouse horticulture as stressed above, the main goal of this study is to identify the factors underlying these changes and their interrelation with investments.

Plantenberg (1987) gives an extensive description of changes in Dutch horticulture focused on the auction system. Changes in horticulture are considered to respond to changes in society and the economy inside and outside the Netherlands. As analysed by Gijsberts (1987), the population growth and related changes in welfare, consumption, unemployment; development of new institutions and policy instruments accompanied by higher level of education, research and technological progress created the conditions for the Dutch glasshouse sector to take a leading position in the world. Authors of chapters in the book

(Plantenberg, 1987) paid much attention to changes in technology, marketing, and management but not to the investments inducing these changes.

Nicholson (1994) gives more statistical information on the changes in the Dutch glasshouse industry with a short overview of investments. This author observes that the main object of investment has changed from expansion of the business to the continuity of the business and to maintaining positions. The author describes the role of the government in regulating and subsidising investments and creating funds for growers. He makes the connection between changes in investments and changes in prices, income and profitability of firms. Although Nicholson (1994) draws some conclusions (e.g. "high income leads to more borrowing and higher investment"), it is not corroborated by any statistical model.

Several studies were conducted (Oude Lansink *et al.*, 2001, Diederen *et al.*, 2003), aimed at understanding the factors underlying investment decisions of horticultural growers, but they did not provide a long-term analysis of changes in investments. Our approach to investments can be characterised as a positive approach, namely empirical modelling, which describes relevant processes and characteristics by statistical data analysis. At the first stage, Principal Component Analysis (PCA) is used to explore and identify the structure of relationships among variables, and eight factors are obtained that provide a rationale for selecting variables. In the second stage, a theoretical model of investment demand is accomplished by a Heckman selection model, which avoids a selection bias due to many zero investment observations.

We examine the investment pattern and distinguish six sections. After this introductory section, a descriptive analysis of investments and closely related economic developments in Dutch glasshouse horticulture in the period 1975-1999 is presented in Section 2. Section 3 presents methods that were used for the analysis. First, the principal component analysis is explained, and then the Heckman selection model is introduced. Section 4 describes the data and results of the Principal Component Analysis. In Section 5, the data prepared for the Heckman selection model and the results of estimation are discussed. The chapter ends with discussions and conclusions in Section 6.

2.2. Descriptive analysis

The purpose of this section is to provide information on investments in the Dutch glasshouse horticulture sector through the examination of data. In *Figure 2.1*, the average yearly investment per firm is shown. Investments are calculated in 1985 prices and transferred to thousands of euros. The first observation is the lumpiness of investments. We observe investment spikes in the years 1978 and 1988 – 1991, with 71.6 and 86 thousand Euros of investments respectively on average per firm. In the period following these years, a significant decrease in investment activities takes place. The investments in 1978 and 1991 were three times as high as in 1981 and 1994. Such an intermittent pattern among firms suggests that there are general factors underlying the investment spikes in glasshouse horticulture.

The changes in investments in Dutch horticulture are closely related to changes in technology, size, and specialisation on the one hand, and economic and social developments on the other hand (Gijsberts, 1987); in other words, through the influence of internal and external factors.

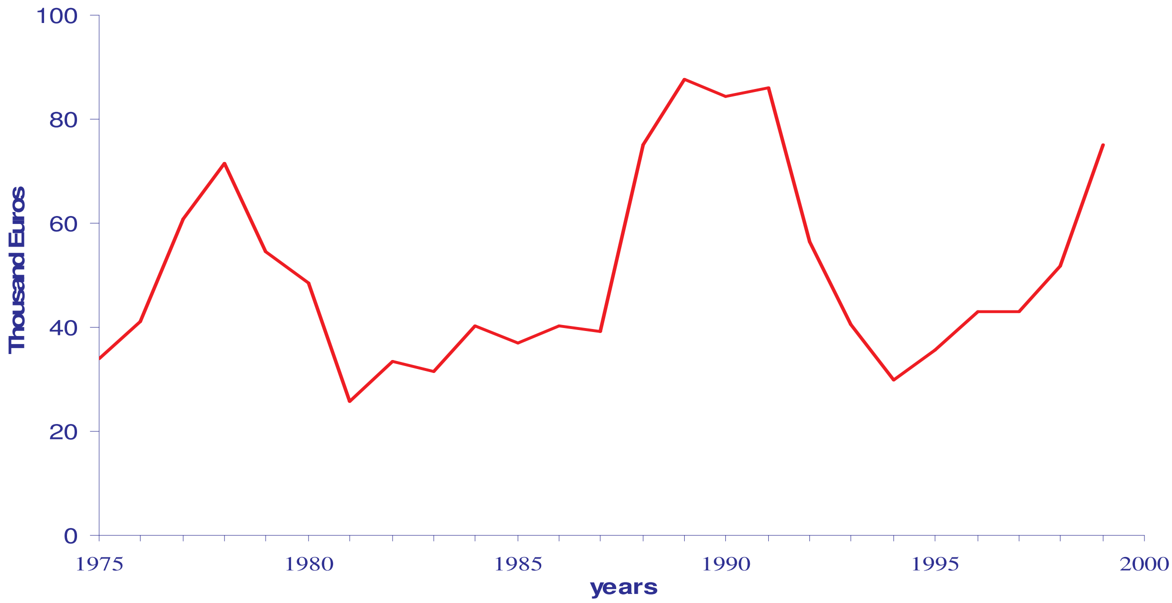


Figure 2.1: **Average investments of glasshouse horticultural firms (normalised by 1985-prices), source: FADN**

Regarding the external factors, there were several possible reasons that could have affected investments. One of the key factors is developments in technology. In the first years (1975-1980) of the period analysed, the glasshouse heating system was converted to run on natural gas, mechanisation improved labour productivity, and automated climate control was introduced. The period 1980-1993 can be characterised as a period of computer technology, which enabled the conversion to substrate culture, trickle irrigation, and CO_2 fertilization. The years 1993-1999 can be seen as a period of change to a demand-driven economy and a close relation with scientific knowledge (Van Meijl *et al.*, 1999; Van der Knijff *et al.*, 2006).

The modernisation of Dutch horticulture has been influenced by government policy instruments. In this context, an investment subsidy called WIR (Wet Investeringsregelingen) should be mentioned. Firms that invested more than 1,760 euros per year in new buildings and installations were eligible for a subsidy (Lught, 1988). The WIR subsidy was considered an instrument of influence on market conditions and on the structure of horticulture firms. It likely played a role in the increase of investments, when it was introduced in 1978 and repealed in 1988, but one of the reasons for its withdrawal (Schlagheeke, 1988) was that it did not stimulate major investments during its years in force. The impact of the WIR repeal on investments could have been caused through this decision being announced in advance (WIR), thereby inducing firms to initiate the investments.

Another explanation, based on changes in the macro-situation, relies on the influence of two oil crises on investments in horticulture. The first increase in the price of imported oil was at the end of 1973 and the second in 1979. These crises induced firms to invest in energy-saving technology. In 1995 this led to an agreement between the glasshouse horticulture sector and the Dutch government to improve energy efficiency. In the literature (Pfann, 1996), we found another possible reason to observe lumps in investments and originated in the theory of Keynes (1936), namely the interrelation of the business cycle with the demand for investments in the way that the rise in demand for investments follows a period of high economic growth.

Our empirical analysis reveals the factors identifying investments in Dutch horticulture (*Figure 2.1*) at the micro-level. We studied investment patterns in two dimensions: among different types of capital (*Figure 2.2, Table 2.1, Table 2.2*) and among different types of firms (*Figure 2.3, Figure 2.4*).

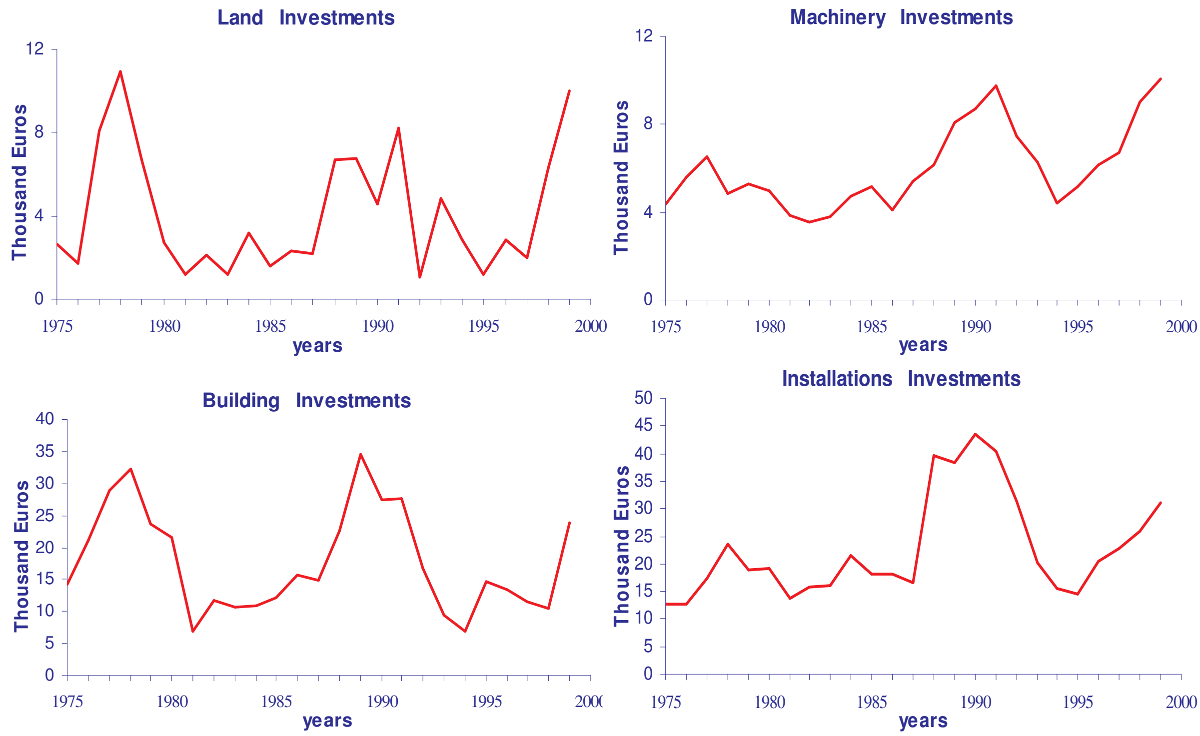


Figure 2.2: **Investment patterns of different investment categories (normalised by 1985 prices, average per firm), source: FADN**

For the first dimension, we used disaggregated data of investment in different types of capital. The figure clearly demonstrates the differences in patterns of the four categories of investment, which are smoothed due to the aggregation in *Figure 2.1*. Another observation is a difference in scale of investment, which can be seen on the vertical scale of *Figure 2.2*. Investment size and investment frequency per firm determine the average level of investments. Details are provided in *Tables 2.1* and *2.2*. For example, the low average level of investment in land is due to a low-frequency investment.

From *Figure 2.2* we can observe that investments during the same years, which were marked out by analysing *Figure 2.1*, exhibit the same pattern of lumpy investments around 1977, 1988-1992 and 1999. The investment in land has some similarities with changes in the investment in buildings, which is plausible because acquiring land in glasshouse horticulture implies the construction of a glasshouse with a possible small time-lag. The time-lag between spikes is about 7-8 years, which is longer than can be observed for machinery and installations (about 6 years) and can be also related to the life-span of the type of capital.

The graph of investments in machinery exhibits investment activities in the years 1977, 1984-1985, and 1990-1991, although they are relatively small at 8,000 euros per firm. The investments in machinery have played a less important role in recent years since modern installations mostly automate processes in glasshouses and replace machinery. The introduction of new technologies and new crops that require modern glasshouses and installations predetermine a large degree of these two types of investments. The similarity of changes in machinery and installations could be due to the complementary nature of these investments.

As the main conclusion, we can suggest that there is a cyclical pattern of investments in different types of capital that results in lumpy investments in particular years, followed by years of low activity. We can provisionally assume that this is a 6-7 year investment cycle, but this assumption requires further statistical analysis, which was conducted separately. Underlying heterogeneity of investments in different types of capital, the possible aggregation of land and buildings investment, as well as machinery and installations investment can be taken into account in future analysis.

Table 2.1: **Summary statistics on the different types of investments (1975-1999)**

Investment	Mean	Std. Deviation	Minimum	Maximum
- in Land	4.1	34.3	-432.6	865.7
- in Buildings	17.7	61.0	-247.7	960.4
- in Installations	22.6	61.9	-150.0	1322.0
- in Machinery	5.9	17.1	-20.9	764.4
Total Investments	50.3	130.6	-510.7	2016.7

** Calculated in thousands of euros and normalised by 1985 year prices*

Table 2.1 presents summary statistics. Scale differences are demonstrated expressed in averages and shares in total investments. Buildings and installations investments are large (35.1% and 45% respectively) compared to land (8.1%) and machinery (11.8%). The high average level of investment (compared to, for example, arable farms) underlines the role of investments in developing glasshouse horticulture as the highly capital-intensive sector. Finally, the high level of the standard deviations reveals considerable heterogeneity across firms and years.

We can see the presence of negative values for all types of investments, with the largest level (-433.000 euros) being for land, although disinvestments are not often observed. By analysing the frequency of observing zero and negative investments that are represented in the first columns of *Table 2.2,* one might be surprised by the high frequency of negative investments, particularly in buildings (15.3%). It is possible to assume that buildings will be sold when a firm exits, but then the land should also be sold. But this is not the case. The high frequency of negative investment in installations is also ambiguous. Further examination of the data showed that investments are very often close to zero; this can be due to low levels of replacement and maintenance of buildings and installations. Therefore we constructed an indicator of relative importance of investment, an investment ratio that is equal to investment divided by accumulated capital. After this, a 'zero' investment was defined where the investment ratio is higher than -0.05 but lower than 0.05.

***Table 2.2:* Zero and negative observations due to a specific definition of 'zero' investments**

Investment	**Zero investment if InvR = 0**		**'Zero' investment if $-0.05 \leq InvR \leq 0.05$**	
	Zero Investment	**Negative Investment**	**'Zero' Investment**	**Negative investment**
- in Land	91.7	1.9	93.9	1.2
- in Buildings	35.7	15.3	77.6	0.6
- in Installations	16.2	8.0	48.6	0.6
- in Machinery	20.4	9.9	43.1	1.4
Total Investments	3.2	6.7	54.0	0.7

Note: InvR is an investment ratio which is equal to an investment divided by accumulated capital

A frequency of negative and 'zero' investments (last two columns of *Table 2.2*) is substantially changed and represents a plausible result, which reveals the high frequency of 'zero' investments and the low frequency of substantial negative ones. This result is consistent with the assumption concerning the irreversibility of investments, because under irreversibility the sunk cost of investments induces firms to postpone investment decisions. Even the total investment, which, due to aggregation usually shows a low level of zero investments (3.2%), reveals 54% of 'zero' investment. Most frequently, 'zero' investment appears in the case of investments in land (93.9%), which can be explained by the location aspects of land and the restricted availability of land.

The second dimension in our analysis is to study investment patterns across different types of firms. To explore the influence of sub-sectors on investment levels, investments in cut-flower firms, vegetable firms, pot-plant firms and mushroom firms are distinguished *(Figure 2.3). Figure 2.3* supports our assumption about heterogeneity among different types of firms in level and pattern of investments. However, it should be noted that all of them exhibit high investment activity around 1977-1978, 1988-1991 and 1999.

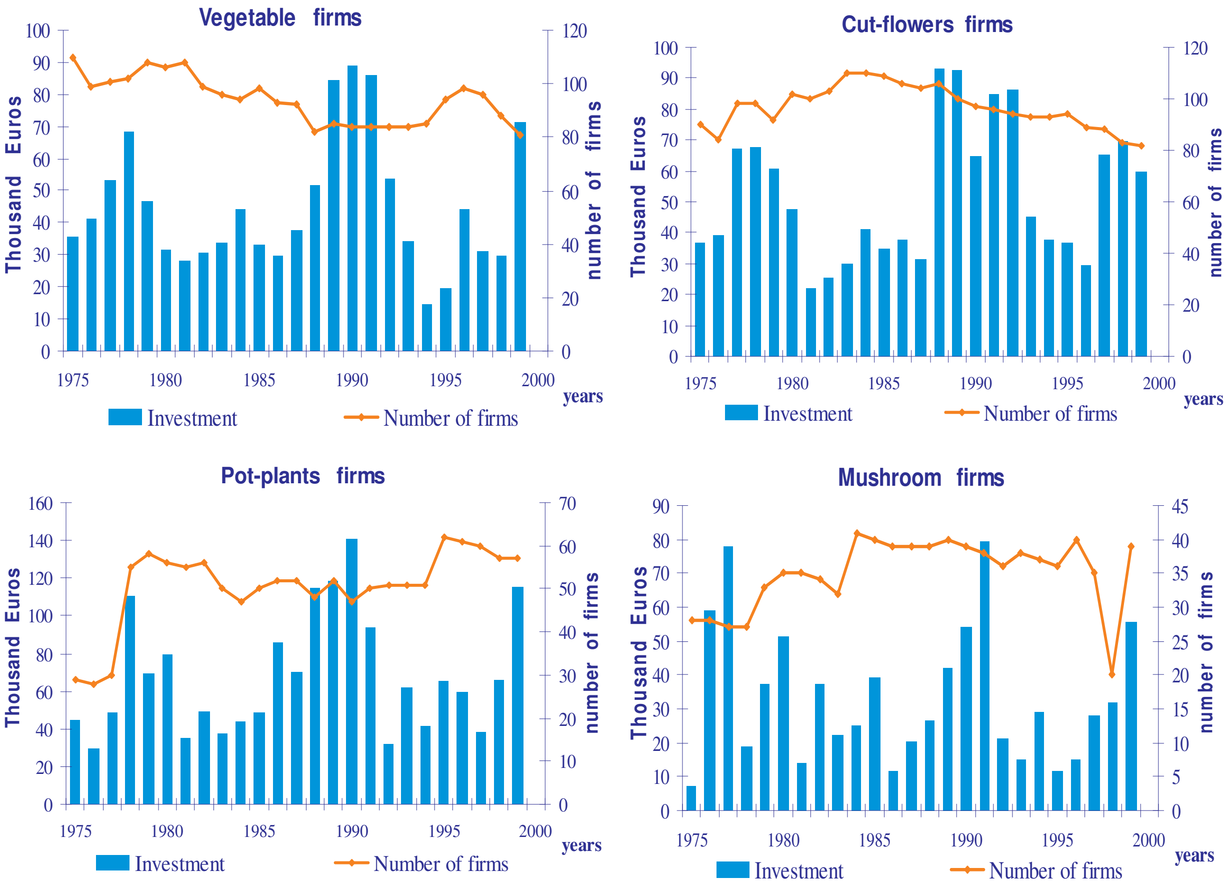


Figure 2.3: **Investments and number of different type of specialised firms in the FADN dataset**

The number of operating firms in our data set is about 240 firms every year, but changes in a share of different types of firms can represent structural changes in the whole population of glasshouse horticulture firms in the Netherlands due to the selection procedure for FADN data[4]. In 25 years, the total population of firms involved in glasshouse horticulture reduced from 17,572 to 11,623 (LEI, 2000b). The changes in numbers of firms for different types of

[4] "The methodology applied aims to provide representative data along three dimensions: region, economic size, and type of farming"(Methodology of the Farm Accountancy Data Network (FADN)).

specialisation for the sample are also presented in graphs (*Figure 2.3*) and, by visually examining these graphs, cannot be related to changes in investments. Although traditional specialisations such as vegetable- and cut-flower firms dominate in the structure of firms in the sample, their quantity is decreasing, i.e. the share of vegetable firms in 1999 was 37% compared to 48% in 1975 (respectively 34% and 51% for the whole population of horticulture firms (LEI, 2000b). Highly competitive surroundings and changes in consumer preferences forced many farmers to introduce new crops and sometimes to change the specialisation on their firms.

The investments of the firms influenced the changes in their size (*Figure 2.4*). DSU (Dutch Size Units) based on the standard gross margins and, calculated by deducting related specific costs from the gross returns per hectare, were used to measure the size (LEI, 2000a). During the period analysed, the average size of a firm increased from 348 DSU in 1975 to 711 DSU in 1999. This indicator also shows a high level of heterogeneity between firms: the standard deviation is 480 DSU in the data set; the smallest firm in our sample had 10 DSU and the largest had 4,887 DSU. During the period analysed, a large increase in scale took place in Dutch glasshouse horticulture, so if, in 1975, there was on average 0.45 ha under glass per horticulture firm, then in 1999 it was doubled to 0.91 ha. The analysis of the sizes of different types of firms suggests that the investment spike in 1988-1991 was complemented by an increase in size of vegetable, cut-flower and pot-plant firms and growth of mushroom firms. The pot-plant firms are larger and clearly show an increase in size after the investment spike in 1978.

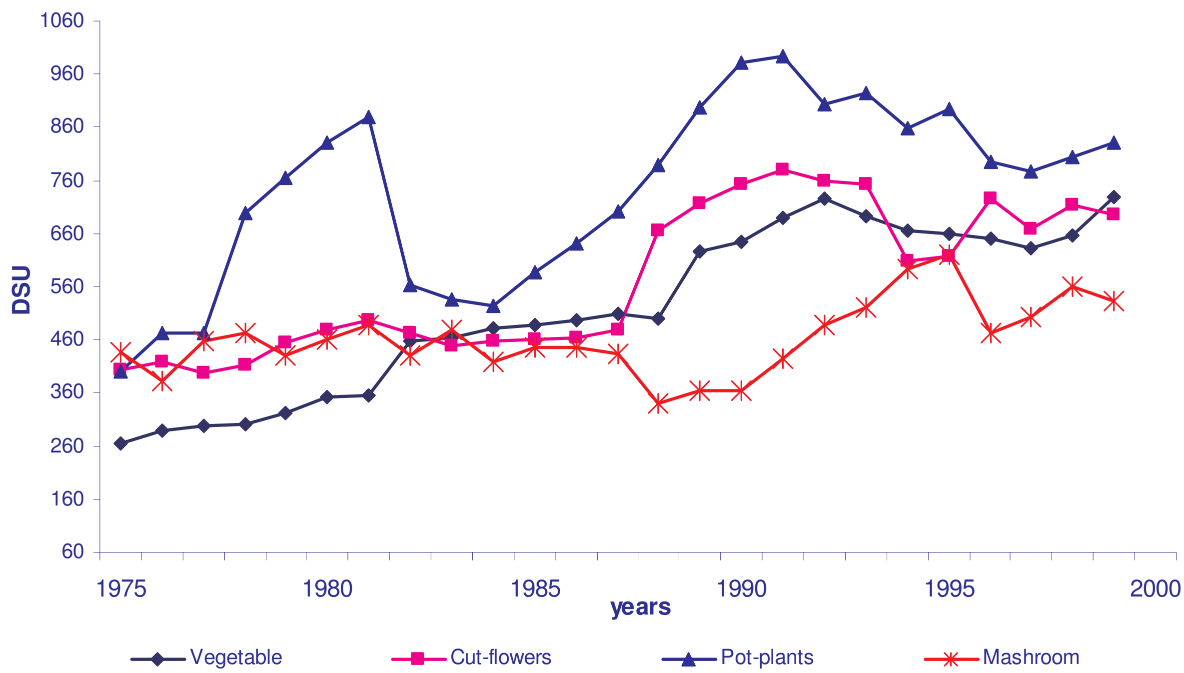


Figure 2.4: **Changes in firm size for different specialisations in glasshouse horticulture, source: FADN**

The simultaneous decrease in number and increase in size of firms in the years of investment spikes indicate the general tendency of leveraging production scale, which can be done by merging small firms into one or acquiring a neighbouring firm. Changes in the economic situation and profitability of investments in glasshouse horticulture may also contribute to the occurrence of investment spikes.

2.3. Methods

Two statistical methods are discussed to provide a framework for data analysis: Principal Component Analysis (PCA) and the Heckman selection model.

2.3.1. Principal Component Analysis

Based on the findings from the descriptive analysis *(Section 2.2)*, the relationships between factors to explain the pattern of investment in Dutch horticulture need to be explored. PCA meets this purpose. In PCA, all variables are simultaneously considered and the aim is to form the components that maximise the explanation of all variables. Each component can be considered as a dependent variable, which is a function of the entire set of observed variables. To perform a principal component analysis, it is necessary to go through several stages (Hair *et al.*, 1998).

By using PCA, two research goals can be achieved: (1) analysis of the structure of the data and (2) data reduction. For the preliminary selection of the variables, a communality test can be used. This test estimates the shared, or common, variance among the variables. The variables with communalities less than 0.50 can be interpreted as not having sufficient explanation.

On the basis of (1) latent root criterion, or (2) percentage of variance criterion, or (3) “scree test” criterion, the number of components (factors) to extract must be defined. The first extracted factor can be considered as the (first) best in the explanation of the variance due to the largest proportion of the variance, the second one as the second best, and so on.

A rotation is useful for interpretation and labelling of the components, because the rotation redistributes the variance between components to achieve a simpler explanation of the components. After rotation, we can consider the component loadings. Component loadings are the correlation between the variables and a component, and can be calculated from the correlation matrix.

After performing the Principal Component Analysis (PCA) and the rotation, the retained components do not explain all variation in the data, but they do explain what is needed to disclose the structure of the data. Because PCA is a purely explanatory tool, it will be used for guiding future hypotheses and the selection of variables in the Heckman selection model.

2.3.2. Heckman selection model

The decision to invest is a very important one due to the long-lasting effect it may have on the operation of a firm. When a glasshouse horticulture firm makes investments, it increases its level of capital in fixed assets, such as glasshouses and installations, to create a suitable production environment. Two characteristics of an investment decision make this type of decision ambiguous: a presence of adjustment costs and irreversibility of investments. Adjustment costs are the costs that are related to the installation of the investment, e.g. planning costs, construction costs, learning costs, and production loss during construction. Irreversibility means nonnegativity of investments, because a firm cannot undo the investment by selling its capital, due to the fixed location of the investment in land, buildings and installations, or due to firm-specific characteristics of capital, e.g. glasshouse firms cannot (easily) be converted to dairy farms. This phenomenon is reflected in the data set, where only 0.7% of negative investments were observed.

Although all firms are potential investors in each year, we saw earlier that a high frequency of zero investments exists. This decision not to invest can be partly explained by both fixed adjustment costs and irreversibility (e.g. Nilsen and Schiantarelly, 2003), but their effect on investment decisions differs. Irreversibility, which reduces the possibility of a firm to disinvest, will be more important when a firm makes the decision to invest or not to invest. Fixed adjustment costs accompany the investment decision as direct costs of search, construction of invested capital, additional administrative costs, as well as indirect costs due to the restructuring of the production process. Variable adjustment costs, which depend on the level of investment, will be more influential on the decision concerning how much to invest.

Every firm operates so as to maximise the expected value of profit. Following the dynamic approach, we consider firms as evaluating the discounted value (with *r* discount rate) of the firm with and without investment (*I*) and then determining whether or not to invest. If the firm is willing and able to invest (decision variable *D=1*) then it counts also for adjustment costs *C(I)*. If the firm is not willing or not able to invest then *D=0*. The Bellman equation (Bellman, 1957) is used to solve the maximisation problem (*Equation 1*).

$$rV(p_t, w_t, K_t, D_t) = \max_I [\prod (p_t, w_t, K_t) - C(I_t * D)] \quad (1)$$

The profit $\prod$ is a function of output (*p*) and input (*w*) prices, capital *K*.

Some variables, such as the presence of a successor or a bad financial situation, relate directly to the qualitative distinction between investing and not investing, and are independent of the amount invested. In other words, some variables can be significant for the participation decision, but insignificant for the investment-level equation. To model an explicit participation decision, it is plausible that firms compare their value function at zero investment versus the value if they decide to invest. Then a participation decision can be written in the form of:

$$D = 1 \quad if \quad \eta > 0, \qquad D = 0 \quad otherwise \tag{2}$$

$$\eta = \Omega([V(\bullet) - V^*(\bullet)],[Q(F) - Q^*(F)]) \tag{3}$$

$\eta = \Omega(.)$ is function of net effects of changes in value of firm and qualitative characteristics due to investments. Firms compare their value function $V(\bullet)$ at positive levels of investment with their value $V^*(\bullet)$ at zero investment. *Q(F)* consists of qualitative characteristics of an investment decision at time *t* and may include the age of the head of the firm, the marketing strategy of the firm, or its corporate structure. The net effect of qualitative characteristics is captured by $Q(F) - Q^*(F)$. If the first term (change in value of the firm) is negative, this can be due to high prices of input (including capital prices) or low output prices. If the second term in Equation (3) is positive, it means that qualitative characteristics associated with investing are greater than those for not investing. As a consequence, it is possible to observe investment, even if $V(\bullet) - V^*(\bullet)$ is negative, but $Q(F) - Q^*(F)$ is positive and offsetting. As an example, investment in fundamental marketing research can be considered, which can introduce direct losses but good positioning in the market. The irreversibility of investments can also offset the positive expectation from the investment and cause a firm to postpone the investment. Another scenario is when the negative second term offsets the positive first term, e.g. when a farmer is not interested in investing because he does not have a successor and he is planning to retire (in other words because he has a short planning horizon); he does not participate even when the investment is profitable. Financial constraints can also introduce the negative offsetting second term: a firm with a high level of debts cannot obtain a loan and cannot participate in the investment decision. Summarizing then, only willing and able firms have a specific participation investment decision reflected by *D*. If *D* is always equal to 1, a firm is assumed to be a potential investor. A Heckman model (Heckman, 1979, Greene, 2003) is an appropriate statistical model for implementing this theoretical approach because it takes into account zero observations of the investments.

Participation Investment equation will then be represented as (for firm *i* at period *t*):

$$\eta_i = \alpha' X_i + u_i, \qquad D_i = 1 \quad if \quad \eta_i > 0, \qquad otherwise \quad D_i = 0 \tag{4}$$

where $u_i \sim N(0, \sigma^2)$

Observed investment:

$$I_i = D_i I_i^{**} \tag{5}$$

Level Investment equation:

$$I_i^{**} = \begin{cases} I_i^* & if \quad InvR_i > 0.05 \\ 0 & if \quad InvR_i \leq 0.05 \end{cases} \tag{6}$$

$$I_i^* = \beta' Z_i + v_i \text{ , where } v_i \sim N(0, \sigma^2) \tag{7}$$

Investment Ratio is defined as $InvR_i = \frac{I_i}{K_i}$; α and β are parameters to be estimated; and X and Z are variables that can be influential on the participation and investment decisions. Large negative investments are excluded from the estimation because of the small (50) number of observations, which makes it difficult to analyse the negative investments.

The error terms u_i and v_i in the Heckman model are assumed to be correlated and the participation decision dominates the investment decision. This model assumes that firms with zero investment observations give no restrictions on the parameters of the investment decision.

The likelihood function corresponding to this model is (Greene, 2003, Gourieroux, 2000):

$$\ln L = \sum_0 \ln(1 - \Phi(\alpha' X_i)) + \sum_+ \ln\left(\frac{1}{\sqrt{2\pi\sigma_v^2}}\right) + \sum_+ \frac{1}{2\sigma_v^2}(I_i^* - \beta' Z_i)^2 + \sum_+ \ln\Phi\left(\frac{\alpha' X_i + \rho\left(\frac{I_i^* - \beta' Z_i}{\sigma_v}\right)}{\sqrt{(1-\rho)^2}}\right) \tag{8}$$

$$(u, v) \sim BVN(0, \Gamma), \qquad \Gamma = \begin{bmatrix} 1 & \sigma\rho \\ \sigma\rho & \sigma_v^2 \end{bmatrix}$$

where BVN is bivariate normal distribution and ρ is a correlation coefficient.

If the correlation between error terms is equal to zero, then the investment decision and the decision about the level of investment are independent and can be estimated separately. This model is called the Complete Dominance Model.

2.4. Principal Component Analysis

2.4.1. Data for Principal Component Analysis

For this study, data of the Dutch Farm Accountancy Data Network (FADN) is used. The Dutch FADN is the main source for investigating changes in glasshouse horticulture in the Netherlands. The concept of the FADN of the European Union was launched in 1965 and currently covers approximately 60,000 holdings, annually representing 15 Member States. The Dutch FADN data represents about 8,500 firms in horticulture. This includes, for each firm, approximately 1,000 variables and provides information about land, buildings, labour, costs, financial aspects, and production.

On the basis of a literature review (Diederen *et al.*, 2003; Oude Lansink and Pietola, 2002; Oude Lansink *et al.*, 2001) and descriptive analysis (*Section 2*), a preliminary selection of 31 variables was made. This selection provides information about input, output of firms, individual firm characteristics (such as size of family, presence of successor), financial indicators (such as income, debts, taxes), and price indices during years of observation. As an indicator of the business cycle, the GDP index is included. In agreement with the previously made assumption about the influence of oil prices on investment decisions, the data set comprises an energy price index. Data from 1975 till 1999 formed an unbalanced panel data set consisting of 6,912 observations for 1,505 firms. *Table 2.3* presents the variables and includes descriptive statistics. The table also contains a communality measure estimating the shared, or common, variance among the variables in the data set. Most of the variables show more than a 0.5 level of communality, but some of them with low levels were still included in the data set due to economic meaning. For example, 'investment in land' and 'investment in machinery' were included to explore the role of investments and their interrelation with other variables in the data set.

By studying mean values, we can obtain some information about the data set. On average, a glasshouse horticulture firm has 383,000 euros of capital and invests 22,600 euros in installations and 17,600 euros in buildings (all in prices of 1985). The low level of investments in land is an indication of infrequent investments, but when a firm invests it is also a major expense for the firm, i.e. the maximum for investments in land in the data set is 865,700 euros.

Horticulture is by far the biggest consumer of energy in the Dutch agriculture sector. The firms in our data set have spent, on average, 90,000 euros on energy. The structure of energy costs has changed from 1975 to 1999, due to innovations in glasshouses and installations. In 1999, costs of gas and electricity, the most important energy sources, were 79.5% and 11% of total energy costs; the costs grew by 1.5 and 2.24 times respectively compared to 1975. In the

1990s, the use of hot water, co-generated with electricity, was introduced for heating greenhouse firms, which has resulted in a 9% share of hot water costs in the total structure of energy costs.

Table 2.3: **Communalities, Mean and Standard deviation**

Variables	Variable Labels	Commu-nality	Mean	Std. Deviation
Firm Size (Standard Farm Unit)	FirmSize	0.860	566.7	478.4
Capital, Euros	Capital	0.847	383044.6	371759.5
Investment in land, Euros	InvL	0.384	4060.5	34246.5
Investment in buildings, Euros	InvB	0.784	17562.8	60619.0
Investment in installations, Euros	InvIn	0.767	22547.5	61711.6
Investment in machinery, Euros	InvM	0.261	5912.1	17042.5
WIR received	WIR	0.760	449.3	4157.7
Family Labour Cost, Euros	CostLabF	0.760	53380.0	25416.2
Hired Labour Cost, Euros	CostLabH	0.733	55881.0	72706.6
Contract work Cost, Euros	CostServ	0.419	5457.5	7818.7
Cost of Materials, Euros	CostMat	0.520	13478.5	24657.2
Cost of Energy, Euros	CostEn	0.716	89995.6	88826.8
Debt at the beginning of the year, Euros	Debt	0.865	31527.6	353797.7
Paid Interest, Euros	Intrest	0.863	20564.0	23316.1
Revenue, Euros	Revenue	0.950	365087.6	333717.9
Profit = Revenue – variable costs	Profit	0.855	88241.6	111655.2
Wealth of family at the beginning of the year, Euros	Wealth	0.803	419991.9	517576.5
Firm Income, Euros	IncFirm	0.811	55083.6	85034.1
Off firm Income, Euros	IncOff	0.518	9570.6	10625.8
Taxes Paid, Euros	Taxes	0.582	13455.4	29038.9
Family Size (people working in firm)	Family	0.822	2.32	1.21
Age of the head of firm, years	Age	0.575	44.3	9.6
Presence of successor or young owner (= 1 if successor is available, = 0 otherwise)	Succ	0.423	0.19	0.39
GDP – index	GDP	0.949	1.10	0.19
Price index of output in horticulture / GPI	PrOut	0.940	0.90	0.12
Price index of land / GPI	PrL	0.621	1.02	0.23
Price index of buildings / GPI	PrB	0.858	1.04	0.04
Price index of installations / GPI	PrIn	0.618	0.99	0.04
Price index of energy / GPI	PrEn	0.519	0.66	0.15
Price index of services / GPI	PrSer	0.800	0.94	0.09
Price index of paid labour / GPI	PrLab	0.861	1.02	0.13

** Extraction method: Principal Component Analysis*
*** All monetary values are calculated in 1985-year prices*
**** GPI is general real price index*
***** Number of observations N=6905, except Successor (n=3783), and Wealth (n=5386)*

There were also changes in the structure of labour costs during the years of observation. In 1975, family and hired labour costs were 62% and 38%, respectively, then by 1999 these were 40% and 60% respectively. With the growth in size of horticulture firms, the proportion of hired labour increased. In the data set, the growth of hired labour costs was 2.3 times, but family labour costs remained at the same level. Although the number of non-family horticultural firms has been growing in recent decades, most of them are still run by a family. This makes it essential to consider individual characteristics of firms such as the age of the head of a firm, family size, and presence of a successor. A glasshouse horticulture firm, on average, is operated by a 44-year-old farmer with 2 family members working on the firm, and only one out of five firms has a successor.

The wealth of the family is good collateral for a bank and it can facilitate a firm to invest. Wealth at the beginning of a year was included as a variable. By the same reasoning, debts at the beginning of a year are included. Other variables, which characterise the financial state of firms, are included, such as revenue, gross margin (as the difference between the profit and variable costs, henceforth referred to as 'profit'), paid taxes and interest, and family income. In family income, we distinguish firm- and off-firm income; the role of the latter has been increasing in recent decades because some firms have been trying to diversify their income sources. The off-firm income includes income from off-firm employment as well as non-labour income, i.e. social security benefits, or income from assets.

The price indices of different types of capital, labour, service and energy were normalised by GPI (general price index), which makes changes in prices comparable. All are so-called 'real' price indices.

2.4.2. Results of Principal Component Analysis

A principal component analysis was performed using a correlation matrix. It generates the factors, or latent variables, which explain as much of the variance in these variables as possible. The use of a correlation matrix ensures that using different scales for variables will not affect the analysis, because it takes the standardized form of the matrix. For this analysis, we do not use any prior knowledge we might have about the factor structure of the data and allow any variable included in the factor analysis to be associated with any factor. The components (or factors) reflect both common and unique (specific and error) variance of the variables. Relying on initial eigenvalues of the components, we selected those factors that had an eigenvalue greater than 1, as recommended by Kaiser (1960). The total explained variance after the orthogonal (Varimax) rotation is shown in *Table 2.4*.

PCA seeks a linear combination of variables such that a maximum variance is extracted from the variables. It then removes this variance and seeks a second linear combination, which explains the maximum proportion of the remaining variance, and so on. It results in eight orthogonal factors[5], explaining 71.1% of the total variance of the data. The first two factors have the highest eigenvalue (5.851 and 4.795) and explain 34.3% of the total variance.

Table 2.4: **Total Variance Explained**

Factor	Rotated Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	5.58	18.88	18.88
2	4.80	15.47	34.34
3	3.70	11.95	46.29
4	2.07	6.68	52.97
5	1.99	6.41	59.38
6	1.45	4.67	64.04
7	1.11	3.59	67.64
8	1.08	3.47	71.11

The reliability of Principal Component analysis is dependent on sample size. It can be checked by a test of Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) that is equal to 0.79, and much larger than the 0.5 critical value. This indicates that PCA should yield distinct and reliable components. The Bartlett's Test of Sphericity at 0.000% level ($\chi^2(465)=88840.8$) rejects the hypothesis that correlations between variables are close to zero. These tests indicate that PCA can be useful to reveal the inter-variables relationships in the data.

After the Varimax rotation, the next important step in this PCA is to interpret the factors. For this purpose, the rotated component matrix (*Table 2.5*) is analysed and factors are labelled. The loading of each variable shows a correlation of the variable with a factor. The variables with a coefficient of more than 0.5 are selected as loading a factor and are grouped and enclosed by red lines. Factor loading significance depends on sample size. From Stevens's table of critical values, (Stevens, 1992), a loading of 0.162 can be considered significant for a sample size of 1,000. Coefficients higher than 0.25-value can be considered as important for a factor.

The first is a factor of "Scale", which is highly correlated with variables of firm size and variables such as capital, costs and debts, which also represent the size of a firm. One can see that investments in installations (0.250) and machinery (0.261) are also positively correlated with the first factor. For larger scale firms, more debts and paid interest will typically be observed; these variables have coefficients exceeding 0.8. Among the costs that load the "Scale" factor, the cost of energy has the strongest correlation (0.793). As can be seen in Table 5, a cross-relation exists between the scale factor and the income factor. Some variables

[5] The components from PCA after rotation are defined as factors. Further on in the discussion the term "factor" is used.

that have the highest loading on "Scale" also have quite high loadings on "Income" and vice versa.

Price indexes loaded the second factor and did not include prices of energy and installation prices. The "Prices" factor is negatively correlated with output and service prices but positively with GDP index and prices of labour, building and installations. The result of the PCA does not reveal a correlation of prices with investments. The price indices explain 15.5% of the variance in the data and because the factor does not explicitly show a relation of the price indices with other variables, we can assume that the impact of price is captured by costs and revenue variables in the third factor. GDP-index (0.944) was included to pick up the possible interrelation of the business cycle with investments. This assumption is not confirmed by factor analysis, which may be due to a time lag between years of high profit and years with high investments.

The third "Income" factor accounts for a significant level of variation in the data (12.0%) and includes variables of wealth, profit, firm- and off-firm income and paid taxes. As denoted before, there are interrelations between the "income" factor and the "scale" factor. This demonstrates that although the factors are orthogonal, some variables can still play an important role in more than one factor.

It is also interesting to see that with an increasing income in a family, the debts and paid interest are decreasing (although these are not very important for "Income" factor loading). This seems plausible, because a farmer can prefer to use internal funding for the operation to minimise costs.

The fourth factor was loaded by size of a family and labelled "Family", because it also included the individual characteristics such as the age of the head of a firm, or the presence of a successor. The occurrence of this factor underlines the importance of paying attention to individual owner- or entrepreneur characteristics.

The fifth factor "Investments" (with eigenscore 1.99) explains 6.4% of the variation of the data and underlines the role of two types of investments: investments in buildings (0.872) and investments in installations (0.813). The low correlation coefficient of investment in land illustrates a different position: decisions to invest in land also require 'availability'. Although investments load a factor and, by definition, factors are independent of each other, investments in installation and machinery reveal a relatively high score for the first factor loading. This can be explained due to the importance of capital for the "Scale" factor, and capital can be defined as accumulated investments. The fifth factor reveals the complementarity of investments in different capital assets.

Table 2.5: **Rotated Factor Matrix**

Variable	Component							
	Scale	**Prices**	**Income**	**Family**	**Investment**	**Energy Price**	**Service**	**WIR**
FirmSize	**0.836**	0.126	***0.337***	0.124	0.118	-0.008	0.051	-0.004
Capital	**0.844**	0.034	***0.308***	0.126	0.075	-0.054	-0.010	0.117
DebtBeg	**0.866**	0.223	-0.113	0.081	0.086	0.050	0.187	0.031
Intrest	**0.853**	0.017	-0.220	0.100	0.200	0.145	0.119	0.026
Revenue	**0.815**	0.105	***0.483***	0.079	0.147	-0.017	0.119	0.014
CostEn	**0.793**	0.059	0.180	0.146	0.118	-0.045	-0.077	0.092
CostLabH	**0.785**	0.108	***0.304***	-0.064	0.081	-0.029	0.027	-0.012
CostMat	**0.568**	0.112	***0.368***	0.007	0.130	-0.030	-0.064	-0.166
PrOut	-0.135	**-0.958**	0.000	-0.020	0.014	0.040	0.031	0.023
GDP	0.112	**0.944**	0.047	-0.014	0.011	-0.202	0.036	0.009
PrLab	0.124	**0.894**	0.061	0.018	-0.018	-0.197	0.041	0.042
PrSer	-0.083	**-0.878**	0.009	0.000	0.039	0.136	-0.029	0.043
PrB	0.116	**0.857**	0.022	0.015	0.022	***0.327***	-0.039	0.011
PrL	0.003	**0.665**	0.031	-0.013	0.042	***0.416***	0.056	0.002
IncFirm	0.202	-0.046	**0.837**	0.111	0.067	-0.047	0.221	0.015
Profit	***0.380***	0.009	**0.797**	0.072	0.095	0.021	0.242	0.044
Taxes	0.070	-0.016	**0.753**	0.020	0.084	-0.004	-0.043	-0.029
Wealth	***0.369***	0.158	**0.750**	0.099	0.112	-0.070	-0.225	0.051
IncOff	0.114	0.066	**0.521**	0.177	0.037	0.105	-0.429	0.035
Family	0.181	0.125	0.209	**0.803**	0.046	0.199	0.164	0.126
CostLabF	0.219	-0.023	***0.265***	**0.754**	0.076	0.047	0.233	0.107
Succ	0.066	-0.127	-0.094	**0.597**	0.021	-0.066	-0.088	-0.159
Age	-0.062	0.144	0.094	**0.574**	-0.079	-0.057	***-0.446***	-0.059
InvB	0.121	-0.049	0.040	0.061	**0.872**	-0.015	0.020	-0.012
InvIn	***0.250***	0.016	0.105	0.022	**0.813**	0.013	-0.012	0.177
InvL	0.000	0.000	0.067	0.036	**0.451**	-0.049	-0.024	***-0.415***
InvM	***0.261***	0.019	0.147	-0.036	**0.404**	-0.008	0.076	0.000
PrEn	-0.100	-0.141	0.047	0.065	-0.062	**0.669**	0.166	0.057
PrIn	-0.114	-0.035	0.090	0.007	-0.019	**-0.716**	***0.264***	0.111
CostServ	0.246	0.157	0.121	0.143	0.053	-0.029	**0.535**	-0.095
WIR	0.079	-0.007	0.052	-0.015	0.107	-0.061	-0.076	**0.854**

** Extraction Method: Principal Component Analysis based on correlation matrix*
*** Rotation Method: Varimax with Kaiser Normalization*
**** Rotation converged in 8 iterations*

Price indexes of installations and energy load the sixth factor, but they have different signs. This means that when energy price increases the price of equipment for glasshouses decreases, and vice versa. Variables of price indexes in land (0.416) and buildings (0.327) are also relatively important for this factor and can indicate that changes in energy prices can be related to changes in capital prices. Taking into account the high importance of energy costs in explaining variation in the data, one can assume the interaction of energy prices with investment decision. The two last factors, named "Service" and "WIR" (although included in the table because of eigenscore greater than one), can be excluded from the analysis due to a "Scree plot" criterion, since the line tails off from the seventh factor. Following Cattell (1966), the point of inflexion of the curve should be the cut-off point for selecting factors. One can say that these two factors do not make an important contribution to variation in the data. It means that the WIR subsidy played a minor role during the years in which it was in force.

The result of the PCA reveals the most important components to explain the variance in the data set. Because the investments loaded one factor, it is not really possible to say what variables explain the investment pattern. One can say that an investment decision is very complicated, and decisions are made based on a combination of different variables. Yet, the capital, which is the accumulated investments, is one of the most important variables distinguished by PCA. Therefore, based on the analysis of the first factor, we hypothesize that investments affect the *scale* of business through capital. Another hypothesis from the PCA is the interrelation of different types of investments. The presence of correlation between different types of investment can lead to the assumption that investments in one type of capital can possibly predetermine investments in another type, due to complementarity of investments or due to common causes (e.g. the repeal of the WIR subsidy).

2.5. Heckman selection model

2.5.1. Data for Heckman selection model

Following the theoretical discussion (*Section 2.3.2*), two sub-samples can be distinguished: one which represents zero investments, and another which represents positive investments. Thus, the dependent variable for the Investment Participation Equation is a dummy variable with zero or one values. The total level of investments is used as a dependent variable for the Investment Level Equation. The choice of explanatory variables was based on the results of the PCA. Because one of the conclusions in *Section 2.4* concerned the indirect correlation of investments with other variables in the data, the variables representing main factors are selected for further investigation.

Rationalizing the selection, why one variable should affect participation and not investment level, or vice versa, is difficult to determine. Therefore, both equations were postulated to be a function of the same variables, which were chosen to represent components extracted by PCA: capital, wealth, debts, firm size and labour cost represent the factor of "Scale", prices of output (as the prices which loaded the factor "Prices"), land, capital and energy representing the second and fifth factors, wealth representing the "Income" factor. To capture the effect of the planning horizon of a manager, the age of the head is included. The WIR variable, although it did not contribute much to the variation of the data, was included to analyse its effect on investment. Some of the variables give qualitative characteristics of a firm, which can offset (*see Equation* 3) the profitable investment decision. One additional variable, which indicates a firm entry, is also included. The reason is that the first year of operation is usually accompanied by investments. The decision concerning participation due to entry can have a different structure compared to the decision of the existing firm. Following our earlier discussion on the Heckman selection model, the first decision is made concerning participation (invest or not invest) and this decision dominates the second decision about the level of investment.

Table 2.6: **Sample means**

Variable	**Mean**		
	Full Sample N=5341	**Zero investment n1=2927**	**Positive investment n2=2414**
Investment, level*	50.360	6.790	103.190
Investment, observation	0.457	0	1
Capital*	390.790	388.262	393.855
Wealth*	419.897	379.724	468.607
Debts*	330.864	337.554	322.751
Firm Size, SFU	0.584	0.554	0.621
Output Price Index	0.887	0.870	0.907
Land Price Change	0.059	0.054	0.064
Capital Price Change	0.005	0.005	0.005
Energy Price Change	0.015	0.011	0.020
Revenue*	376.993	338.375	423.818
Labour Cost*	111.553	104.346	120.292
WIR*	0.435	0.317	0.579
Age	44.8	45.7	43.8
Entry (=1 if first year of operation, =0 otherwise)	0.005	0.003	0.007

** All monetary values are calculated in 1985-year prices and transformed to thousands of euros*

Table 2.6 contains variable means for the entire sample and for sub-samples. To make our estimation and post-estimation consistent, all observations with missing values were excluded, resulting in 5,341 observations on 1,390 firms in a full sample. An examination of the table reveals a substantial difference between variables. This difference can lead to the different estimation results conditional to what sample is used. Comparing sub-samples with zero and positive investments, one can see that an investing firm has a bigger scale, which exposes a higher level of revenue, wealth and capital; and it is run by a younger entrepreneur. A higher level of debts at the beginning of a year is typical for firms that choose not to participate. The combination of the lower debt with the larger family wealth allows firms to overcome the financial constraints in acquiring investment, and it is typical for the second sub-sample. The difference in output-price index between sub-samples is obvious: presumably for reasons of tax deduction, firms prefer to invest in years of high output prices.

2.5.2. Results of the Heckman selection model

In this section the participation- and level equations are analysed within one framework. The results of estimation[6] (taking into account a firm-specific effect) are represented in *Table 2.7.* The Wald test ($\chi^2(5)=335.4$) confirms that coefficients of Level Investment equation are significantly different from zero. To accomplish the validity of choice of the Heckman selection model, we should test the hypothesis that equations are independent. The Wald test rejects this ($\chi^2(1)=2.04$) at 5% level; this means that standard regression techniques applied to the Investment Level equation could have yielded biased results. The selectivity effect is represented by λ, for which $\sigma\rho$ is the coefficient. This coefficient is -14.9, because it is the product of the correlation coefficient (-0.1023) and standard error of the residuals of the level equation (145.8). The Heckman model is only identified through the nonlinearity of the Inverse Mill’s Ratio (IMR), as there are no exclusion restrictions on other variables. Including a number of exclusion restrictions on variables, however, led to the conclusion that the identification via IRM does not depend very much on those restrictions.

Most of the coefficients in the participation equation are significantly different from zero. The firm is likely to participate in investment if it has a low level of capital, relatively low debts, a small firm size, a younger manager and if it experiences growing output and land prices. The participation equation has many negative coefficients; this can be an indication of an irreversibility barrier, which makes the decision to invest more complicated. The investigation of the effect of changes in prices reveals that the increase in land prices and energy price can motivate a firm to invest, but the growth of capital prices has an opposite effect (that is not surprising due to a consequently increasing cost of investment). The positive

[6] For estimation, STATA 9 software is used.

sign of changes in energy price can be explained by the fact that an increase in energy costs forced many firms (particularly after the oil crises) to invest in energy-saving glasshouses and installations. Higher land prices also run parallel to investment participation. Revenue, as expected, has a significant positive effect on the decision to invest: the more revenue a firm gets, the more positively it views the future.

Table 2.7: **Parameters estimates of Dominance (Heckman) Model**

Variable	Participation Investment Equation		Level Investment Equation	
	Coefficient	Standard Error	Coefficient	Standard Error
Capital	-0.0011****	0.0002	-0.0500*	0.0333
Wealth	0.0002***	0.0001	0.0849****	0.0210
Debts	-0.0004****	0.0001	0.1938****	0.0368
Firm Size	-0.1027	0.1199	46.1812**	26.1817
Output Price	0.8479****	0.0972	46.8212****	14.0034
Land Price Growth	0.2054**	0.1113	-17.7921	20.4733
Capital Price Growth	-2.1004***	1.0665	737.7840****	156.9896
Energy Price Growth	0.4240****	0.1743	-15.0097	21.8154
Revenue	0.0017****	0.0002	-0.0176	0.0402
Labour Cost	0.0004	0.0008	-0.0407	0.1242
WIR	0.0084*	0.0056	0.7517	0.7918
Age	-0.0232****	0.0020	-0.6436**	0.3578
Entry	0.4075*	0.2659	-16.1270	20.6867
Sigma	145.8498	7.8384		
Rho	-0.1023	0.0711		
Lambda	-14.9247	10.3988		
Wald[1)] chi2(1): rho=0	2.04			
Prob>chi2	0.15			
Wald[2)] chi2(13)			398.18	
Prob>chi2			0.00	
– Log Pseudolikelihood	18875.45			

*****; *** ; **, * 1%, 5%, 10%, 15% -level significance*

[1)] The test is the comparison of the joint likelihood of an independent probit model for the participation equation and a regression model on the observed level of investment against the Heckman model likelihood

[2)] The test is if all coefficients in the level regression model being 0

The estimation of the level equation reveals a number of insignificant variables. This can be some indication of the dominance of the participation decision, which is in compliance with the Heckman selection model framework. The variables that influence the investment level positively are wealth, firm size, debts and growth of output- and capital prices. The negative (but not significantly) coefficient of revenue can indicate a concern of firms about adjustment costs, particularly internal ones, which imply a reduction in production. Some variables are important for both decisions and have a similar effect. A higher level of wealth as a source of internal financing and also as collateral positively influences both decisions. The output price has a positive impact because it implies a positive expectation about future revenue. As more capital in fixed assets is in the operation, a firm is less likely to invest and so the firm invests less. Growth of capital prices has a direct effect on the increase of the investment level and can be related to the business cycle effect. Age has the same negative effect in both equations, which can be explained by the fact that a younger manager has a longer time-planning horizon and might also be less risk-averse.

Although the equations are correlated, the correlation is not very strong and this can explain why the effect of explanatory variables varies in sign and significance level. The difference in signs for significant coefficients highlights the importance of using a selection model, rather than, for example, a Tobit system (Amemiya, 1974) or, as it was later classified, (Amemiya, 1984) a Standard Tobit Model (Tobit I), which could disguise the differentiated effects of conditioning variables on the probability and level of investment. For this reason, the previously assumed double effect of debts at the beginning of the year on investments is clearly revealed here. The debts have a negative effect on the decision to undertake investment, because it makes it difficult for a firm to get a loan or because it can indicate recently made investments; but they also have positive effects on the level of investment. If a firm decides to invest in spite of the presence of debts, it indicates an innovative or growing firm with a good financial reputation. Firm size also exhibits opposite signs. It can have a plausible explanation if a bigger firm invests infrequently, but once it has made the decision to invest, it induces a bigger investment compared to smaller firms.

As was expected, some variables that influence the participation equation have no significant impact on the level of investment, e.g. the entry decision assumes the participation in investing but does not predetermine a level of investment. The latter variable may require further investigation. A possibility of getting a WIR subsidy has a slightly significant positive coefficient for the participation equation, but not for the level equation. This outcome confirms the assumption (*Section 2*) about the influence of the revocation of WIR on the occurrence of a burst of investments in the late 90s. The WIR subsidy was considered as an instrument of influence on market conditions and on the structure of horticulture firms, and likely played a role in the increase in investments, when it was introduced in 1978 and repealed later in 1988, but during its years in force it did not stimulate large investments, which was one of the reasons for its withdrawal (Schlagheeke, 1988). This is a possible explanation of the not significant coefficient in the level equation.

The goodness of fit of the participation model is represented in *Table 2.8*. Zero investments were predicted better (2,189 out of 2,927) than positive ones (1,197 out of 2,414), but in general the prediction power of selection (63.4%) is good, compared to "naive" prediction. But the goal of the model is to predict the level of positive investment taking into account the participation equation estimation.

Table 2.8: **Goodness of fit for participation model**

		Predicted values*		
		Zero investment	**Positive investment**	**Total**
Actual observations	**Zero investment**	2189	738	2927
	Positive investment	1217	1197	2414
Total		3406	1935	5341

** Predicted values defined by (0.5 , 0.5) criterion*
*** 3386 correct observations, Count R^2 = 63.4 %*

As a type of goodness of fit for the level equation, the investigation of the expected conditional mean and the actual mean total investments was conducted. The conditional mean is calculated by formula (Rosinski and Yen, 2004):

$$E(I_i^* \mid I_i^* > 0) = \exp(\beta' Z_i + \sigma_i^2 / 2) * \Phi(X_i\alpha + \rho_{ii}^{vu}\sigma_i) / \Phi(X_i\alpha) \qquad (9)$$

and equals 46.7. Using the t-test, the null hypothesis that the conditional mean is equal to the actual mean of investments cannot be rejected (*t=2.14, df=534)*.

2.6. Conclusions and discussion

This chapter investigates investment patterns in Dutch glasshouse horticulture. The descriptive analysis of investment patterns was conducted over the period 1975-1999. The investments in different types of capital were explored separately, as well as the investments for different firm specialisations. On this basis, it was concluded that for the analysis of investments, it is important to take the heterogeneity of capital into account. The descriptive analysis obviously reveals an intermittent and lumpy pattern of investments. It was shown that including relatively small ("maintenance") investments in the definition of zero investments better reflects the occurrence of zero and negative investments. The high frequency of the former and low frequency of the latter is consistent with irreversibility of investment, as was also discussed by (Nilsen and Schiantarelli, 2003). From the analysis of increasing firm sizes and decreasing numbers of firms, we can conclude that investments in fixed assets underline the increase of scale in horticulture business. As a supplementary conclusion, we can propose that a distinctive analysis of entry-exit and operating investments are interesting areas for future research. The specialisation of firms is one of the factors that should be taken into account due to the differences in required capital on the one hand, and the dissimilarity between the output-, input prices on the other.

The different mean values for the different types of investments indicates the different role of the assets, but there are quite some similarities of patterns between land and building investments and between machinery and installations investments. This was confirmed by the fact that investments loaded on the same factor.

The explorative study was concluded by Principal Component Analysis, which generated 8 factors covering 71.1% of total variance in the data. The most important factors were labelled scale, prices, income, and family characteristics. Investments in land, glasshouses, installations and machinery loaded the fifth factor, which counted for 6.4% of variance. Variables that loaded high on these factors were used for an estimation of investments by a Heckman selection model.

A Heckman selection model, as an appropriate statistical model for implementing the proposed theoretical approach, was chosen due to the censoring (zero observations) in the dependent variable, which is the yearly total investment of a firm. The model distinguishes two decisions: the (participation) decision whether or not to invest and the (level) decision on how much to invest. The results confirm that changes in variables that increase the profitability of firms, together with limited financial constraints and a younger head of the firm, make the decision to invest more probable. Nevertheless, with increasing land- and energy prices, a firm is more willing to invest. This can be explained by the fact that increasing land prices can include the business cycle effect, which builds up the expectation of higher profitability in farming, which attracts investments; and energy-price shocks push to invest in energy-saving technologies.

A smaller set of significant variables predetermines the decision about the level of investment. Some of these variables exhibit an opposite sign compared to the participation decision. So, the high level of debt is negative with respect to participation decision, but positive for the investment-level decision, presumably separating conservative firms from progressive ones.

Because the two equations are not significantly correlated, the decisions about participation can be distinguished from the investment-level decision. The results of estimation show two reasons for this: first, for some variables as debts, revenue, labour cost, prices of land and indication of firm entry, the opposite signs are observed; second, some variables are significant for participation-equation (e.g. energy- and land prices, revenue) but not significant for the investment-level equation. The difference can be referred to the discussion about the effect of qualitative characteristics on investment decision. For example, the irreversibility of investment can entail a firm to postpone investment, even if investments may be profitable. Adjustment costs can influence the decision about level of investment; for example, due to the high learning costs a firm may choose investments in conventional technology instead of introducing a new one.

The results of this chapter can be used in three main ways. First, this is the descriptive analysis of the changes in horticulture in the Netherlands during 1975-1999, which were achieved through intensive investments. The revealed lumpy and intermittent investment pattern suggests that a future study of this phenomenon would be fruitful. Second, the Principal Component Analysis gives an explorative overview of the variables (and their relations) that play an important role for Dutch glasshouse horticulture firms, and which can be used for selecting variables for empirical models. Third, the result of the Heckman selection model demonstrates the rationale of using a two-step approach to the investment decisions and represents the impact (or occasionally lack of impact) of each variable for both steps. Policy makers can use this outcome to better select policy instruments for guiding investment decision-making within glasshouse horticulture and outside it.

Chapter 3

Investment Spikes in Dutch Glasshouse Horticulture

Natalia V. Goncharova, Arie J. Oskam,
Alfons G.J.M. Oude Lansink, Arno van der Vlist, Jos A.A.M. Verstegen

"One of the principal consequences of the irreversibility of time is that past and future are different. Not just different as front and back are different; you cannot turn past into future, or future into past, as by turning round you can turn back into front. The past is over and done with; it is there and cannot be changed"

John Hicks, 1976

3.1. Introduction

When analysing firms' investment behaviour over time, one typically observes periods with little or no investment, followed by periods with intensive 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, lumpy and 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 and creating investment spikes in particular years (Jovanovic, 1998). When investments are irreversible, firms usually cannot disinvest without incurring high costs, affecting their decision about the timing of investment. Investments are partly or completely irreversible due to incomplete markets for used capital goods, and the time- and firm-specific nature of capital goods. Nilsen and Schiantareli (2003) conclude that irreversibility increases the likelihood of intermittent patterns of investments. The implications of irreversibility for aggregated investments are analysed by Bertola and Caballero (1994), while Abel and Eberly (1999) concentrated on the effects of irreversibility on capital accumulation. Bertola (1998) found that irreversibility can explain the occurrence of investments at distinct times that could possibly generate a fairly regular cycle in a macroeconomic model. The cyclical behaviour of all economic variables is influenced by irreversibility, because large installed capital impacts the responsiveness of prices, employment and production with respect to unfavourable changes in a firm's business conditions (e.g. drop in demand, introduction of new regulations).

The impact of non-convexities on investments was discussed by Davidson and Harris (1981). They postulate that in the presence of a fixed cost component in adjustment costs, one of the optimal long-run policies is a sequence of investment cycles with a constant period, each cycle involving a period of investment followed by a period of no investment. Caballero and Leahy (1996) focus on fixed costs to provide a model of a firm's investment decision that can generate lumpy investment patterns. Cooper and Haltiwanger (2006) find that a model that includes both convex and nonconvex adjustment costs with irreversibility fits the data best, because it is able to produce nonlinear relationships between investment and fundamentals, measured as profitability shocks.

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 and Eberly (1999) show that increasing uncertainty raises the expected level of capital in the long-run.

Empirical contributions considering time spells between investment spikes are rather scarce. The time spell is defined as the time elapsed since the firm's most recent investment spike. Cooper *et al.* (1999) is one of the few studies analysing spells between machinery replacements for the US manufacturing industry. They found an increasing probability of an investment spike in time after the previous spike. Nilsen and Schiantareli (2003), analysing 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 absent.

The aim of this chapter is to identify factors explaining an intermittent and lumpy pattern of investments. The methodology to investigate the existence of investment spikes and spells will be further developed and applied. The timing of investments in Dutch greenhouse horticulture has been investigated using duration analysis.

In the period 2001-2003, greenhouse horticulture produced about 30% of total Dutch agricultural production. It is an important and highly capitalised sector that changes rapidly due to investments in new technologies in installations, machinery, equipment and glasshouses (all with different life cycles). Generally, installations take the biggest share of the capital investments in greenhouse horticulture. Contrary to many industries or manufacturing firms, greenhouse horticultural firms are owner-operated, often as family operations, leading to limited access to capital markets and subsequently a higher need for own capital compared to the manufacturing firms that were used in the analyses of Nilsen and Schiantareli (2003) and Cooper et al. (1999).

In this chapter, we discuss the theoretical background of the empirical analysis, formulating the investment decision as a dynamic optimisation problem where firms invest to maximise the discounted present value of profits, which provides information about the timing of investments. In the empirical application, we constructed duration data from an unbalanced panel sample of greenhouse firms in the Netherlands for the period 1975-1999. In addition to the panel data, an average data was used of the analysis. Because of the applied rotating sample, individual firms are represented in the data set only for a limited number of years. To be able to analyse investment spikes over a longer time period, ten groups of firms were formed based on their size, and data of firms within each group was averaged. The probability of an investment spike is modelled as a function of time elapsed since the last investment spike, and of firm-specific variables. The results are obtained for two specifications of the model: a 'standard' model and an extended model adjusted to the situation of greenhouse horticulture. The durations of spells between investment spikes are analysed in a discrete-time proportional hazard framework. This framework allows us to model a baseline hazard for all firms, proportional to a hazard indicating systematic differences between firms. This hazard model is augmented with a gamma distribution to test for the presence of unobserved heterogeneity among firms.

The estimation results indicate that the model with extended specification outperforms the one including only theoretically specified variables. Another finding is the upward-shape of the baseline hazard, which is consistent with the presence of fixed adjustment cost. The highest probability of observing an investment spike is in the sixth year. These results are consistent with results from a model estimated on average firm data, covering a much longer period.

The chapter proceeds as follows: *Section 3.2* provides the theoretical background, *Section 3.3* describes the data and the empirical model and *Section 3.4* presents the estimation results first at firm level and then for average firms. The chapter ends with the discussion and conclusions.

3.2. Theoretical framework

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

$$V(X,t) = \max_{I} \prod(X,t) - C(I,X,t) + \alpha E\, V(X',t' | X) \tag{1}$$

with unprimed variables indicating current values and primed ones indicating future values of variables in time t′. Π(X,t) denotes the profit flow, I investment, $C(I,X,t)$ the adjustment cost function, and α the discount rate (see also notational glossary in Appendix 1).

The adjustment cost function $C(I,X,t)$ includes both convex and non-convex costs components, which result in a pattern of periods of no investments punctuated by lumps of investments (Cooper and Haltiwanger, 2006; Gardebroek, 2004). From the theoretical framework of Cooper and Haltiwanger (2006), the profit function *Π(X,t)* depends on capital *(K),* a profitability shock *(A)* and other state variables representing firm-specific characteristics (*x*). Then the state vector *X* will be defined as (*K, A, x*). We define a profitability shock *(A)* 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.

In the case that the firm operator decides not to invest, the value function (V^W) is given by:

$$V^{W}(A,K,x,t) = \prod(A,K,x,t) + \alpha E[V(A',K',x',t' | x)] \tag{2}$$

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

$$V^I(A, K, x, t) = \max_I \prod(A, K, x, t) - C(I, A, K, x, t) + \alpha E[V(A', K', x', t' | x)] \quad (3)$$

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

$$V(A, K, x, t) = \max[V^W(A, K, x, t), V^I(A, K, x, t)] \quad (4)$$

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

$$E[T] = \begin{cases} T \quad if \quad V^I > V^W \quad invest \\ \\ > T \quad if \quad V^I < V^W \quad not \quad invest \end{cases} \quad (5)$$

The solution to (4) entails investments in period *T* if $V^I > V^W$, given the state vector *(A, K, x).* We characterise this solution by a hazard function θ*(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,* given capital *(K)*, profitability *(A)* and other firm-specific characteristics *(x).*

The influence of the profitability shock *A* on θ*(A, K, x)* depends on the nature of adjustment costs and the distribution of profitability shocks. Cooper *et al.* (1999) showed that the conditional probability to invest θ, is independent of *A* when shocks are identical and independently distributed and when there are fixed adjustment costs. For positively serially correlated profitability shocks, hazard function θ increases in *A* and investment is pro-cyclical. In the case of proportional-to-output adjustment cost, θ decreases in *A*. In other words, in periods characterised by high profitability, investments are too costly, because of reduced output during the investment period.

We expect the hazard function $\theta(A, K, x)$ to decrease in *K*, that is, the lower the level of capital (mostly due to depreciation, because disinvestment of capital is rather rare), the more likely an investment spike. This expectation is based on the discussion in Cooper *et al.* (1999) that "the older the capital, the more likely is replacement".

The main objective is to estimate the hazard function $\theta(A, K, x)$, which shows whether there are lumps of investments.

3.3. Data and empirical model

3.3.1. Data

The empirical analysis is based on panel data of greenhouse horticultural firms over the period 1975-1999. Data come from a stratified sample of Dutch greenhouse firms keeping accounts on behalf of the LEI farm accountancy data network (FADN). The firms rotate in and out of the sample to avoid attrition bias; and they usually remain in the panel for about four to six years.[7] The original sample used in the analysis contained 6,905 observations on 1,500 firms. For our empirical analysis, we construct two data sets: a data set based on individual firm-level data and a data set based on average firm-level data. To analyse lumpiness of investments, we define an investment spike if the investment rate exceeds 20 percent of the value of installed capital[8].

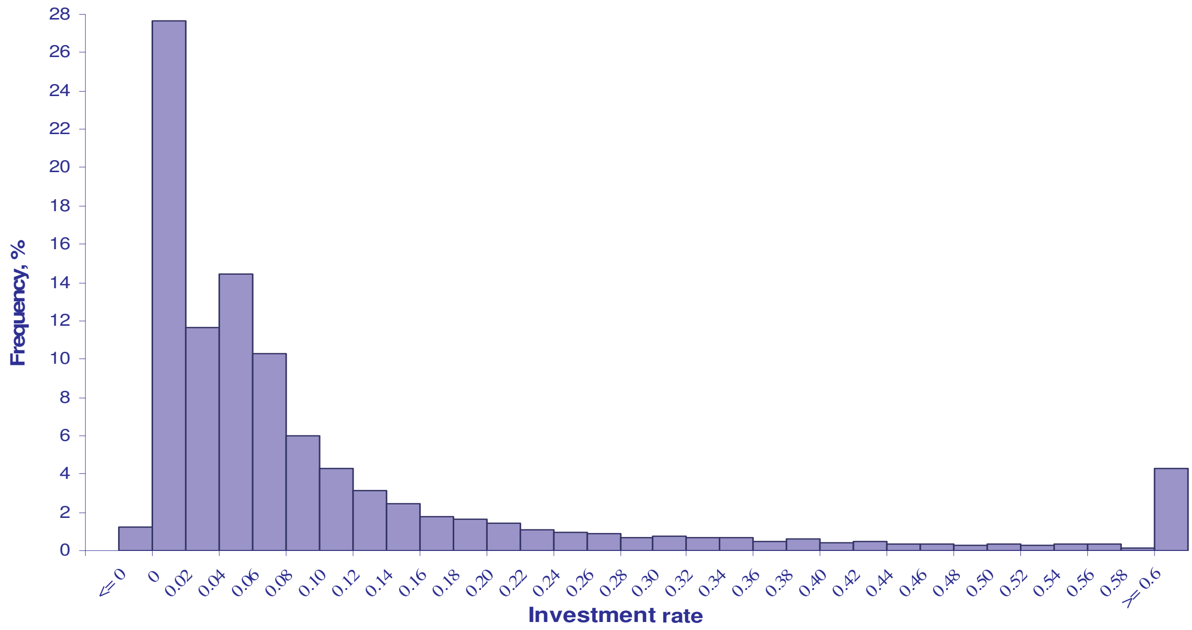


Figure 3.1: **Distribution of investment rates**

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 0.6, the maximum equals 7.18*

Investment patterns can be assessed by the distribution of the investment rates *(Figure 3.1)* that is highly peaked and skewed, with a long right-hand tail. Zero-investments account for about 27.7% of the observations. The majority of observations (36.3%) show 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. Caballero and Engel (1999) extended their model to acknowledge the existence of "maintenance" investment, which allows them to obtain a more

[7] More detailed information about design and methodology of FADN data can be found in Vrolijk and Cotteleer, 2004. The reasons for using a rotating sample can be found in Hsiao *et al.*, 2002.

[8] The value of 20% was chosen due to the arguments in the articles (Cooper *et al.*, 1999, Nilsen and Schiantarelli, 2003) about robustness of results to other definitions of investment spikes.

realistic distribution of observed changes in capital and average investment rates. Negative investments are rare (1% of observations) in the period under investigation and they are caused by the selling of capital. Although only 16.5% of firms experience an investment spike with an investment rate more than 20%, they account for 67.7% of total investments.

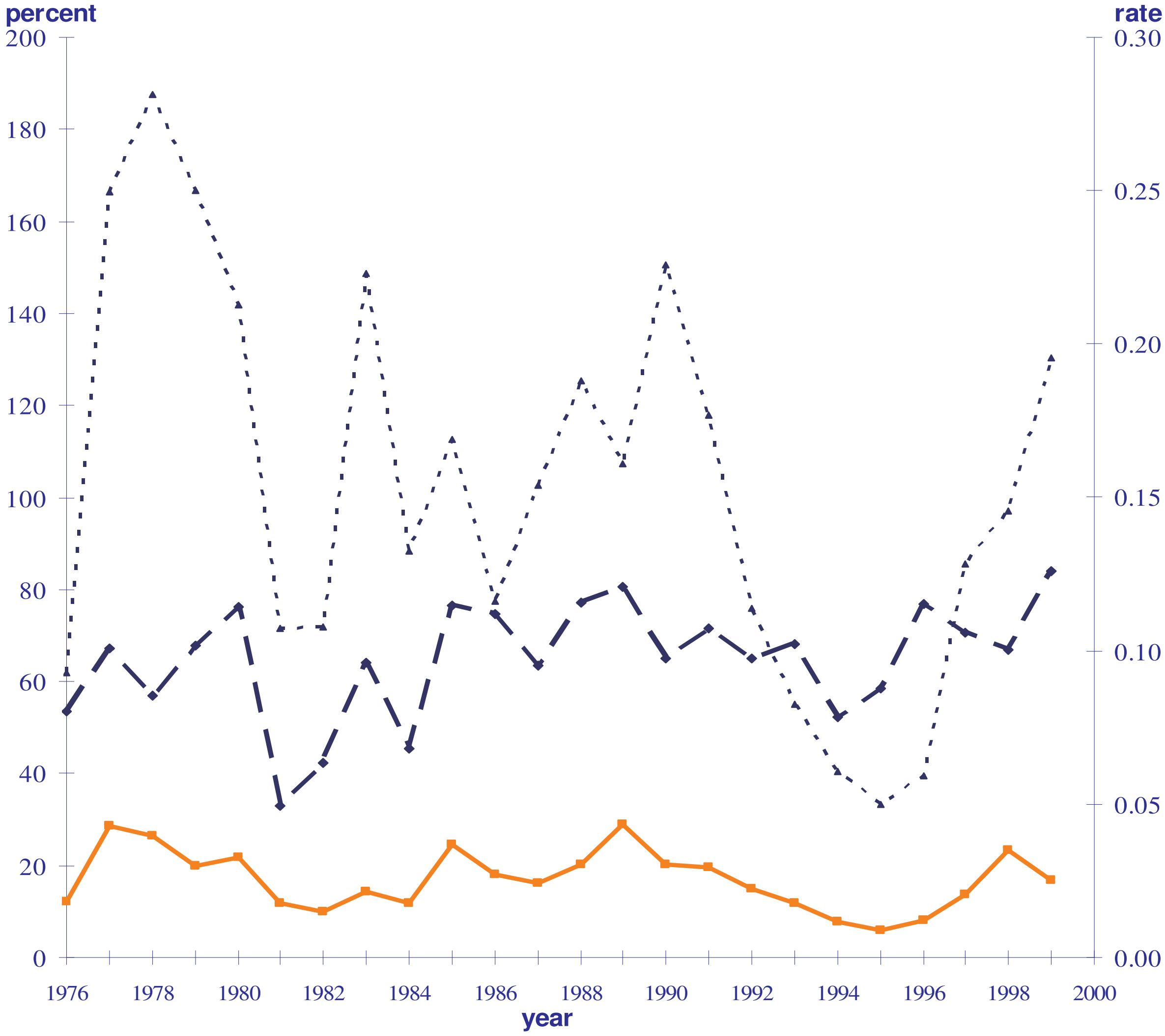


Figure 3.2: **Investment rate and investment spikes**

Notes: The dotted line represents an investment rate that is the ratio of investments to accumulated capital*

*** The dashed line represents the percent of investment accounted by firms having investment spikes*

**** The solid line is the percentage of firms having investment spikes*

Figure 3.2 depicts the relative importance of large investment episodes. The percentage of firms having investment spikes fluctuates from 6-7% in 1994-1996 to 29% in 1977 and 1989, but they account for 76-80% of gross investment. The gross investment rate (which is plotted on the right vertical axis) exhibits peaks in the years 1977-1978, 1983, 1988, 1991, and 1999.

The persistence of time-series fluctuations of investment rate on aggregate level can indicate a presence of an investment cycle effect. But it could also be the influence of some changes in the macro-situation that make investing attractive for firms. For example, the WIR law (Wet Investeringsregelingen, 1988) was in force between 1978 and 1988, allowing firms to obtain a subsidy in the case of significant investments. The announcement in advance of the revocation of this law may have induced firms to invest.

By comparing the percentage of firms having investment spikes with the investment rate, one can see that years of high gross investment ratio can be characterised by a higher frequency of investment spikes. The combination of these two factors results in a lumpy and intermittent pattern of investments.

3.3.2. Characteristic of firm-level data set

The firm-level sample, which we used for the duration analysis, consists of 2,270 observations of 678 firms. All left-censoring observations were deleted to overcome the initial conditions problem[9]. In the final data set, the average number of years in observation for firms is 3.35, and only a few firms were observed for longer than 7 years (with a maximum of 12 years).

A dummy variable *InvSp* represents an occurrence of large investments. For the duration analysis we use "spell", which is the time spent from the previous investment spike until the next investment spike *(T),* or until a firm is dropped from the observation (or at the end of the observation period). In the first case, we have a completed spell (375 spells) and the second case is a right-censored spell (313 spells). More than one (single) spell can be observed for the same firm; in this case, a firm has multi-spells and the average duration of a single spell will be lower than the duration of observation of a firm in the data. In our data –set, the average duration of a single spell is 2.66 years (with a maximum of 10 years).

In the model, we include interval-specific duration dummy variables *(Durat1-Durat7)*, which is equal to one if the investment spike occurred in time-specific interval *T*, and is equal to zero otherwise. The estimation of these dummies provides a specification for the baseline hazard and the age of investments. The interval-specific baseline hazard is only identified for those duration intervals during which investment spikes occur. The number of occurrences is very small after the 7th year. *Table 3.1* gives a description of variables and statistics of our sample.

Capital (CapTot) (as well as all monetary variables) is measured at constant 1985-year prices in thousands of euros and is valued at replacement cost. Capital was normalized by the

[9] We do not know how long ago a previous investment spike occurred and hence we do not know how long the existing duration was at the moment the firm was included in the sample.

price indices of capital in horticulture. The Profitability shock[10] (A) has been calculated as the residuals of a Least Squares regression (OLS), including fixed effects[11], of profits on capital on original data (6,905 observation of 1,500 subjects). The residuals obtained from the model represent firm-specific changes in profit that are not due to changes in the level of capital and can also be interpreted as a lower or higher return than expected on installed capital. The first specification of the model *(Model 1)* includes only capital, profitability shock and dummies for years of duration.

Table 3.1: **Description, mean and standard deviation of the variables used in the models**

Name of variables	Description	Mean	SD
InvSp	= 1 if ratio of investment to installed capital >=20% (investment / installed investment)	0.165	0.371
DuratT	= 1 if investment spike occurred in time specific interval T, = 0 otherwise		
yearY	Dummy for year. =1 if year =Y; =0 otherwise		
Profit*	Profitability shock	15.718	128.03
CapTot*	Capital	500.684	479.40
Firm Size	1000 Standard Farm Units	0.705	0.596
Entry	= 1 if age of firm is less or equal to 3 years; = 0 otherwise	0.028	0.164
Debt*	Long debt at the beginning of year	389.85	390.45

*Notes: * all monetary values are given in 1000 euros, 1985-year prices*

Other firm-specific characteristics, such as a firm's size or debt level, were found important in empirical analysis conducted on Dutch horticulture (Oude Lansink *et al.*, 2001; Diederen *et al.*, 2003). Hence, the second specification of the model for empirical testing *(Model 2)* includes firm's size, entry indicator, and debt. Dummies for some years of observation were included as well as duration spells, capital and profitability shock. Firm size is measured in 1,000 standard farming units (DSU[12]), and it is a measure of the income-generating capacity of a firm. Our data set shows large variations between firms ranging from 52 to 4,887 DSU. Based on the findings (Asano, 2002) that small firms show slower adjustments in capital stock than medium or large firms, the firm size is expected to have a positive effect on the probability of an investment spike.

---

[10] The shock shows considerable variation across firms: from a negative value of -581.500 euros to a maximum of 1,400,700 euros. The coefficient of capital in OLS is equal to 56.6 and significant at 1%-level; R^2 for model is 0.33, F-statistic is F(1, 5405)=82.51.

[11] We used a fixed-effect model due to a Hausman test result of fixed-effect model vs. random-effect model (chi 2(1)=244.90).

[12] Dutch Size Units (DSU) is the national equivalent of European Size Units, an economic measurement based on standard gross margins (sgms) (de Bont *et al.*, 2003).

Long-term loans play an important role in the financing of the large lumpy investments. As an indicator of financial constraints, the long-term debt at the beginning of the year (Debt) is included in the model. A large debt at the beginning of a year can have a negative effect on the probability of observing an investment spike for two reasons. First, it can indicate high levels of investments in previous years, leaving the firm uninterested in investing. Second, it is difficult (and, thus, more costly) to get an additional loan for a firm with a high debt. It is also important to distinguish the debts at the beginning and the end of the year. Although they are highly correlated (R^2 =0.95), they are related differently to investment activity. If long-term debt at the beginning of a year can indicate an obstacle for undertaking a new investment, then the debt at the end of the year can reflect the investment during the year.

An indicator of entering firms is included to take into account the higher probability of observing an investment spike because a firm needs large investments to overcome the entry barriers. Additionally, in the first years, the ratio of investment to accumulated capital will be very high, which is also due to the low level of accumulated capital. We considered the first three operational years as the entry phase because a horticultural firm deals with plant maturation time and organising the firm's operations processes.

Dummies for the years 1977, 1983, 1988, 1990, and 1999 were chosen to reflect the time-series fluctuations of investment rate (Figure 2), and included in the second specification of the model to take into account year-effects and exclude their influence on duration dummies. Consecutive years (1978, 1984, 1989, and 1998) were also included due to the possibility of a multi-year spike phenomenon, as revealed by Doms and Dunne (1998). This can be explained by the effect of the indivisibility of investments: a firm starts with investments in one calendar year and finishes in the second. A tax deduction can be an additional reason to spread investments, because most agricultural firms in the Netherlands are allowed to spread their taxable income over three consecutive years. As a result, the investment decisions are mostly made at the end of the year, which implies the appearance of investment activity in two consecutive years.

3.3.3. Characteristic of grouped data set

We constructed a cohort approximation of panel data by grouping individual observations into 10 groups, distinguished by size, and using the means for empirical estimation. To check the stability of groups, additional tests were performed. Stability is defined as no large fluctuation in groups due to two effects: (1) the rotation of the sample and (2) switching between groups for the same firms. Switching may occur because the group-mean firm-size changes or the firm has changed its size. These two effects were captured by calculating the share of individual firms for each particular year that continue to be in the panel (first effect) and that continue to be assigned to the same group (second effect). Then the changes in groups' means were estimated as a function of changes in whole data average and two shift effects. This has been done for wealth, income and investment. All effects were insignificant, except the switching effect for investment, see Appendix 2. This switching effect of investment, however, reflects that firms that invest change in size. Therefore, we conclude that the stability of groups causes no problems for this incomplete set of panel data.

The original sample consisted of 250 observations, with 207 observations being left for the estimation after deleting left-censoring spells. As a result, the year 1975 is not observed in the data set. Dummies (Durat1-Durat23) for duration of spell were generated, but in a different way compared to firm-level data. Each group is observed for 20-24 years (except for the 2nd group, which has 8 years of observations) and during the observation exhibits more than one investment spike. DuratT indicates the time-specific interval when one of the spikes (it can be the second or fifth investment spike, for example) is observed since the previous spike. Due to aggregation and the smoothing of investment spikes, no investment spikes are observed in 16-18th interval, leading to the creation of a dummy representing 15-18 intervals (Durat1518).[13]

The model specification for the grouped data set excludes an entry variable, which cannot be calculated on an aggregated level, and firm size, which is used to construct the grouped data. After excluding left-censoring observations, the years 1976 and 1977 do not provide sufficient numbers of observations and are not included as dummies in the model.

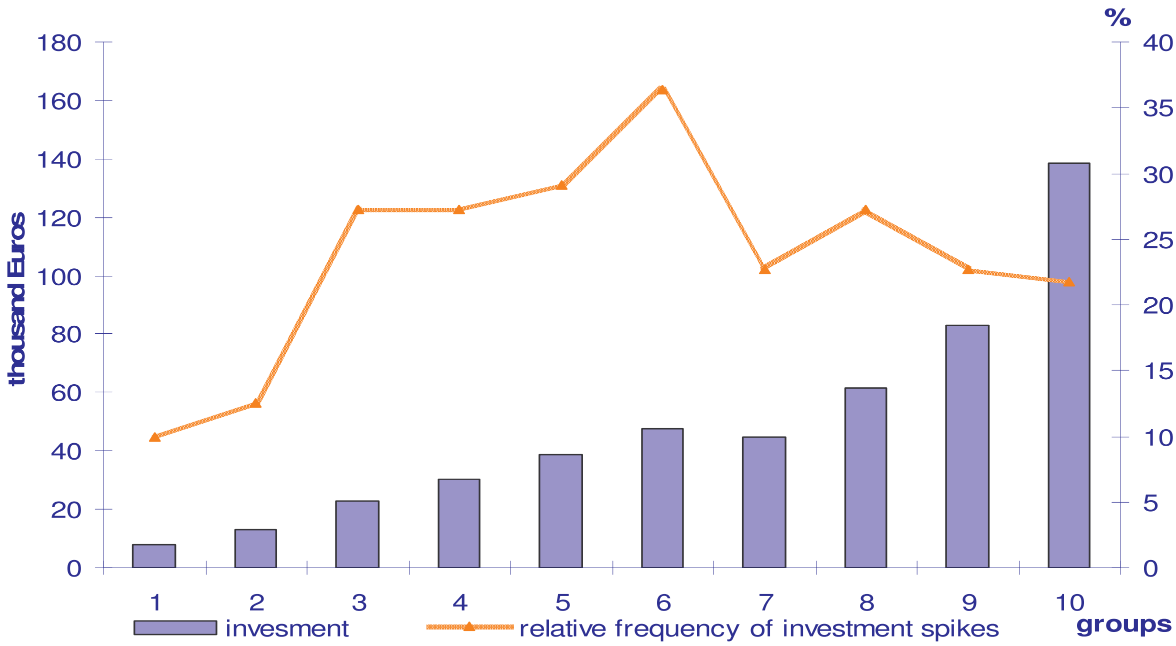


Figure 3.3: **Occurrence of investment spikes and average investments from 1976 – 1999 by 10 groups**

[13] The reasons and explanation of grouping of time intervals for the estimation of hazard is given by Jenkins, 2005.

Figure 3 reports the difference between groups in average investments and the relative frequency of investment spikes. The distribution of the occurrence of investment spikes among the groups shows that the episodes with no investment spike prevail over large investment episodes for every group. The two smallest groups invested not more than 10,000 euros per year, and occur rarely in the data set. Middle-scale firms often present investment spikes, although their average investments are not high (about 20-40,000 euros per year). The highest frequency of large investments (every 3 years) is observed in the 6th group, which also exhibits substantial investment (48,000 euros). Large-scale firms (7-10 groups) engage in larger investments, but not often. The differences between middle and large groups can be explained by the fact that middle-scale groups invest intensively to catch up with the larger firms.

3.3.4. Empirical model

In the empirical analysis, we examine the spells between investment spikes at the firm level using discrete time duration analysis. Duration analysis provides estimates of factors that have a significant effect on the length of a spell. We use the hazard function, which represents how likely the investment spike is to occur at (or around) time t. In other words, the hazard function is the probability that a firm invests in the short interval of length Δt after t, conditional on not having invested until t. Let T_i be the length of the spell between investment spikes for firm i. Then the hazard rate θ_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)

$$\theta_i(t) = \lim_{\Delta t \to 0} \frac{P[t + \Delta t > T_i \geq t | T_i \geq t]}{\Delta t} \tag{6}$$

For the proportional hazard model a hazard is specified as:

$$\theta_i(t | x(t)) = \theta_0(t) \cdot \exp(X_i(t)'\beta), \tag{7}$$

where $\theta_0(t)$ is the baseline hazard at time t, X is a vector of covariates, and β is vector of unknown parameters. The probability that a spell lasts until t+1 given that it has lasted until t given by:

$$P[T_i \geq t + 1 | T_i \geq t, X_i(t)] = \exp[-\int_t^{t+1} \theta_i(\tau | X_i(\tau) d\tau]$$

$$= \exp[-\exp(X_i(t)'\beta) \cdot \int_t^{t+1} \theta_0(\tau) d\tau] = \exp[-\exp(X_i(t)'\beta + \gamma_t)] \qquad (8)$$

where $\gamma_t = \ln[\int_t^{t+1} \theta_0(\tau) d\tau]$ is the integrated baseline hazard at t.

This formulation assumes that the covariate vector x(t) is constant between t and t+1. The probability that a spell ends in the interval [t, t+1) given that it lasted until t time is then:

$$P[t \le T_i \le t+1 | T_i \ge t, X(t)] = P_t = 1 - P[T_i \ge t+1 | T_i \ge t, X_i(t)] =$$
$$= 1 - \exp[\exp(X_i(t)'\beta + \gamma_t)] \qquad (9)$$

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 (i.e. variables that account for variations in distribution)[14]. 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). We may write the hazard in the case of the proportional hazard model as:

$$\theta_i(t | X(t), \varepsilon_i) = \theta_0(t) \cdot \exp(X_i(t)'\beta + \varepsilon_i) \qquad (10)$$

with parameter vector (σ^2, β) estimated using STATA 8. The model (10) incorporates a gamma distributed[15] random variable ε with mean 1 and variance σ^2 to describe unobserved (or omitted) heterogeneity among firms[16].

Following Meyer (1990), the likelihood function for a sample of N individuals with augmented Gamma heterogeneity can be written as:

---

[14] For the specific research considered here, unobserved heterogeneity refers to a situation in which some firms are more likely to show investment cycles than other firms. Unobserved covariates may lead to spurious negative duration dependence patterns and also to biases in covariates that are time-varying, even if there is no correlation between the unobservable determinants and the observable covariates.

[15] The main argument for choosing a gamma distribution for heterogeneity is that the distribution of the heterogeneity converges to a gamma distribution. The convergence for hazard models was proven by 2003.

[16] For our data, we also estimated a Proportional Hazard model with normally distributed heterogeneity. This specification led to a lower Log-Likelihood than the model with gamma distributed heterogeneity. The value of Log-Likelihood was almost the same as for the model without taking into account heterogeneity (Table 2). It confirmed the theoretical findings.

$$L(\gamma,\beta)=\prod_{i=1}^{N}L_i(k_i,d_i\mid\gamma,\beta)=$$

$$=\prod_{i=1}^{N}[[1-\exp\{\exp[\gamma(k_i)+X_i(k_i)'\beta+\varepsilon_i]\}]^{d_i}\times\prod_{i=1}^{N}\left[\exp\{-\sum_{t=1}^{k_i-1}\exp[\gamma(t)+X_i(t)'\beta+\varepsilon_i]\}\right] \qquad (11)$$

where TC_i is the censoring time and d_i =1 if $T_i \le TC_i$ and 0 otherwise, and k_i = min[int(T_i), TC_i]. The first term in equation (10) represents the probability of an investment spike in the interval [k_i, k_i+1) given that the spell has lasted until k_i and thus represents the discrete interval hazard rate. The second term represents the probability of observing a spell that lasts at least until k_i.

3.4. Results

3.4.1. Results obtained from panel data set

We estimated two proportional hazard models, with different specifications that allow for firm-specific fixed effects. The empirical model is based on *Equation 10* that estimates the probability of observing an investment spike, which is represented by the dummy variable *(InvSp)*. Maximum Likelihood estimation results are presented in *Table 3.2*. For our data, we also estimated a Proportional Hazard model with normally distributed heterogeneity. This specification led to lower Log-Likelihood than the model with gamma distributed heterogeneity. The values of Log-Likelihood are almost the same as for models without taking into account heterogeneity *(Table 3.2)*, and confirm the importance of correcting a model for unobserved heterogeneity.

Both models are jointly significant and useful in explaining variations in investment spells across firms. 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. The Log-Likelihood of the second model is higher.

The results of estimation in *Table 3.2* display the coefficients, but by calculation of $\exp(\beta)$ one can obtain the hazard ratios, which report the response in probability to a one-unit change in the explanatory variable.

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, because firms may wish to replace installations and machines at times when the opportunity costs of lost output are small. On the other hand, firms are encouraged to introduce new installations and machines and increase productivity when returns are high (Nilsen and Schiantarelli, 2003), as well as for tax avoidance reasons. The estimation results suggest that the latter factor is dominant.

Table 3.2: **Estimation results of the Proportional Hazard Models of Investment**

Variables	Model 1		Model 2	
	Coefficient	St. Error	Coefficient	St. Error
Durat1	-2.914****	0.193	-3.713****	0.256
Durat2	-2.044****	0.171	-2.348****	0.196
Durat3	-1.306****	0.173	-1.448****	0.187
Durat4	-1.377****	0.242	-1.475****	0.255
Durat5	-1.719****	0.398	-1.764****	0.415
Durat6	-0.670*	0.425	-0.579	0.480
Durat7	-1.478*	1.054	-1.377	1.100
Capital	-0.001****	0.0002	-0.001****	0.0004
Profitability Shock	0.003****	0.0006	0.002****	0.0007
Firm Size			0.880****	0.266
Entry			0.778**	0.443
Long Debt			-0.001**	0.0004
year77			1.939****	0.384
year78			1.557****	0.590
year83			0.356	0.634
year84			-1.127	1.018
year88			0.389	0.346
year89			0.716*	0.499
year90			-0.364	0.608
year98			0.816***	0.365
year99			0.918****	0.336
σ^2	-1.150*	0.769	-0.063	0.474
Log Likelihood for Model: [1)]				
- with Gamma distributed heterogeneity	-614.9		-570.7	
- without heterogeneity	-1005.1		-984.8	
- with Normal distributed heterogeneity	-1004.4		-981.7	
LR-statistic [2)]	780.5		828.3	
Number of observations	2270		2270	

*****; *** ; **, *   1%, 5%, 10%, 15% -level significance*

[1)] *Log Likelihood for intercept only model = -1017.4*

[2)] *Model without heterogeneity vs. Model with gamma-distributed heterogeneity*

Elhorst (1993), considering investment decisions in Dutch horticulture, also found a positive effect of profitability on the probability of investment. The coefficient is significant but small, which can be due to a non-linear relationship between investment rates and profitability shocks. Cooper and Haltiwanger (2006) also found that investment is relatively insensitive to small variations of profitability, but responds quite strongly to large shocks.

In line with prior expectations, current capital has a negative impact on the probability of observing an investment spike, which can be explained by the indivisibility of capital investments. Moreover, with the vintage of capital goods (and consequently with a decreasing level of capital in operation), a firm will be more inclined to invest. A similar effect of capital on investments was found in energy installations for the Dutch greenhouse horticulture by Oude Lansink and Pietola (2005).

In *Model 2*, the effect of firm-specific variables on probability of investments can be seen. The same significant effects of capital and profitability shock are observed. Firm size shows a positive coefficient, as expected by studying the grouped dataset in *Figure 3.2*. This can be explained by the presence of fixed adjustment costs, since large firms can have relatively larger fixed adjustment costs, leading to lumpy investments. As expected, the debt situation at the beginning of the year has a negative effect, which is in line with Elhorst (1993).

One can see that the effect of entry on investments is positive and significant (0.778). Year effects, which were captured by year dummies, also have a highly positive influence in the years 1977-1978 and 1998-1999. One of the possible explanations of positive coefficients in the 1970s lies in the drastic growth of energy prices after the 1973 world oil crisis, leading many horticultural firms to introduce energy-saving technologies that involved the reconstruction of buildings and installations. The positive impact of 1989 could be associated with the revocation of the WIR law in 1988. Many firms initiated investments in that year, but actually carried out the investments and received the WIR subsidy later. The years 1998-1999 can be characterised by positive expectations associated with the growth of the Dutch economy.

Both models were estimated taking into account gamma-distributed heterogeneity, which is not (highly) significant, but plays an important role. The LR-statistic (780.5 for *Model 1* and 828.3 for *Model 2*) confirms the importance of including heterogeneity in the models.

An additional issue of the comparison between the models is the baseline hazards that represent changes in the probability of observing an investment spike for all firms, given that other variables have no impact. Since no structure is imposed on the shape of the hazard, it can be defined as the empirical hazard. Three baseline hazards[17] are presented in *Figure 3.4*. All three baseline hazards reveal the importance of the 3rd and 6th years for investment activity of firms. *Model 1*, which counts only on effects of capital and profitability shock, slightly overestimates the baseline hazard, but the shape is the same as in *Model 2*. The model that

[17] Hazard ratios are equal to $exp(\beta)$.

does not take into account gamma heterogeneity overestimates the probability of investments in the first two years, and underestimates their probability in later years. This difference is consistent with the conclusion of Cooper et al. (1999) that unobserved structural heterogeneity can yield a downward-sloping hazard even if the hazard for any firm is upward-sloping. Eliminating this effect demonstrates a substantial difference in the first and sixth years of estimated hazard.

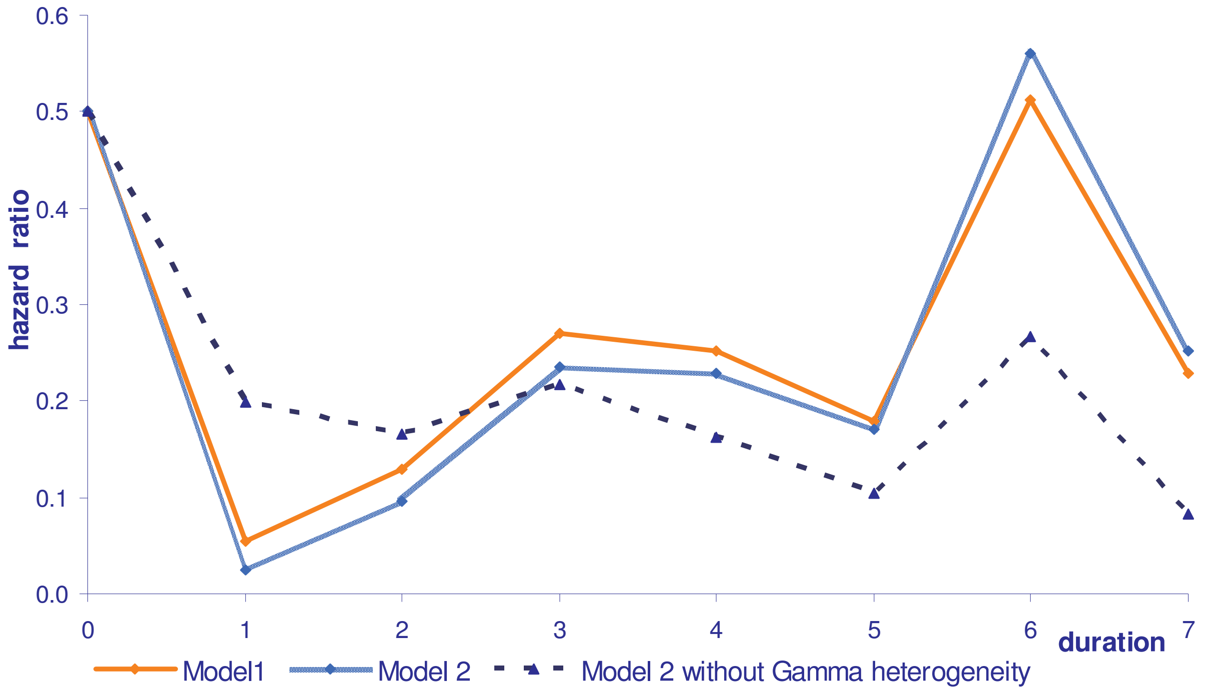


Figure 3.4: **Baseline hazards for models with different specification**

The probability of having an investment spike increases in the time after the initial fall, and in the sixth year there is a high probability of observing another spike. An increasing hazard is also found by Cooper et al. (1999), Meyer (1990), Nilsen and Schiantarelli (2003). A high and not-significant level of coefficients for 6th together with 7th duration can be due to a multi-year spike effect, when a firm initiates the investment in one year and completes it in a following year. The significance of observing an investment spike is tested for both specifications of the model. The results *(Table 3.3)* confirm the relevance of observing investment spikes in the 6th year for both model specifications. The null hypothesis that the 5th and 6th -year coefficients are equal is rejected, which implies that the difference between baseline probabilities is significant. The hypothesis that there is no difference between 5th and 7th year probabilities of observing an investment spike can not be rejected. This can lead to the assumption about the presence of a 6-year investment cycle on the firm level. We also can not reject 6th- and 7th-year coefficients being significantly different; as was discussed earlier, this can be due to the multi-year spike effect.

Table 3.3: **Test of the relevance of investment spike**

Null hypothesis	Model 1		Model 2	
	Chi2(1)	Prob>chi2	Chi2(1)	Prob>chi2
durat5=durat6	3.87	0.05	4.69	0.03
durat5=durat7	0.04	0.84	0.05	0.82
durat6=durat7	0.75	0.39	0.52	0.47

Therefore, we can expect the average firm data set, which covers a much longer period, to also reveal investment cyclicity.

3.4.2. Results obtained from average firm data set

The averaged data by size groups are used to observe investment spells over a longer period. The same specification as for *Model 2* on the individual-firm level data was used (*Figure 3.5*, for details see *Appendix 3*). Focusing on the baseline hazard, few spikes are observed that can be considered as confirmation of findings from the firm-level data and also as evidence of investment cycles. An average firm will probably have investment spikes in the 6^{th}, 13^{th} and 21^{st} years. A three-year effect can also be seen from the estimation where there are substantial shifts of hazard in the 3^{rd} and 9^{th} years.

Ignoring the investment cycle can lead to errors in prediction of investment fluctuations. A 7-year investment cycle in the US economy is also observed by Wen (1998), who proposes a general equilibrium model to explain this phenomenon. Cooper et al (1999) concluded that machine investments were procyclical.

Figure 3.5 depicts empirical hazard obtained from the grouped data set versus average level of investment during the years 1975-1999. Comparison of the lines in the graph reveals that the estimated probabilities of observing investment spikes during the years under observation are a good approximation of real changes in the average level of investments of Dutch horticulture firms.

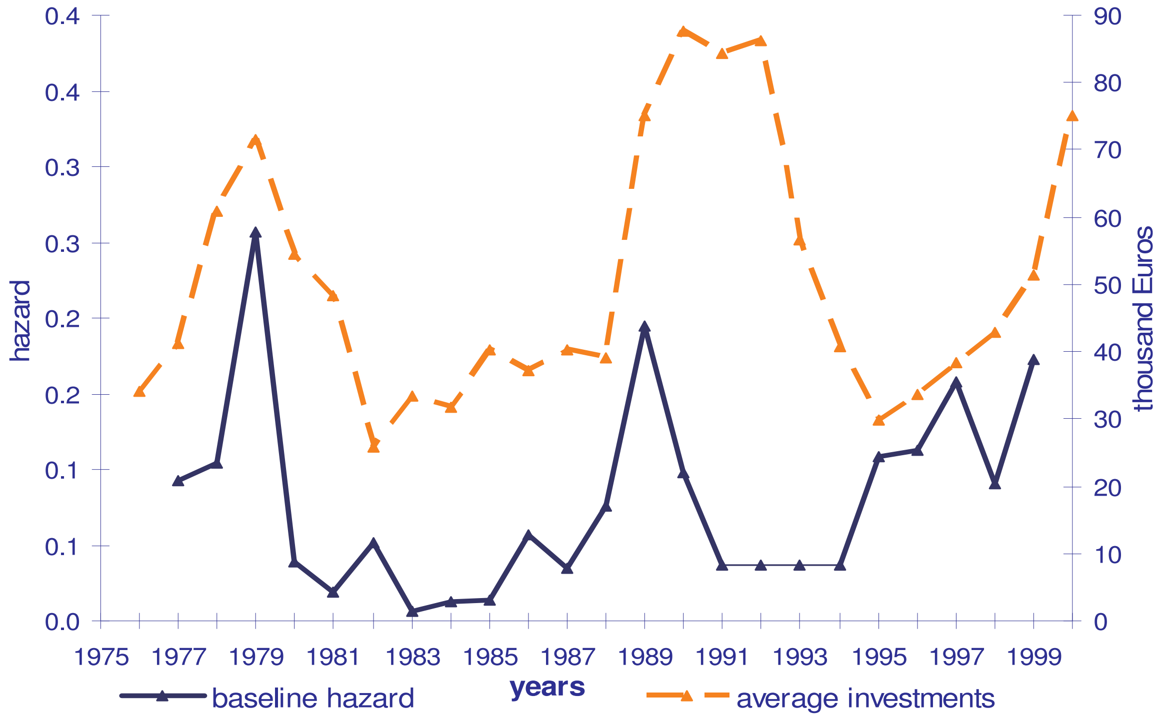


Figure 3.5: **Average investments in Dutch horticulture and estimated hazard**

3.5. Conclusions and discussion

An intermittent and lumpy pattern of investments is observed in Dutch greenhouse horticulture: only 16.5% of firms experience an investment spike, but they account for 67.7% of total investment. These facts determine the importance of understanding this phenomenon. The existence of investment spikes with a period of low investment in between is in contrast to the investment theory based on convex adjustment costs without fixed costs, which would lead to a smooth pattern of investments over time.

Duration analysis has been used to investigate the factors determining the variation in timing between investment spikes. Two model specifications were estimated by the proportional hazard model, which controls for unobserved heterogeneity. The baseline hazards only show slight differences in coefficients. The results at firm level demonstrate an upward-sloping baseline hazard: the lowest probability of lumpy investment is just after an investment spike, followed by a sharp increase in the sixth year. This pattern is consistent with the presence of irreversibility and fixed costs. The results at average-firm level confirm the findings at the firm level. Because the average firm data cover a period of 24 years, more successive investment spikes can be determined. Moreover, the results of the duration analysis can be linked to the time period of observation.

Different specifications were estimated. First, only the variables derived from a theoretical model are included. Second, the model has been enlarged by firm-specific variables and year dummies. Although the second model improves the understanding of the investment pattern, the first one provides useful insights about the baseline hazard and relationship between investment rates and fundamentals, measured as profitability shock and capital. The more capital slows down, the more profitability speeds up the occurrence of an investment spike. The positive impact of a variable indicating entry investment on the probability to observe lumpy investment would suggest that a separate analysis of entry investment is an area for future investigation. One of the results is that the inclusion of gamma-distributed heterogeneity yields a significant increase in the log-likelihood and a quite different pattern of baseline hazards. The importance of the heterogeneity was also identified by Gardebroek (2004) for machinery investments at pig farms, but in his study testing could not be done in a proper framework because the initial model was rejected.

Even though the Dutch greenhouse horticulture has some specific characteristics compared to manufacturing sectors in previous studies (in USA, Norway, Colombia), the baseline hazard exhibits a similar shape. Thus, the results of the present study contributes empirical evidence in studies on investment patterns among production operations, and confirm the value of the theoretical approach that includes fixed or partly non-convex adjustment costs and irreversibility of investments.

The present study has shown that duration analysis enhances our understanding of investment behaviour. Conventional statistical approaches are not able to capture the effects of time-varying determinants and length of time-span between investment spikes. However, the present results do not provide further insight into the factors that drive the 6-year investment spike. One of the extensions for the model is to include the assumption about asymmetry of a profitability shock and explore the difference of the effects. The next steps in this direction should consider estimating models focusing on the sources of heterogeneity by addressing different types of capital goods separately. The existence of specific investment cycles implies that new policy instruments to increase the adoption of new energy-saving technologies will not necessarily lead to an immediate increase in investments, but will depend on other factors associated with the vintage of the installed technologies.

Appendix 3.1. Estimation of stability of groups

Variables	Income	Wealth	Investment
	Coefficient	**Coefficient**	**Coefficient**
Dependent variable	Average per year group- income	Average per year group- wealth	Average per year group- investment
Average per year for whole sample	1.014**** (0.079)	0.946**** (0.110)	1.234**** (0.284)
Rotation shift	0.110 (0.139)	- 0.011 (0.082)	0.016 (0.551)
Group shift	- 0.114 (0.133)	0.018 (0.079)	0.894** (0.465)
Constant	- 0.011 (0.111)	0.068 (0.119)	-0.484 (0.575)
Adj R-squared	0.41	0.24	0.08
F(3,236)	56.99	25.71	8.31

*****; ***, **, * 1%, 5%, 10%, 15% -level significance*
Standard errors in parentheses

$$\left|\frac{YG(t)}{YG(t-1)}\right| = \alpha + \beta_1 \left|\frac{Y(t)}{Y(t-1)}\right| + \beta_2 S(t) + \beta_3 SG(t) + \varepsilon$$

where ε is iid.

YG - is group average for particular variable, which are not related to size of firm;
Y - is year average of particular variable calculated for whole sample;
$S(t) = \frac{N(t-1)}{N(t)}$ - is share for firms that were in the whole sample in previous year *(t-1)* and in recent year *(t)*;
N – is number of firms under observation in whole sample per year;
$SG(t) = \frac{n(t-1)}{n(t)}$ - is share for firms that were in a group in previous year *(t-1)* and in recent year *(t)*;
n – is number of firms under observation in *j*-group per year.

Appendix 3.2. Estimation results of the proportional hazard model of investment on average firm data-set

Variables	Coefficient		St. Error
Durat1	-2.378	***	1.182
Durat2	-2.265	***	1.116
Durat3	-1.361	**	0.785
Durat4	-3.233	****	1.169
Durat5	-3.985	****	1.545
Durat6	-2.958	****	1.380
Durat7	-4.994	****	1.491
Durat8	-4.345	****	1.473
Durat9	-4.303	****	1.536
Durat10	-2.862	****	1.139
Durat11	-3.359	****	1.407
Durat12	-2.584	****	1.109
Durat13	-1.637	*	1.161
Durat14	-2.319	****	0.981
Durat15-18	-3.288	****	0.964
Durat19	-2.222	***	1.028
Durat20	-2.187	****	0.923
Durat21	-1.844	*	1.227
Durat22	-2.403	**	1.316
Durat23	-1.755		1.782
Capital	-0.0014		0.0023
Profitability Shock	-0.0084		0.0081
year78	2.094	**	1.107
year79	1.304		1.081
year83	1.389		1.332
year84	4.379	****	1.354
year88	2.132	***	1.250
year89	1.638	***	0.923
year90	1.146		1.105
year98	-0.101		1.113
year99	1.276		1.101
Long Debt beginning	0.0039		0.0034
Log Likelihood	-86.8		
Log Likelihood for intercept only model	-115.6		
LR-statistic	57.5		
Number of observations	207		

****; ***, **, * *1%, 5%, 10%, 15% -level significance*

Chapter 4

The Role of Risk and Uncertainty in Investments: Dutch Glasshouse Horticulture

Natalia V. Goncharova, Arie J. Oskam

"The greatest loss of time is delay and expectation, which depend upon the future. We let go the present, which we have in our power, and look forward to that which depends upon chance, and so relinquish a certainty for an uncertainty."

Seneca, 5 BC - 65 AD

4.1. Introduction

Firms operate in dynamic circumstances and their decisions are affected by risk and uncertainty. The decisions most sensitive to the influence of risk and uncertainty are long-run decisions (e.g. the introduction of a new technology or a product, a market entry or exit, an increase in scale of production), which are usually accompanied by investments. There is much theoretical discussion concerning the impact of risk and uncertainty on investments, although in empirical applications these two phenomena are often not distinguished. This can be explained by the fact that both components influence the ability (or rather the inability) to precisely predict what the future holds. Risk, in our perception, can be described as "stochastic variability", when the outcome is uncertain but characteristics of the variability are "known" and uncertainty as an unpredictable part of variability. The distinction between risk and uncertainty can be found in Knight (1921) and Keynes (1921). In Knight's (Knight, 1921: p.20) interpretation, "risk" refers to situations where the decision-maker can assign mathematical probabilities to the randomness which he is faced with. In contrast, "uncertainty" refers to situations when this randomness "cannot" be expressed in terms of specific mathematical probabilities. Later, based on the work of Savage (1954), the Bayesian approach was introduced, which postulates that vagueness has no role in a rational theory of choice, but that subjective probabilities influence the individual's decision. The "risk versus uncertainty" debate is a long-running one and is far from being resolved. To our knowledge, there are no empirical studies based on micro-data that explore and compare the difference in the impact of risk and uncertainty.

In general, we can classify three types of risk and uncertainty[18] that can affect an investment decision. The first is "Output Supply" uncertainty, which can be seen as the fluctuation in output prices and quantity of production that creates fluctuations in the revenue of the firm. The influence of this type of uncertainty on investments was analysed by e.g. Ghosal and Loungani (1996). They found that output-price uncertainty can have different impacts due to the different seller-concentration levels. As discussed in Dixit and Pindyck (1994), an increase in price uncertainty will lower current investment. This conclusion holds for both output- and input- price uncertainty. The latter we consider as the second type of uncertainty: "Input Demand" uncertainty.

Changes in input prices have a direct impact on the profitability of firms and on the expected net present value of a firm. Abel and Eberly (1999) examined changes in the distribution of demand shocks and interpreted demand shocks as changes in the quantity demanded at any given price. They concluded that higher uncertainty increases the level of the expected long-run capital stock. Few examples of explicit analysis of the importance of

---

[18] As many authors of the analysed articles do not distinguish between risk and uncertainty, we use the joint term "uncertainty" in the Introduction section.

input-prices uncertainty for investments were found in the literature. Bell and Campa (1997) approximated changes in input prices by oil price changes.

By firm-environmental uncertainty, we imply a firms' uncertainty concerning such factors as changes in society, governmental regulations and policies. Governmental regulation can include tax policy, subsidies and export-import rules. Other factors include the global warming problem, worries about the environment, global sources of oil, gas and water. Taking into account ethical aspects of manufacture and selling of production also create changes in social demands. Political instability, as well as interchanging periods of economic growth and depression, can be additional sources of uncertainty. The results vary in different studies. Cassimon *et al.* (2002), using variance of interest rate and exchange rate as a proxy for uncertainty, found a negative impact on investments; Hasset and Metcalf (1998) showed that increasing tax uncertainty can bring forward the moment of investment. Grzegorz and Kort (2001) argued that a low level of uncertainty can have a positive influence on investments, and a rise in uncertainty beyond a certain critical point reverses this relationship and suppresses investments by raising the optimal investment threshold.

Generally, one can assume that the many changes in the environment of firms, which are mentioned above, will result in changes in output- or input prices and will respectively introduce output- or input uncertainty.

The Dutch glasshouse horticulture sector is one of the most intensive farming systems in the world, and it has to permanently cope with possible future changes (which can be unexpected) that provide a good opportunity to analyse a relation between uncertainty and investment. The goal of this study is an empirical investigation of whether uncertainty significantly affects the investments in Dutch horticulture sector. To achieve this goal, we will first specify the objectives of the chapter. The first aim is to incorporate the risk and uncertainty in a theoretically sound model of investment behaviour in relation to input demand and output supply. The second is to identify and quantify variables that are able to reflect risk and uncertainty. The final objective is to estimate the relationship between investments and risk/uncertainty, using data on Dutch greenhouse horticulture. The Dutch greenhouse horticulture is a very dynamic sector, which is influenced by a highly uncertain environment, as can be seen from examples provided above. One of the advantages is the possibility to use a large panel data set collected by LEI on an individual firm level. This data gives the opportunity to analyse investments, output supply, and input demand in one framework.

The chapter starts with a theoretical and empirical framework *(Section 2)*, which is divided into four sub-sections. In the first sub-section, the theoretical model of determining investment demand is discussed, which incorporates the uncertainty. In the second sub-section, the model for estimating uncertainty is introduced; moreover the distinction between risk and uncertainty is explained. In the third sub-section, the empirical model of estimating investment in the system of equations using 3SLS is described that takes into account risk and uncertainty. The fourth sub-section provides the explanation of the GMM-estimator of investments in a dynamic panel-data framework. The investment equation incorporates output-, input- and capital prices risk and uncertainty. *Section 4.3* provides information about the price-indexes data used for estimation uncertainty *(sub-section 4.3.1)* and the firm-level data for estimating investments *(sub-section 4.3.2)*. Results are presented in *Section 4.4* and discussed in the same sequence as the theoretical framework. In *sub-section 4.4.1,* the estimation of uncertainty and risk is obtained by a moving window ARIMA model. *Sub-section 4.4.2* presents the effect of risk and uncertainty on input demand, output supply and investment-goods demand. In *sub-section 4.4.3*, the impact of different types of risk and uncertainty on investment demand is estimated. *Section 4.5* provides a summary of the empirical results and discusses the implications of this study.

4.2. Theoretical and empirical framework

4.2.1 Theory of investment

Neo-classical theory uses the duality that exists between the production function and the value function. This implies that no explicit specification of technology is required to derive the behaviour of firms. The value function is defined as the maximum sum of discounted flow of future profits for the firm producing multiple outputs using multiple variable, fixed and quasi-fixed inputs.

Suppose a firm maximizes the value of the firm over time by choosing the optimal level of investment. Then the value function of the firm has to be defined. The conventional objective function of the firm is widely used to express the value of the firm (Gould, 1968, Nickell, 1978, Vasavada and Chambers, 1986, Abel and Eberly, 1997), The value function (equation 1) is the discounted flow of short-run profit minus cost of capital *pk'K* (defined as a product of capital *K* on prices of capital *pk*) and adjustment costs *C(K,I)*. The short-run restricted profit function is $\pi(p, pv) = \max_{Y,X} \{p'Y - pv'X\}$, Y - is output and p is the vector of output prices, X is variable input and pv- is the vector of input prices. The adjustment cost, which is a function of gross investment *I* and capital *K*, contains both external and internal costs. External adjustment costs are purchase costs, and search costs. Internal adjustment costs are the costs that are internalised in the production process such as installation costs, learning costs, production losses due to implementing the new capital goods. Following the approach of Abel and Eberly (1997) we also assume that profit can be affected by a random variable ε, which represents uncertainty due to the factors discussed in *Section 1*. Unlike Abel and Eberly (1997) we do not make any assumption about a functional form of the random variable[19].

$$J(p, pv, pk, K, \varepsilon) = \max_I \int_0^{\infty} e^{-rt} [\pi(p, pv, X(t), K(t), \varepsilon(t), t) - pk' K(t) - C(K(t), I(t))] dt \qquad (1)$$

s.t. $\dot{K}_t = dK_t = (I_t - \delta K_t) dt$

δ – is depreciation rate and r – is discount rate. The value function is assumed to be twice differentiable, convex and linearly homogeneous in prices.

Production factors may be divided into different kinds: variable inputs X and quasi-fixed inputs (land, buildings, installations, machinery) K. The solution for the maximization problem in (1) gives the Hamilton-Jacobi-Bellman equation (similar to Abel and Eberly, 1994, Abel and Eberly, 1997):

$$rJ(p, pv, pk, K, \varepsilon) = \max_I \{ p'Y - pv'X - pk'K - C(K, I) + \left(\frac{1}{dt}\right) E(dJ) \} \qquad (2)$$

The last element represents expected changes of the value of the firm due to the changes of capital and prices, and can be calculated as

$$E(dJ) = [J_K (I - \delta K) + J_p - J_{pv} - J_{pk} \pm J_\varepsilon] dt \qquad (3)$$

Subscripts denote partial derivatives. We expect that when output prices increase, firm value will also increase and when input prices increase, firm value will decrease; our expectations are shown by the positive sign at J_p and the negative sign at J_{pv}, J_{pk}. We do not make any prior assumptions about the sign of changes in value function of the firm (J_ε) due to the random shocks. It is one of the objectives of this chapter to determine the effect of uncertainty on investments.

Substituting (3) in (2) yields:

$$rJ(p, pv, pk, K, \varepsilon) = \max_I \{ p'Y - pv'X - pk'K - C(K, I) + J_K (I - \delta K) + J_p - J_{pv} - J_{pk} + J_\varepsilon \} \qquad (4)$$

This equation shows firms choosing optimal level inputs and outputs as well as the necessary level of capital to achieve the required rate of return, represented by stars *. These optimal decision variables can be expressed in terms of derivatives of value function J.

$$rJ_{pk} = -K + J_{pk,K}(I - \delta K) - J_{pk,pk} \pm J_{\varepsilon,pk};$$

$$\dot{K}^* = (I - \delta K) = J_{pk,K}^{-1} (rJ_{pk} + K + J_{pk,pk} \pm J_{\varepsilon,pk}) \qquad (5a)$$

$$rJ_{pv} = -X + J_{pv,K}(I - \delta K) - J_{pv,pv} \pm J_{\varepsilon,pv};$$

$$X^* = -rJ_{pv} + J_{pv,K}\dot{K}^* - J_{pv,pv} \pm J_{\varepsilon,pv} \qquad (5b)$$

[19] Abel and Eberly (1997) assume that value of a firm depends on capital and a random variable that follows a Geometrical Brownian Motion.

$$rJ_p = Y + J_{p,K}(I - \delta K) + J_{p,p} \pm J_{\varepsilon,p};$$

$$Y^* = rJ_p - J_{p,K}\dot{K}^* - J_{p,p} \pm J_{\varepsilon,p} \qquad (5c)$$

It is then straightforward to derive the optimal level of investments from equation (5a):

$$I^* = J_{pk,K}^{-1}(rJ_{pk} + K + J_{pk,pk} \pm J_{\varepsilon,pk}) + \delta K \qquad (5d)$$

A normalized quadratic second-order Taylor series expansion is used (see also Elhorst, 1993, Vasavada and Ball, 1988) to specify value function *J(.)*. Then the empirical specification can be defined as derivatives of the value function.

$$J = a_0 + [a_1 a_2 a_3 a_4 a_5]\begin{bmatrix} p \\ pv \\ pk \\ K \\ \varepsilon \end{bmatrix} + 0.5[p' pv' pk' K' \varepsilon']\begin{bmatrix} A_{11} & A_{12} & A_{13} & A_{14} & A_{15} \\ A_{12} & A_{22} & A_{23} & A_{24} & A_{25} \\ A_{13} & A_{23} & A_{33} & A_{34} & A_{35} \\ A_{14} & A_{24} & A_{34} & A_{44} & A_{45} \\ A_{15} & A_{25} & A_{35} & A_{45} & A_{55} \end{bmatrix}\begin{bmatrix} p \\ pv \\ pk \\ K \\ \varepsilon \end{bmatrix} \qquad (6)$$

where a_0 is scalar, a_1, a_2, a_3, a_4, a_5 are vectors, and $A_{11}, A_{12}, ..., A_{55}$ are matrices.

Applying (5a)-(5c) to the value function (6), we obtain the structural model that can be used in econometric estimation.

$$I^* = A_{34}^{-1}[r(a_3 + A_{13}p + A_{23}pv + A_{33}pk + A_{34}K + A_{35}\varepsilon) + K + A_{33} \pm A_{35}\varepsilon_3] + \delta K$$

$$X^* = -r(a_2 + A_{12}p + A_{22}pv + A_{23}pk + A_{24}K + A_{25}\varepsilon) + A_{24}\dot{K}^* - A_{22} \pm A_{25}\varepsilon_2$$

$$Y^* = r(a_1 + A_{11}p + A_{12}pv + A_{13}pk + A_{14}K + A_{15}\varepsilon) - A_{14}\dot{K}^* - A_{11} \pm A_{15}\varepsilon_1$$

or

$$I^* = A_{34}^{-1}ra_3 + A_{34}^{-1}rA_{13}p + A_{34}^{-1}rA_{23}pv + A_{34}^{-1}rA_{33}pk + (r + A_{34}^{-1} + \delta)K + A_{34}^{-1}A_{33} + A_{34}^{-1}(r+1)A_{35}\varepsilon_3 \qquad (7a)$$

$$X^* = -ra_2 - rA_{12}p - rA_{22}pv - rA_{23}pk - A_{24}(r+\delta)K + A_{24}I^* - A_{22} - A_{25}(r \pm 1)\varepsilon_2 \qquad (7b)$$

$$Y^* = ra_1 + rA_{11}p + rA_{12}pv + rA_{13}pk + A_{14}(r+\delta)K + A_{14}I^* - A_{11} + A_{15}(r \pm 1)\varepsilon_1 \qquad (7c)$$

The meaning of the last two terms is in representing changes of value function due to fluctuation in prices. The terms of equations *(7a)-(7c)* A_{11}, A_{22}, A_{33} correct the equations due to expected changes of capital prices, variable input prices, and output prices. The expectations of variance of the prices induce risk-bearing in the decision-making.

The last terms can be considered as the effect of unpredicted changes in prices and we define them as capital-, input- and output-price uncertainty in the equations *(7a)-(7c)*. In this way we explicitly include risk and uncertainty in the theoretical model.

4.2.2. Modelling expectations of changes in price

Our primary focus in this section is to theoretically substantiate a choice of modelling uncertainty and provide further investigations of uncertainty by econometric methods. For this reason we will start from a traditional model of the market: the relation between supply and prices can be written as a system:

$$q_t = \gamma p_t^e + u_t \tag{8a}$$

$$p_t = -\mu q_t + v_t \tag{8b}$$

Where q_t is quantity of supply at time *t* that depends on producers' expectations of the output prices p_t^e conditional on the information set containing all relevant information available at time *t-1* (superscript *e* refers to expectations) and some exogeneous supply shift u_t. Prices at time *t* are negatively dependent on output quantity and depend on the exogeneous demand shift term v_t. In this way we model the response of the market on changes in supply. $\gamma > 0$ and $\mu > 0$ are coefficients.

Following the Fama (1970, updated 1991) efficient market model, an efficient market is one that accurately incorporates all known information in determining price and is based on the efficient market hypothesis (*EMH*), which postulates that firms do not waste their profit opportunities. Determining prices on the efficient market is heavily dependent on the rational expectation theory originally proposed by Muth (1961). Rational expectations assume that firms' expectations are identical to the optimal forecast of the market and in this way assume that predicted prices do not differ systematically from the market equilibrium In other words, the deviations are only random. Prices on the efficient market already reflect all known information and therefore are accurate in the sense that they reflect the collective beliefs of all investors about future prospects. Then, for the Fama efficient market, we can derive from equations *(8a)-(8b)*:

$$p_t = -\mu\gamma p_t^e - \mu u_t + v_t \tag{9}$$

Taking the expectations we get:

$$p_t^e = (-\mu\gamma p_t^e - \mu u_t + v_t)^e = -\mu\gamma p_t^e - \mu u_t^e + v_t^e , \tag{10}$$

Rearranging, we get predicted prices:

$$p_t^e = (1+\mu\gamma)^{-1}(v_t^e - \mu u_t^e) \tag{11}$$

As one can see under Rational Expectations, efficient market prices depend only on the random term representing the role of ignorance and errors. Because the market is efficient, $p_t^e = p_{t-1}$, and the unexpected exogeneous supply and demand shifts are unpredictable shocks based on p_{t-1}. As a consequence, the time series process of the output price follows a random walk, which means that there are no strategies by which one may expect to obtain a higher price than p_{t-1}. Hence, realising the *EMH,* the model for defining a price expectation is:

$$p_t = \alpha + \beta p_{t-1} + e_t \tag{12}$$

where α and β are parameters, and e_t is a random error term which is independently and identically distributed with mean *0* and constant variance σ^2.

The equation *(12)* can also be rearranged as follows:

$$p_t - \beta p_{t-1} = \alpha + e_t \tag{13}$$

Under Fama, efficiency is assumed as $\alpha = 0$ and $\beta = 1$, then

$$p_t - p_{t-1} = e_t \tag{14}$$

Taking the expectation at time *t-1* of equation *(14)* yields the conclusion about zero expectation of changes in price:

$$\mathrm{E}_{t-1}(p_t - p_{t-1}) = 0 \tag{15}$$

Equation *(14)* is referred to as a random walk (Campbell *et al.*1997, Tomek and Querin, 1984). A characteristic of a random walk is that it can deviate substantially from its initial value. If $\mathrm{E}_{t-1}(p_t - p_{t-1}) \neq 0$ or in other words, $\alpha \neq 0$, then the process is described as a random walk with drift, which in terms of Fama's definition is also considered as efficient and characterised as a price bias due to the compensation for risk, which is equal to α and can vary over time[20].

Thus preliminarily we can assume that the time series of the output-, input- and capital prices in the case of the presence of FAMA-efficiency will follow a random walk process (possibly with drift). Hence, revealing this process also implies testing price expectations of firms and, as a consequence, testing market efficiency for Dutch greenhouse horticulture.

By exploring the deviations of actual prices from predicted prices, we can reveal price-related uncertainty and explicitly calculate price uncertainty. The deviation of actual prices from predicted ones can be divided into two parts: predictable and unpredictable deviation.

The predictable part of price changes is related to known variance of prices. This introduces the risk in the equations. The influence of risk on decision is affected by risk perception, which measures the effect of risk on the level of satisfaction of the risk-taker. It is

[20] Some modification of the model has been done by Grossman and Stiglitz (1980), who introduced the costs of acquiring information in an efficient market. This model is known as noisy rational expectations and implies that β may not equal 1.

commonly expected that a decision-maker is risk averse, although risk-neutrality and risk-seeking are also discussed in the literature (Gollier, 2001).

The unpredictable part of the price changes (in equations *7a, 7b, 7c*) introduces uncertainty in the theoretical model. The importance of modelling the uncertainty itself and carefully estimating the uncertainty model is underlined by Onatski and Williams (2002).

4.2.3. Empirical model of system of equations

Now we can estimate the whole structural model, including output supply, input demand and investment equations. In the theoretical model *(Equation 2),* the last term $\left(\frac{1}{dt}\right)E(dJ)$ represents the changes in value of a firm due to the fluctuations of prices. After the estimation of expected prices *(Section 4.2.2),* the variance of residuals can be obtained and included in equations as a measure of risk. As was argued in *Section 4.2.2*, the unexpected changes in prices can change the value of a firm, thus introducing uncertainty concerning the optimal choice of output supply as well as input demand, which also influences investment demand. It is also reasonable to assume an asymmetry of uncertainty: the un-expectable changes in prices can increase the profit of a firm (e.g. increase of output prices or decrease of input prices) or a decrease in the profit of a firm (e.g. increase of capital- and input price but decrease of output prices). In the first case, we define uncertainty as "positive" relative to the profit of a firm, and in the second case as a "negative" uncertainty. The asymmetry assumption is based on the earlier work of Roy (1952), who recognized that investors care differently about downside losses than about upside gains. Later, the behavioural framework of Kahneman and Tversky (1979) allows investors to give greater weight to losses relative to gains in their utility function. Recently, this idea has been developed in the axiomatic approach to dissappoinment aversion preferences taken by Gul (1991).

The system of equations that include risk and uncertainty can be re-written as:

$$I^* = b_0^1 + b_1^1 p + b_2^1 pv + b_3^1 pk + b_4^1 K + b_6^1 R^I + b_7^1 U^{I+} + b_8^1 U^{I-} \quad (16a)$$

$$X^* = b_0^2 + b_1^2 p + b_2^2 pv + b_3^2 pk + b_4^2 K + b_5^2 I + b_6^2 R^D + b_7^1 U^{D+} + b_8^1 U^{D-} \quad (16b)$$

$$Y^* = b_0^3 + b_1^3 p + b_2^3 pv + b_3^3 pk + b_4^3 K + b_5^3 I + b_6^3 R^S + b_7^1 U^{S+} + b_8^1 U^{S-} \quad (16c)$$

where $b_0^1 = A_{34}^{-1} r a_3$, $b_1^1 = A_{34}^{-1} r A_{13}$, $b_2^1 = A_{34}^{-1} r A_{23}$, $b_3^1 = A_{34}^{-1} r A_{33}$, $b_4^1 = r + A_{34}^{-1} + \delta$, and in the same way for input demand and output supply equations. The last terms of the equations *(7a-7c)* are represented here as a combination of risk, "positive" and "negative" uncertainty.

Adding firm index *i*, we obtain the empirical specification of a system of equations with incorporated uncertainty. The equations in the system are correlated because the underlying decisions are also correlated. This must be taken into account when choosing the right methods for estimation. Based on Greene's (2003, p. 404) discussion about methods of estimation, the Three-stage least square (3SLS) estimator is chosen. 3SLS estimates a system of structural equations where some equations contain endogenous variables among the explanatory variables. All dependent variables are treated as correlated with the disturbances in the system's equations. Some of the independent variables can be also considered as being endogenous. All other independent variables, which are defined as exogenous, are assumed to be uncorrelated with the disturbances and are used as instruments for the endogenous variables.

4.2.4. Empirical model of investment

Another option is to simplify the model without paying attention to underlying structural parameters (see e.g. Elhorst, 1993; Vasavada and Ball, 1988).

The investment equation *(7a)* can be re-written as:

$$I^* = b_0 + b_1 p + b_2 pv + b_3 pk + b_4 K + b_6 R^I + b_7 U^I \tag{17}$$

where $b_0 = A_{34}^{-1} ra_3$, $b_1 = A_{34}^{-1} rA_{13}$, $b_2 = A_{34}^{-1} rA_{23}$, $b_3 = A_{34}^{-1} rA_{33}$, $b_4 = r + A_{34}^{-1} + \delta$, $b_6^1 = A_{34}^{-1} A_{33}$, $b_7 = A_{34}^{-1}(r+1)A_{35}\varepsilon$

Adding firm index *i* and time *t,* we obtain the empirical specification of a model of investment with risk and uncertainty. For investment in time *t,* the value of capital at the beginning of the year *t* should be included, which is equal to the level of capital in time *t-1*, therefore $K_{i,t-1}$ is specified. Following the discussion in *Section 2.3,* uncertainty is represented as "positive" and "negative" uncertainty. Because the equations of the system are correlated, we can assume that risk and uncertainty related to output- (equation *7b*) and input prices (equation *7c*) will have an impact on investments. Therefore, for the estimation of the investment equation, we also include variables of output- and input-price risk and uncertainty. It is also reasonable to introduce time into the investment equation.

The equation (17) can be re-written as:

$$\begin{aligned} I_{it} = {} & b_0 + b_1 p_t + b_2 pv_t + b_3 pk_t + b_4 K_{i,t-1} + b_6 R_t^I + b_7 U_t^{I+} + b_8 U_t^{I-} + \\ & + b_9 R_t^S + b_{10} U_t^{S+} + b_{11} U_t^{S-} + b_{12} R_t^D + b_{13} U_t^{D+} + b_{14} U_t^{D-} + b_{15}' X_{it} + e_{it} \end{aligned} \tag{18}$$

where X_{it} is a vector of firm-specific variables (with vector of coefficients b_{15}), variables R_t^I, R_t^S, R_t^D estimate the impact of risk (or expected variation of prices), terms $U_t^{\pm I}$, $U_t^{\pm S}$, $U_t^{\pm D}$ correct the equations due to unexpected (positive or negative) variation of prices, e_{it} is an error term which is assumed to be white noise. Although it is not straightforward from the theoretical model, it as also possible to include some firm-specific variables in the equation, as can be found in Elhorst (1993), Oude Lansink *et al.* (2001).

The investment decision is dynamic by nature and should be modelled as such. It means that investment of the previous period should be included as an explanatory variable in equation *(18),* which can be shown by taking into account:

$$K_{t-1} = K_{t-2} + \dot{K}_{t-1} = K_{t-2} + (I_{t-1} - \delta K_{t-1}) \tag{19}$$

This leads to the re-formulation of equation *(18)* such as:

$$I_{it} = b_0 + b_1 p_t + b_2 pv_t + b_3 pk_t + b_4 (K_{i,t-2} - \delta K_{i,t-1}) + b_5 I_{i,t-1} + b_6 R_t^I + b_7 U_t^{I+} + b_8 U_t^{I-} + \\ + b_9 R_t^S + b_{10} U_t^{S+} + b_{11} U_t^{S-} + b_{12} R_t^D + b_{13} U_t^{D+} + b_{14} U_t^{D-} + b_{15} X_{it} + e_{it} \tag{20}$$

Panel data analysis allows us to study the dynamic nature of the investment decisions at the firm level. However, the fixed or random effects models may give biased and inconsistent estimators because the error term may be correlated with the lagged variable. To deal with variables that may be correlated with the error term, we use instrumental variables. For panels with a limited number of years and substantial number of observations, Arellano and Bond (1991) suggest estimation equation in first differences and using all lags of the level of variables from the second lag as instruments for individual firm *i*:

$$Z_i = \begin{pmatrix} [y_{i0}] & 0 & \cdots & 0 \\ 0 & [y_{i0}, y_{i1}] & & 0 \\ \vdots & & \ddots & 0 \\ 0 & \cdots & & [[y_{i0}, \ldots, y_{i,T-2}] \end{pmatrix} \tag{21}$$

where *i*=1,…, n; *T* is the number of time periods. The difference GMM solves the following minimum loss function:

$$\min_{\hat{\theta}} \left(\frac{1}{N} \left[Z' \hat{\Delta\varepsilon} \right]' \cdot W_N \cdot \frac{1}{N} \left[Z' \hat{\Delta\varepsilon} \right] \right) \tag{22}$$

where $\hat{\theta}$ is the parameter vector; N is sample size, Z is the matrix of instruments; $\hat{\Delta\varepsilon}$ are consistent estimates of the first differenced residuals obtained from a preliminary consistent estimator; W_N is a weighting matrix, which is $\left[\frac{1}{N} \left(Z' \hat{\Delta\varepsilon} \hat{\Delta\varepsilon}' Z \right) \right]^{-1}$. Unbalanced data is handled by dropping the rows of instrument matrix for which there are no data, and filling zeroes in columns where missing data is required.

Using the first differences eliminates the specific firm effect, thus avoiding any correlation problem between unobservable firm-specific characteristics and explanatory variables.

For a brief illustration of GMM (for more explanations on GMM see Hall, 2005), we can rewrite equation *(20)* as:

$$y_{it} = \theta_i y_{i,t-1} + \varphi_1 w_{it} + v_i + \varepsilon_{it} \qquad |\theta| < 1 \qquad (23)$$

where y_{it} denotes I_{it}; w_{it} is a vector of explanatory variables that may contain lagged variables; v_i is an unobserved individual effect; and ε_{it} is an unobserved white noise disturbance.

We assume that the transient errors are serially uncorrelated $E[\varepsilon_{it}\varepsilon_{is}] = 0$ for *i=1,…,N* and $s \neq t$ and that the initial conditions are predetermined: $E[y_{i1}\varepsilon_{it}] = 0$ for *i=1,…,N* and *t=2,…,T*. Together these assumptions imply the following moment restrictions: $E[y_{i,t-s}\Delta\varepsilon_{it}] = 0$ for *t=3,…,T* and $s \geq 2$.

If we assume that some of the right-hand-side variables can be endogenous in the sense that $E[w_{i1}\varepsilon_{is}] \neq 0$ for *i=1,…,N* and $s \leq t$, which allows both contemporaneous correlation between the current error ε_{it} and w_{it}, as well as between past errors $\varepsilon_{i,t-s}$ and current value of w_{it}, then we have additional moment conditions $E[w_{i,t-s}\Delta\varepsilon_{it}] = 0$ for *t=3,…,T* and $s \geq 2$. Lagged values of endogenous w_{it} variables dated *t-2* and earlier can be used as instruments for the equations in first differences.

Additional instruments are available for the equations in first differences if the w_{it} variables satisfy more restrictive assumptions. They can be predetermined with respect to ε_{it} (there is no contemporaneous correlation but possible correlation with the past errors) or strictly exogenous with respect to ε_{it} (there is no correlation between ε_{it} and w_{it}).

4.3. Data

4.3.1. Data for estimation uncertainty

The annual data-series of output-, input- and capital-price indexes is obtained from CBS. One of the main channels of realisation (and for determining the prices) of horticulture production is by auction (50-90% of a firm's total production); therefore, daily data for output prices are also available, which can be analysed by a GARCH model. Nevertheless, yearly data are preferred for two reasons. First, it is unlikely that farmers consider high-frequency data for the planning of production; second, daily data may contain noise that disappears after aggregation and might better reveal economic relationships (Kuiper *et al.*, 2002).

For an estimation of uncertainty, we use annual data of price indexes of total output, of input, and of investment goods for the period 1949-1999. As can be seen from *Table 4.1*, all series are non-stationary on the level. By differentiating series, we obtained the stationarity, which is confirmed by the statistics of Dickey-Fuller GLS test[21].

Elliot *et al* (1996) proposes local-to-unity detrending (demeaning) using generalized least squares to improve upon the known low power of the DF test. As shown in the comparative study of Cook (2004), the DF-GLS test is relatively robust in the presence of breaks in innovation variance.

Given a time series p_t the unit root test is carried out in a standard ADF framework using regressions of the form

- for series stationary about linear time trend (DF-GLS$^{\tau}$)

$$\Delta p_t^{\tau} = \beta_0 p_{t-1}^{\tau} + \sum_{j=1}^{k} \beta_j \Delta p_{t-j}^{\tau} + e_t \qquad (24)$$

- for series stationary with (possible) non-zero mean, but without time trend (DF-GLS$^{\mu}$)

$$\Delta p_t^{\mu} = \beta_0 p_{t-1}^{\mu} + \sum_{j=1}^{k} \beta_j \Delta p_{t-j}^{\mu} + e_t \qquad (25)$$

and p_t^{τ} and p_t^{μ} are obtained using the equations

$p_t^{\tau} = p_t - (\hat{\alpha}_0 + \hat{\alpha}_1 t)$ and $p_t^{\mu} = p_t - \hat{\alpha}_0$

where the $\hat{\alpha}$ are estimated coefficients from regressions. This involves firstly constructing the variables $\tilde{p} = (p_1(1-\overline{\beta}L)y_{2,...,}(1-\overline{\beta}L)p_T)$ and $\tilde{z} = (z_1(1-\overline{\beta}L)z_{2,...,}(1-\overline{\beta}L)z_T)$ where z is constant and trend $\{1, t\}$ for the DF-GLS$^{\tau}$ and a constant $\{1\}$ for the (DF-GLS$^{\mu}$) test and L is the lag operator. $\overline{\beta}$ is determined by the constant $\overline{c}$ and is given by $\overline{\beta} = 1 + \overline{c}/T$, which takes the value -13.5 and -7 in the detrended and demeaned cases, respectively; T is the sample size. The $\hat{\alpha}$ are given by the coefficients in a regression of $\tilde{p}$ on $\tilde{z}$. A t-test is used to test the null hypothesis $H_0 : \beta_0 = 0$ against $H_1 : \beta_0 < 1$.

The lagged differences are included in order to eliminate any serial correlation in the residuals. Specifically, as shown by Hall (1994) and Ng and Perron (1995), the ADF test suffers from low power when the lag length is too small, and this problem leads to too few

---

[21] The possibility to apply a rolling unit-root test was considered. But this approach was not accepted due to the fact that the power of the test can depend crucially on the window width (as it is shown in the extensive study of Rober Taylor (2005) and can suffer from a small (25 years) window in our case. Moreover, in the article of Taylor (2005), the critical values for rolling unit-root tests are calculated for a minimum of a 100-observations sample, which is not applicable to our sample.

rejections. For the lag selection we used the Ng-Perron (1995) sequential *t*, which offers a good combination of size and power. With the Ng-Perron procedure, no lags should be included in the test for all price series where we can use the original DF-test, which detected unit root on the level for all prices. In the same routine, the test for unit root was performed on the first difference. First, the DF-GLS test using the Ng-Perron procedure rejected the presence of the autocorrelation in the error term (0 lags); second, the unit root was rejected by the DF test. The constant term had significant coefficients for all price series in a regression of the prices in first differences on a constant term. This means that the series are stationary in the first difference.

We also checked the series using the Johansen procedure on the presence of stationary equilibrium relationships among them, but the presence of cointegration vectors was rejected[22].

***Table 4.1:* Results of Dikkey-Fuller unit root test**[1)]

DF test: $\mid \beta_0 \mid < 1$	**On the level**	**On the first difference**
Prices of:		
Output		
- test statistic [2)]	-1.414 (-2.407)	-7.634 (-2.408)
Data generating process	$p_t = \delta_0 + p_{t-1} + e_t$	
Input		
- test statistic [2)]	-1.298 (-2.407)	-5.610 (-2.408)
Data generating process	$p_t = \alpha_0 + p_{t-1} + e_t$	
Capital		
- test statistic [2)]	-1.765 (-4.150)	-6.522 (-2.408)
Data generating process	$p_t = \alpha_0 + \alpha_1 t + p_{t-1} + e_t$	

[1)] *The presence of autocorrelation in the residuals was rejected by the Ng-Perron procedure*
[2)] *1% critical value in parentheses for the DF test*

Statistical investigation of the time series results in the conclusion that prices follow a random walk process with drift. Output- and input prices exhibit a stochastic trend in addition to a deterministic linear trend, while the capital price exhibits a stochastic trend around a

[22] The concept of integration was introduced by Granger (1981) for testing the correlation between non-stationary time-series variables. If two or more series are themselves non-stationary, but a linear combination of them is stationary, then the series are said to be cointegrated.

deterministic quadratic trend. By revealing a random walk we can conclude that current prices are the best, unbiased, estimate of prices tomorrow. The only factor that affects these prices is the introduction of previously unknown news, which can be termed as uncertainty. Furthermore, we can conclude that farmers have rational expectations and this confirms the assumption about efficiency of the market.

These findings are consistent with our theoretical model, because by assumption about maximizing expected profit, we already implicitly incorporated the rational expectations hypothesis (*REH*) into the theoretical model.

4.3.2. Data for estimation of investments

For an estimation of investment, the unbalanced panel data of horticulture firms is used. The data was collected by LEI over the period 1975-1999. The panel consists of 1500 firms with 6905 observations. On average, firms stay under observation for a period of 4-5 years.

Summary statistics of the data are presented in *Table 4.2*. Investment (as all monetary variables) is calculated in euros and measured in 1985 prices. Capital is the replacement value of land, buildings (including glasshouses), installations and machinery. The depreciated level of capital is also included as a variable, because it will be used for an estimation of investment as a single equation *(Equation 20).* The output is measured in revenue; input is measured in total variable costs. Price indexes are included in first difference in compliance with the above discussion *(Section 4.3.1.)*. Comparing the means of the time series, one can see that growth of input prices is larger than that of output prices, which can reflect a tendency of decreasing marginal profit of a firm in time.

Additionally to the variables from the theoretical model *(Equation 7a-7c),* some firm-specific variables are also presented. They provide more information on the state of a horticulture firm that can influence investment decision. Standard deviation from the mean is very high, which can lead to the assumption about heterogeneity among the firms.

Firm size is measured in standard farming units (DSU[23]), and it is a measure of the income-generating capacity of a firm, which is included in the system of equations additionally to the variables defined in equations *(16a)-(16c),* and which can capture the effect of heterogeneity among the firms. The debt at the beginning of the year *(Debt)* is included in the model as it can influence the investment decision. One can expect two contradictory effects of debt: a negative effect as an indicator of constraints for acquiring new debts for the investment, and a positive effect as an indication of financial stability of a firm. By the specification of the model, all dependent variables from the equation of the system are

[23] Dutch Size Units (DSU) is the national equivalent of European Size Units, an economic measurement based on standard gross margins (de Bont *et al.*, 2003).

treated as endogenous. We also define the variable of capital as being endogenous, because level of capital is predetermined by the system and correlation with the error term can be possible.

Table 4.2: **Variables, Mean and Standard deviation**

Variable		Mean	Std. Deviation
Investment*	Inv	50.08	129.84
Capital*	Cap	383.04	371.76
Capital depreciated* ($K_{i,t-2} - \delta K_{i,t-2}$)	CapDep	342.76	334.73
Output (total revenue*)	Out	372.36	307.07
Input (total costs*)	In	343.22	372.94
Debts at the beginning of a year*	Debt	315.27	353.80
Firm Size (Standard Firm Units)	SFU	566.70	478.38
Price index of real prices			
- capital (investment goods)	IndCap	3.708	0.650
- output	IndOut	3.087	0.278
- input	IndIn	4.493	0.419

** All monetary variables in 1000 euros, normalised by 1985 year*

For the estimation of investments by a single equation *(Equation 20)* the use of a lagged variable (*CapDep)* results in a decrease in data size. The data consist of 1,232 firms with 3,985 observations. Firms were observed on average for a period of 3.23 years. We define *Capital* as an endogenous variable—because it can correlate with the error in the equation—but variables of prices growth, risk and uncertainty are defined as exogenous ones.

4.4. Results

4.4.1. Estimation of expected prices and price uncertainty in Dutch glasshouse horticulture

To obtain the expectation about changes in prices, we use an ARIMA(0,1,0) process (Maddala and Kim, 1998). We assume that firms incorporate a maximum of a 25-year period to form expectations. Therefore, we use estimation with a moving window of a span of 25 years. Due to this, for a prediction of price change in 1975 we use the period 1950-1974; for the 1976 prediction, the 1951-1975 period is used, and so on.

One of the salient results is a variation in estimated constant term, which is, following Fama *(Section 4.2.2),* characterised as a price bias due to the compensation for risk. *Figure 4.1* shows the expected drift of prices for 1975-1999.

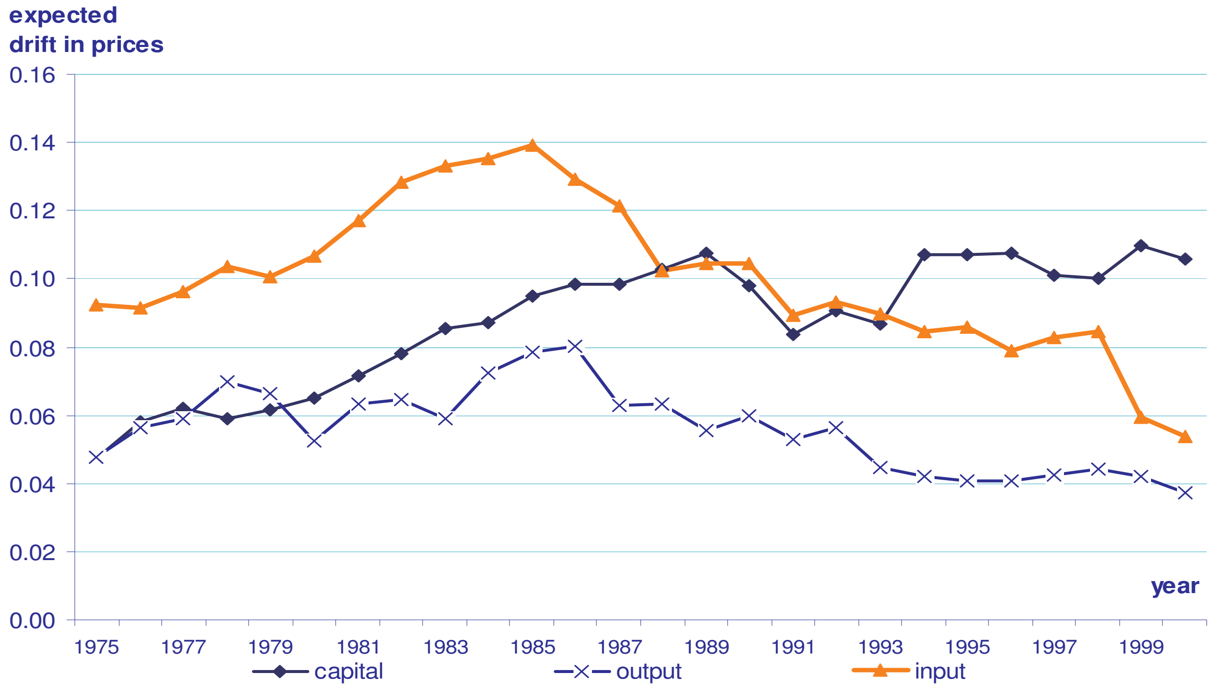


Figure 4.1: **Variation of estimated constant term $\hat{\alpha}_t$ in ARIMA(0,1,0) for prices**

By using a moving window, we captured the effect of a farmer including the most recent information to form expectations about future prices. By analysing the graph (*Figure 4.1*), we can see the difference in expectations of drift in prices over the years and between prices. Until 1982, the expectations were of rapidly growing prices, with the biggest drifts in input prices, e.g. estimated drift was 0.13 in 1982; then during the mid-eighties the expected growth is slower and expectations arise about a decline in prices. In the nineties, output- and input prices are expected to decline and capital prices are expected to exhibit little growth.

One of the interesting observations from the graph is that the expected growth of output prices is lower than the expected growth of input prices. An expected drift for output prices is smaller than for others and after the mid-eighties (0.08) it steadily declines to a 0.04 level. Firms in the horticulture industry know that due to large productivity increases, output prices will grow less quickly than input prices. This can also be related to the risk-averse nature of firms: they include a higher "risk premium" to input prices, which are related to cost of business, and a smaller "risk premium" to output prices, which influence revenue.

After estimation by ARIMA(0,1,0), we can obtain predicted values of changes in prices:

$$\Delta\hat{p}_t = \hat{\alpha}_t \qquad (26a)$$

The estimated variance of error terms is extracted for every year of prediction and represented in *Table 4.3* as a variable of Risk.

Table 4.3: **Estimated Variables, Mean and Standard deviation**

Variable		Mean	Std.Deviation
Growth of prices indexes (Δp_t) of:			
- capital	PrCap	0.105	0.148
- output	PrOut	0.038	0.176
- input	PrIn	0.055	0.180
Risk (estimated standard deviation of drift) of prices:			
- capital	RCap	0.025	0.006
- output	ROut	0.031	0.006
- input	RIn	0.033	0.004
Positive Price Uncertainty:			
- capital (actual price < expected price)	$UnCap^+$	-0.032	0.087
- output (actual price > expected price)	$UnOut^+$	0.040	0.061
- input (actual price < expected price)	$UnIn^+$	-0.070	0.111
Negative Price Uncertainty:			
- capital (actual price > expected price)	$UnCap^-$	0.043	0.072
- output (actual price < expected price)	$UnOut^-$	- 0.054	0.102
- input (actual price > expected price)	$UnIn^-$	0.024	0.052

We also assume that a rational firm making the prediction of prices and observing variation in prices during the 10 previous years also has rational expectations about possible variation in the prediction. Therefore, the prediction of future prices is done at intervals. Due to this, we computed a confidence interval of prediction by formula:

$$\Delta \hat{P}_t = \hat{\alpha}_t \pm 2 * S_{\hat{\alpha}_t} \qquad (26b)$$

where $S_{\hat{\alpha}_t}$ standard error of predicted constant term.

By comparing actual changes of prices with predicted interval of changes, we can obtain the "unpredictable part" of changes, which we define as uncertainty (*Table 4.3)*. We can see that for more fluctuating prices like output and input, the expected deviation of prediction is 3-4 times of annual growth of these prices; for capital prices with a high annual growth (10.6%) but of a less fluctuating nature *(Figure 4.3)*, the expected risk is on the level of the growth.

As can be seen, the magnitude of shocks, which indicates the excess of price realisation above the expectations, is substantial. The negative shocks were bigger than the positive ones for output prices, and the opposite trend applied to capital and input. By distinguishing the predictable error of prediction and unpredictable changes in actual prices, we explicitly separated two phenomena: risk and uncertainty, which can be considered as Knight's "statistical probability" and "estimates" respectively (Knight, 1921 : pp. 224-225). Although in empirical applications parameters of variability of prices are mostly used as proxies for risk and/or uncertainty, by distinguishing between risk and uncertainty (as is shown in *Figure 4.2*), we can better capture the effect of unpredictable changes on investments.

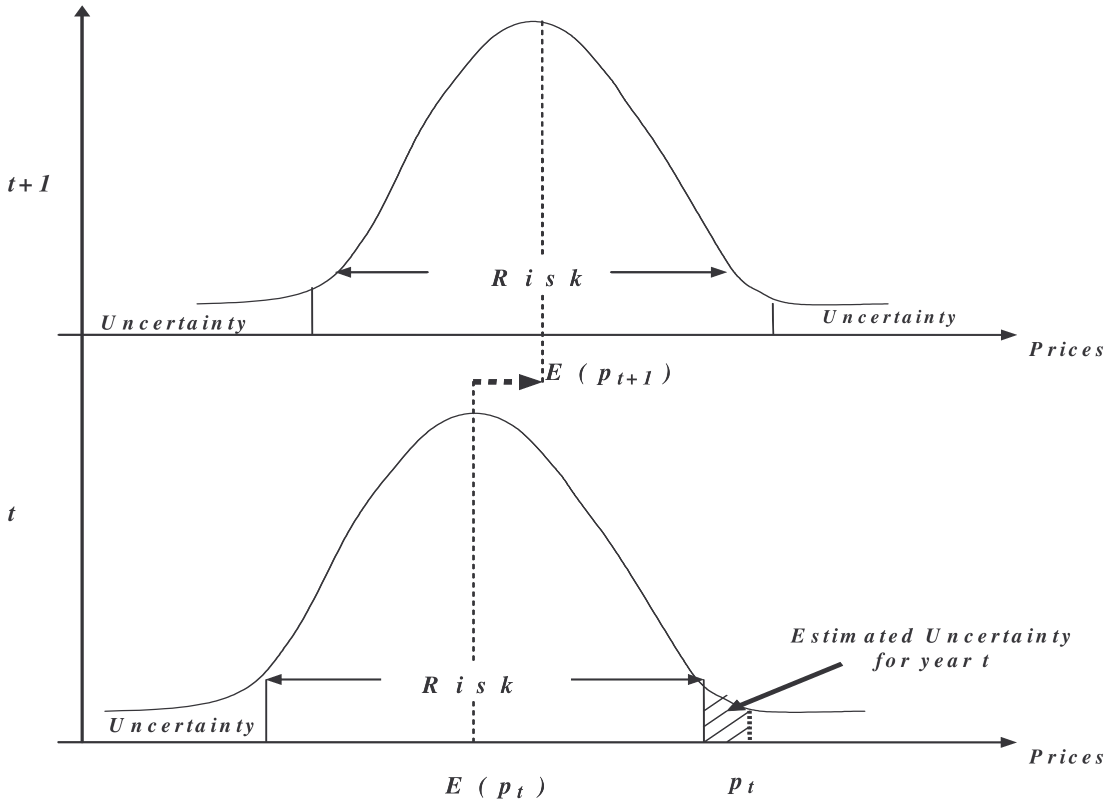


Figure 4.2: **Estimation of Risk and Uncertainty and effect of real prices on forming of expectation of prices**

Additionally, as was discussed in *Section 4.2.3*, the positive and negative uncertainty is distinguished. For example, unexpected growth of output prices can motivate investments, but a negative shock can suppress them assymetrically. As can also be assumed, the impact of a negative shock can be stronger than the impact of a positive one.

Summarising then, we can write the formula for the estimation of uncertainty, where uncertainty represents outcomes in the tails of distributions and is calculated as a distance from expected interval estimation of prices to the realised prices in year *t*:

$$U_t^{\pm} = \Delta p_t - \Delta \hat{p}_t = \Delta p_t - \hat{\alpha}_t \mp 2 * S_{\hat{\alpha}_t} \qquad (27)$$

Figure 4.3 demonstrates the concept of distinguishing between risk and uncertainty. The estimated (positive) uncertainty for year *t* impacts the following year's expectation of prices by shifting the mean in year *t+1*. However, if there were to be no positive or negative uncertainty, then the estimation for the following year only results in a shift of the mean equal to the drift and changing the width of deviation from the mean. The empirical application of estimation risk and uncertainty to the real data of price indexes (*Figure 4.3*) shows the role of unexpected changes of prices in defining the expected growth of prices by defining expected price changes.

The analysis of *Figure 4.3* demonstrates when the actual value of changes in prices was different from the expected value. As can be seen, output price shows a great deal of variation, with the biggest negative shocks in 1986 and 1992. Positive shocks in 1975, 1980, 1983, 1996, when prices were higher than expected, were followed by 1-2 years of growth. Input prices were much lower in 1981 than expected, but in most years (e.g. 1985-1987, 1990), there are negative shocks, which result in the decrease of profitability of a firm. Compared to output- and input prices, capital prices are more easily predicted because they have more stable growth, although there were "decreasing shocks" in 1989-1990, and an "increasing shock" in 1993. The statistics of estimated variables are presented in *Table 4.3*. Because the core of this chapter is the analysis of the effect of risk and uncertainty on investment, we are not providing the analysis of sources of the price-uncertainty in depth. But we can make a suggestion that explanations can be found in firm-environmental uncertainty on the macro-level as well as on the micro-level.

As examples of an event influencing output prices, drops in prices of tomatoes due to negative perception of them in Germany in the middle of the nineties (The New York Times, 19 October, 1994) can be mentioned. Another example is the prohibition of Dutch flower exports to Russia in 2004 due to injurious insects on some of the exported plants (Pravda, 2 July 2004). In the first case, the changing preferences influenced quantity of demand and resulted in lower output prices in an important export market. The same process of changes in output prices in the second case originated from an unexpected application of trade regulations. The salient example of input prices uncertainty is changes in energy prices after global oil crises. Glasshouse horticulture is highly dependent on energy prices; they consume the biggest share (75%) of energy within Dutch agriculture. The interaction of firms' surrounding uncertainty with the input-prices uncertainty can be shown through the example of the introduction of subsidies for investments in energy-saving technologies (Van der Knijff *et al.*, 2006). Another investment-related subsidy is the WIR subsidy, which lowered the actual capital prices. According to WIR law, a firm could obtain a subsidy on investments in the period between 1978-1988 for the purpose of stimulating investments (VNO, 1980). The agreement about the reduction of gas emissions (VROM, 1999), which increased the capital demand on new types of installations, could have raised the prices of capital. The examples quoted shed light on possible causes of uncertainty shocks and show that it is very important to take into account possible future changes (which can be unexpected) when an investment decision is being taken.

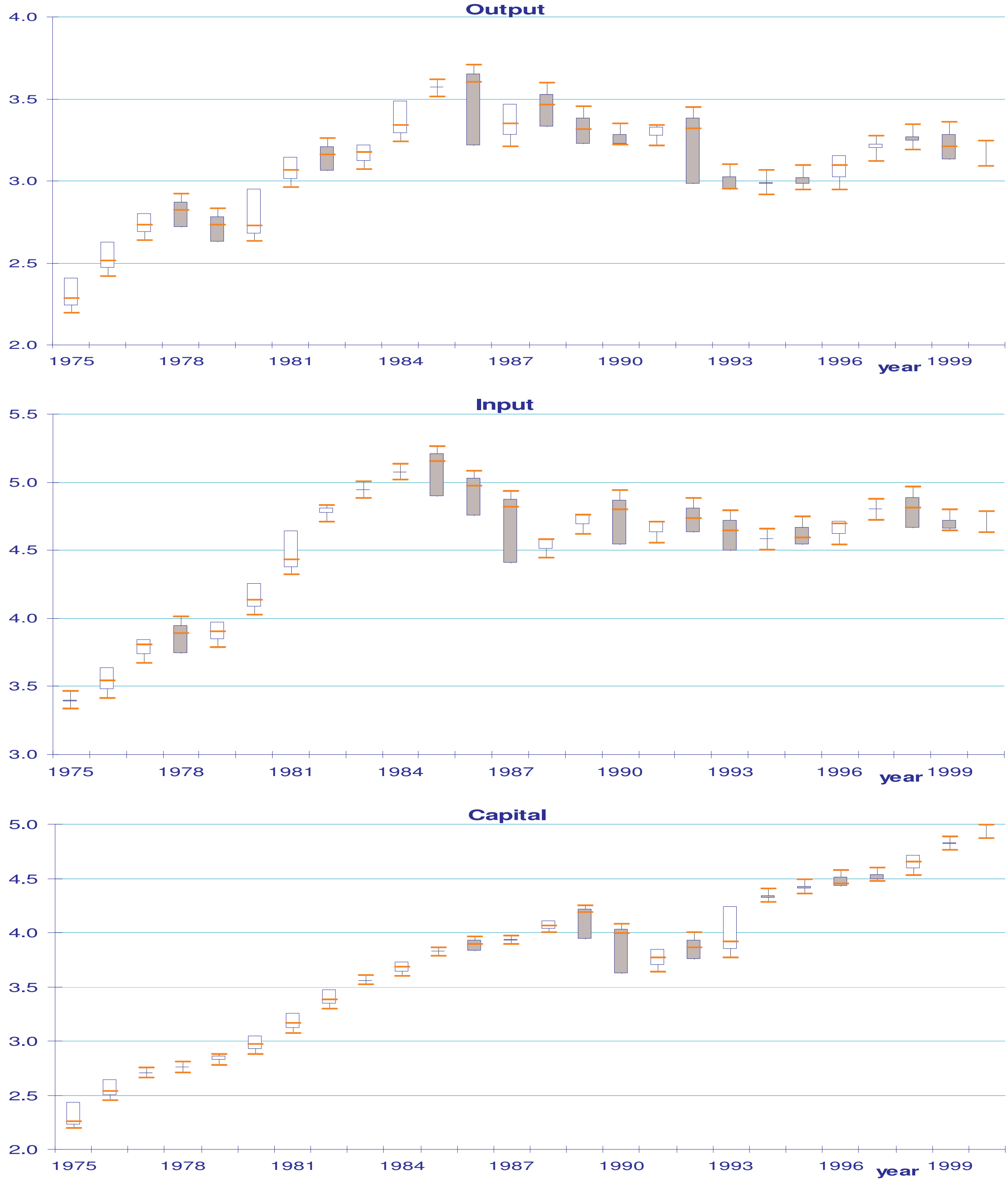


Figure 4.3: **Output-, input- and capital price uncertainty**

Notes: * vertical lines represent the confidence interval
** bars represent the difference between actual value and predicted value
*** bars have white filling if actual value bigger than predicted value
**** bars have grey filling if actual value is smaller than predicted value

As examples of an event influencing output prices, drops in prices of tomatoes due to negative perception of them in Germany in the middle of the nineties (The New York Times, 19 October, 1994) can be mentioned. Another example is the prohibition of Dutch flower exports to Russia in 2004 due to injurious insects on some of the exported plants (Pravda, 2 July 2004). In the first case, the changing preferences influenced quantity of demand and resulted in lower output prices in an important export market. The same process of changes in output prices in the second case originated from an unexpected application of trade regulations. The salient example of input prices uncertainty is changes in energy prices after global oil crises. Glasshouse horticulture is highly dependent on energy prices; they consume the biggest share (75%) of energy within Dutch agriculture. The interaction of firms' surrounding uncertainty with the input-prices uncertainty can be shown through the example of the introduction of subsidies for investments in energy-saving technologies (Van der Knijff *et al.*, 2006). Another investment-related subsidy is the WIR subsidy, which lowered the actual capital prices. According to WIR law, a firm could obtain a subsidy on investments in the period between 1978-1988 for the purpose of stimulating investments (VNO, 1980). The agreement about the reduction of gas emissions (VROM, 1999), which increased the capital demand on new types of installations, could have raised the prices of capital. The examples quoted shed light on possible causes of uncertainty shocks and show that it is very important to take into account possible future changes (which can be unexpected) when an investment decision is being taken.

4.4.2. Estimation of the system of equations

The estimation of the investment as an equation of the system implements the investment decision as part of the more complex decision about the production process in a firm. The results of estimation are represented in *Table 4.4*[24].

Table 4.4 shows a negative influence of risk and uncertainty on investment. By analysing the investment equation, we can see that with the expected 10% increase in standard deviation of prices, the average firm is willing to invest 62.97 euros less than expected. Thus, the estimated increase in risk (10% of standard deviation in average equal to 0.25% change in prices) will suppress investments. The not-expected changes in prices have a negative impact on investments. Indifference with respect to "positive" or "negative" uncertainty can be explained by the fact that it might capture the effect of instability on the capital market, which is not desirable for firms. The positive coefficient of the capital-prices growth could indicate that firms should invest more because capital is becoming more expensive. The presence of

[24] The STATA 9 software was used for estimation *(Table 4.4)*.

high levels of debt will suppress investment, which confirms the impact of financial constraints on the level of investment.

***Table 4.4:* Estimation of system of simultaneous equations by 3SLS**

	Investment equation	Demand equation	Supply equation
Dependent variable	Inv	In	Out
Coefficients of equations[1]			
PrOut	0.007 (11.0)	-13.2 (11.9)	- 196.6 (68.8)
PrIn	11.3 (10.2)	60.8** (31.2)	- 40.7** (19.4)
PrCap	267.5*** (83.6)	- 18.8 (14.0)	- 55.0** (24.2)
Cap	0.282*** (0.050)	0.221*** (0.053)	0.025 (0.099)
Inv		-0.544*** (0.180)	-1.029*** (0.289)
Debt	-0.023 (0.043)		
R	-629.7*** (107.9)	- 16.7 (162.4)	- 1211.1*** (310.0)
Un^+	-291.9*** (101.8)	-112.8*** (38.1)	102.6 (116.6)
Un^-	-408.8*** (107.9)	- 144.5*** (53.5)	245.2*** (79.6)
SFU_t	-0.097 (0.071)	0.549*** (0.033)	0.793*** (0.067)
R-sq	0.071	0.898	0.726
Chi2	1346.1	58177.1	18302.4
N	6905	6905	6905
Test of coefficients[2], *Chi2 (1)*			
$Un^+=Un^-$	9.40*** (0.00)	0.78 (0.38)	4.88*** (0.00)
$Un^+ + Un^- = R$	0.02 (0.88)	2.84* (0.09)	23.18*** (0.00)

[1] Error in brackets
[2] Probability in brackets
***, **, * are 1%, 5%, 10% level of significance

Although it is not our primary goal to investigate input demand and output supply equations, analysing the effect of risk and uncertainty in these equations can be useful for understanding the role of these variables in the economic system. If we take into account that capital is (quasi-fixed) input, then we can see that risk and uncertainty suppress demand. The uncertainty shocks, caused by output prices, stimulate a firm's supply, which gives an indication that in the case of a positive effect, the firm uses the opportunity to increase revenue, and in the case of a negative effect tries to compensate an unfavourable situation. Output can be suppressed if there are expectations that output prices will variate in the following year. Overall negative impact of risk on the decisions can be due to agents having more concern about losses, which can affect the formation of their expectations.

The most important observation among the three equations is that negative uncertainty (if calculated on one unit change) has a larger absolute effect than a positive one, which confirms the hypothesis that asymmetry influences uncertainty. In general, we can also confirm the validity of distinguishing between risk and uncertainty due to their different impact on dependent variables.

The R-square indicates a high level of goodness-of-fit for Demand and Supply equations, but a low level for the Investment equation. This can indicate that investment decision-making is considered here as "auxiliary" for defining input demand and output supply of the firm. However, the desirable level of capital and actual investments can differ, because some important determinants are outside the scope of the model. In other words, there are omitted variables in the investment equation which are important for investment decisions, but not included in the system. The R-square indicates a high level of goodness-of-fit for Demand and Supply equations, but a low level for the Investment equation. This can indicate that investment decision-making is considered here as "auxiliary" for defining input demand and output supply of the firm. However, the desirable level of capital and actual investments can differ, because some important determinants are outside the scope of the model. In other words, there are omitted variables in the investment equation which are important for investment decisions, but not included in the system.

By testing the equality in the effect of negative and positive uncertainty, the assumption about asymmetry of uncertainty is examined. For investment and supply equations the asymmetry is confirmed: the impact of positive and negative shocks is different in size. For the demand equation, the equality of the coefficients cannot be rejected.

Although the assumption about the difference in effect of risk and uncertainty is not confirmed for investment equation, for demand and supply equations the distinction between the effect of risk and uncertainty shock should be made. This finding is one of the more persuasive arguments that supports the Knight (1921) and Keynes (1921) distinction between the role of risk and uncertainty in decision-making.

4.4.3. Estimation of the impact of risk and uncertainty on investments

To estimate a firm's investment demand, the investment equation was estimated[25] by GMM, in compliance with the theoretical discussion in *Section 4.2.4.* GMM is robust to potential misspecification bias from omitted variables (which was probably a problem for defining the investments by system), because as discussed above, by using the first differences, the firm-specific effect is eliminated, thus avoiding any correlation problem between unobservable (or omitted) firm-specific characteristics and explanatory variables. As discussed in Hall (2005: p.117), the over-identifying restriction test is powerful against certain types of misspecification (including omitted variables) and can be used to test whether the model has been correctly specified.

We use Arellano and Bond's (1991) two-step estimator for our dynamic model, which allows for heteroscedasticity across firms. The obtained results are shown in *Table 4.5*. Arellano and Bond (1991) show that when the number of firms is limited, the asymptotic standard errors associated with the two-step estimates may be biased downward. However, the one-step estimators are less efficient than the two-step estimators, even in the presence of homoscedasticity of the error terms. Since the standard errors associated with one-step estimators are more reliable for the purpose of making inferences (2003: p. 21), they are reported in *Table 4.5*.

The heterogeneity of firms, which can be caused by differences in specialisation, locations or management characteristics, is an important issue in panel data models due to the possible correlation of an individual effect with regressors. By first-differencing we remove the individual effect. The error term in the differenced equation has a first-order correlation and is correlated with the transformed first lag of dependent variable of investments. Due to this, the following moment conditions can be defined: $E[I_{i,t-2}\Delta\varepsilon_{it}]=0$. In model (20), the explanatory variable of depreciated capital is potentially endogenous because vintage of capital induces firms to invest. Thus, in the differenced equations, the first difference of this variable is instrumented by the lagged levels, which implies the following moment conditions: $E[(K_{i,t-3}-K_{i,t-2})\Delta\varepsilon_{it}]=0$. The other variables are treated as exogenous variables.

The number of firms that have more than 4-year observations is not substantial, which means that fewer observations are available for the moment conditions in later years. Because this can cause a problem for the asymptotic approximations in GMM, the number of lags of endogenous regressors was restricted to four.

The reliability of our econometric methodology depends crucially on the validity of instruments. We check it with Sargan's test of over-identifying restrictions, which is

[25] The STATA 9 software was used for estimation *(Table 4.5).*

asymptotically distributed as *Chi2* in the number of restrictions. Sargan's test is highly non-significant (with a probability of 0.595), therefore we cannot reject the null hypothesis that the instruments used are valid. The GMM estimator is consistent if there is no second-order serial correlation between error terms of the first-differenced equation. We present test statistics for first-order (-6.25) and second-order (-1.04) serial correlation that confirms the presence of negative first-order serial correlation and rejects second-order serial correlation. This is completely in compliance with the theory.

Table 4.5: **Estimation of Investment equation**

Dependent variable Inv_t	**Coefficient[1)]**	**St.Error[2)]**	**p-value[2)]**
$PrOut_t$	188.46	77.77	0.009
$PrIn_t$	- 215.40	86.53	0.011
$PrCap_t$	42.14	23.29	0.054
$CapDep_{t-1}$ ($K_{i,t-2} - \delta K_{i,t-1}$)	-0.273	0.086	0.001
Inv_{t-1}	-0.215	0.063	0.001
$RCap_{t-1}$	- 4088.0	1026.8	0.000
$UnCap^{I+}_{t-1}$	123.9	29.1	0.000
$UnCap^{I-}_{t-1}$	- 75.4	44.2	0.075
RIn_t	4235.0	1326.5	0.002
$UnIn^{+}_t$	272.6	111.3	0.013
$UnIn^{-}_t$	140.9	118.0	0.209
$ROut_t$	- 587.4	892.2	0.678
$UnOut^{+}_t$	- 250.9	109.5	0.013
$UnOut^{-}_t$	- 166.1	97.4	0.060
Sargan test[3)] Chi2 (224)	218.29		
Prob > Chi2	0.595		
	z-value	**p-value**	
AR[4)] (1), N(0,1)- statistic	-6.25	0.000	
AR[4)] (2), N(0,1)- statistic	-1.04	0.299	
N	3985		

Note: [1)] Results obtained by two-step Arellano-Bond panel-data estimation
[2)] Results obtained by one-step Arellano-Bond panel-data estimation
[3)] H_0: the over-identifying restrictions are valid
[4)] Arellano-Bond test that average autocovariance in residuals equals zero.
H_0: no autocorrelation

The specification of the investment demand analysed below provides a better explanation of the decision about investments compared to the estimation of investments as an equation of the system. The lagged variables of capital and investment play a negative role in investment decision, which also underlines the dynamic nature of the investment decision. On average, the expected growth of investment in year *t* will be 0.215 euros less if in year *t-1* investment increased by 1 euro. The 1-euro increase of accumulated capital will suppress investment growth in the following year by 0.273 euro.

Growth of output prices has a positive effect on investment, and growth of input prices has a negative effect, as expected. Counter-intuitively, the growth of capital prices has a positive impact on investment; the same was found for the system equations estimation that gives an indication of a persistence of this result. It can be explained by the fact that the capital, which embodies new technology, is more costly but can be preferred due to the increase in efficiency. Another reason could be a supply side effect, because a higher demand for capital goods raises its price. Moreover, business cycle and subsidy regulations were not included in the model.

Our primary interest is to analyse the role of risk and uncertainty in the investments. Three types of price risk and uncertainty are included in the model. The results highlight the important role that these factors play in determining an investment demand.

The growth of risk by one standard deviation, suppresses investments in the case of capital goods (by 4,088 euros) and output prices (by 587 euros), and increase investments in the case of input prices (by 4,235 euros). The positive effect of "input-prices risk" can be explained by the fact that firms are motivated to invest to decrease costs, e.g. an increase in energy prices stimulates investments in energy-efficient technology, glasshouses, and installations.

The 1% decrease in input prices below expectations introduces 2,726 euros growth of investment, the coefficient of unexpected negative (for the profit of the firm) change in input prices is not significant. Output-price uncertainty negatively influences the investments, a 1 % increase in "negative uncertainty" will result in 1,661 euros fewer investments; 1% of "positive output uncertainty" growth suppresses investments by 2,509 euros. One of the possible explanations that growth in output prices, which is positive for the revenue, can suppress the investments, is that firms may like to replace capital at times when the opportunity costs of lost output are small. The effect of a 1% change in capital-price uncertainty on investment is less than a similar 1% change of input- and output-price uncertainty, which can be explained (referring to *Figure 4.2*) by the fact that prices of capital are more predictable than others, and demonstrates the expected signs.

The test of assumption of asymmetry of price uncertainty was conducted and results are shown in the *Table 4.6*. The difference between negative and positive uncertainty is significant for all prices. The bigger negative effect of output-price uncertainty investments, confirmed by the test, gives an additional clarification of a possible postponing of investments during high-profitability periods.

***Table 4.6:* The test of coefficients**

	Chi2(1)	Prob>Chi2
Assymetry of uncertainty		
$UnCap^{I+}_t = UnCap^{I-}_t$	2232.67	0.000
$UnIn^{+}_t = UnIn^{-}_t$	116.36	0.000
$UnOut^{+}_t = UnOut^{-}_t$	201.37	0.000
Equality of risk and uncertainty		
$UnCap^{I+}_t + UnCap^{I-}_t = RCap_t$	970.8	0.000
$UnIn^{+}_t + UnIn^{-}_t = RIn_t$	347.9	0.000
$UnOut^{+}_t + UnOut^{-}_t = ROut_t$	0.70	0.402

The variables of risk show different coefficients compared to the uncertainty variables. This can point to the importance of the distinction of two phenomena: risk and uncertainty. The equality of effects of risk (increase in variance of prices) and uncertainty (unpredictable changes of prices) is rejected for capital- and input prices, and cannot be rejected for output prices (*Table 4.6*). This finding is one of the more persuasive arguments that supports the Knight (1921) and Keynes (1921) distinction between role of risk and uncertainty in decision-making. The possible explanation originates from the work of Ellsberg (1961), which confirms the difference in the preferences of agents between “risk” and “ambiguity”.

4.5. Conclusions and discussion

The main goal of the study was to identify and to estimate the effect of risk and uncertainty on investments, which exerts an influence on the development of Dutch glasshouse horticulture.

The capital-, input- and output-prices risk and uncertainty were estimated. A new framework for uncertainty estimation was proposed that distinguishes between risk and uncertainty as, respectively, predictable and unpredictable deviations of predicted prices from actual prices. The risk and uncertainty were included in the model as different variables, which allow us to demonstrate the different role of these variables. The asymmetry of uncertainty shocks was assumed and implemented in the models as two separate variables, showing the difference in impact of a negative shock, compared to a positive shock.

The investment demand was estimated first as an equation of the system, which also includes equations of input demand and output supply. The estimation using 3SLS, which allows for endogeneity and correlation between equations in the system, provides a good explanation for demand and supply equations, but the degree of explanation of investments at firm level is rather low. This is not usual for investment equations at firm level (e.g., Agbola and Harrison, 2005). An important factor is the clarification of the role of risk and uncertainty in the system. Through estimating three equations, we also obtained richer information on the influence of investments on the economic system through output supply and input demand. In the year in which a firm makes substantial investments, its input demand and output supply are lower, because production factors (e.g. financial, labour sources) are used to get investments into operation. This is demonstrated by clearly significant negative coefficients of investment variables in the output supply and input demand equations.

The dynamic structure of the panel data was exploited for the estimation of the investment demand as a single equation by a GMM estimator, which allows us to overcome problems with heterogeneity and endogeneity, as well as possible omitted variables. The three types of price uncertainty and risk were included in the model. This leads to the conclusion that price risk and uncertainty play an important, but differing, role in the investment decision. An assumption about asymmetry of uncertainty is uniformly confirmed for all three prices included in the model.

The effect of an output-price uncertainty shock, regardless of whether it is profitable for the firm or not, is to suppress investments. The input price uncertainty influence investments positively. The unexpected growth of capital prices decreases the level of investments; but lower-than-expected capital prices have a stimulating effect. Summarizing then, the influence of uncertainty is substantial, even a small shock can introduce large consequences on investments. The research results make clear that distinguishing risk and uncertainty contribute to a better understanding of the investment behaviour of glasshouse horticultural firms.

For future research, it would be interesting to test whether the difference in specialisation of firms (vegetable, cut-flowers, pot-plant) influences the relation between uncertainty and investments. Such a study would provide further knowledge about the nature of uncertainty. More specifically, by comparing horticulture firms with different output prices, we may be able to better capture the fluctuation of market prices and also take into account substitution effect across and between sectors. Another interesting direction of research is to analyse whether the impact of uncertainty varies with the type of capital goods, due to the difference in the degree of irreversibility for different types of capital goods (land, buildings, installations, machinery.

Chapter 5

The Determinants of Entry and Exit decisions in Dutch Glasshouse Horticulture

Natalia V. Goncharova, Arie J. Oskam

"It is not the strongest of the species that survives, nor the most intelligent, but the one most responsive to change."

Charles Darwin

5.1. Introduction

Decisions about entry or exit are accompanied by investments that are likely to be irreversible. These two decisions, which are crucial for the firm, have profound implications for economic growth, because the entry and exit of firms can be beneficial for productivity growth, technological upgrading and employment generation. According to the OECD (2003), the entry and exit of firms accounts for 20-40% of total productivity growth in eight selected OECD countries.

By considering entry as an investment decision and exit as a disinvestment (negative investment) decision, the findings in investment theory can be applied to explain industry dynamics. The economic literature suggests different theoretical and empirical approaches to explain choices of entry, exit and size of firms (for an overview see, for example, Siegfried and Evans, 1994). This article is based on Marshall's model of long-run and short-run equilibriums, which assumes that firms are induced to enter if current revenue exceeds sunk costs ("Marshallian trigger point") and to exit if revenue falls below sunk costs.

However, it is observed that firms sometimes prefer to delay an entry or exit decision, in the expectation that prices and revenue can change in the future. The real option theory postulates that uncertainty will affect the entry-exit investment decisions in such a way that it will change trigger points. In the model of Dixit (Dixit, 1989; Dixit, 1992), a wedge between the Marshallian trigger point and "observed" trigger point produces a zone of "hysteresis" in which firms do not respond to price signals.

By developing this idea, it is possible to suggest that output and input prices (and their fluctuations and expectations) drive investment decisions such that they change cash flow. A change in prices (and in expected cash flow) can attract firms to the sector or push them away. But this assumption can introduce another relation of prices (and uncertainty) and entry-exit investment decision than would have been the case with a change in trigger points.

One of the difficulties of analysing the industry dynamics is related to the high level of heterogeneity of entry and exit and to the absence of a clear classification of these. The different ways of entry can affect the entry decision itself and the length of survival of firm after entry. The different types of exit can indicate different processes in a sector, which provide a better understanding of the reallocation of sources.

The goal of this study is to develop empirically applicable classifications of entry and exit and to investigate the impact of investment trigger points on the number of entering and exiting firms for Dutch glasshouse horticulture. Dutch glasshouse horticulture can be characterised as a dynamically changing, highly competitive, and capital intensive sector. The evolution and adaptation of the sector to new technologies, to consumer preferences and to market requirements are reflected in the process of firms' entry and exit. For this reason, it is suitable data for studying the firms' entry and exit investments.

In the next section *(Section 5.2),* the theoretical model is presented. It also includes the specification of empirical models of entry and exit; the negative binomial econometric model is used for estimation. In *Section 5.3* the classification of entry and exit is proposed and its empirical implementation described. *Section 5.4* discusses the data, and provides a descriptive analysis of entry and exit in Dutch glasshouse horticulture. The analyses of changes in trigger points over time as well as the comparison of different types of trigger points are presented. *Section 5.5* provides the estimation results of the different specifications of econometric models indicating the effect of trigger points on entry and exit. Finally, *Section 5.6* closes with some concluding and qualifying remarks.

5.2. Modelling of entry and exit investment decisions

5.2.1. Theoretical model

The long-run competitive equilibrium is determined not only by the price and output levels of the firms but also by the number of operating firms. Following MsCollel *et al.* (1995, p. 335) the central assumption is: "A firm will enter the market if it can earn positive profits at the going market price and will exit if it can make only negative profits at any positive production level given this price."

The long-run equilibrium price (p^*) equates demand with long-run supply, where the long-run supply takes into account firms' entry and exit investment decisions.

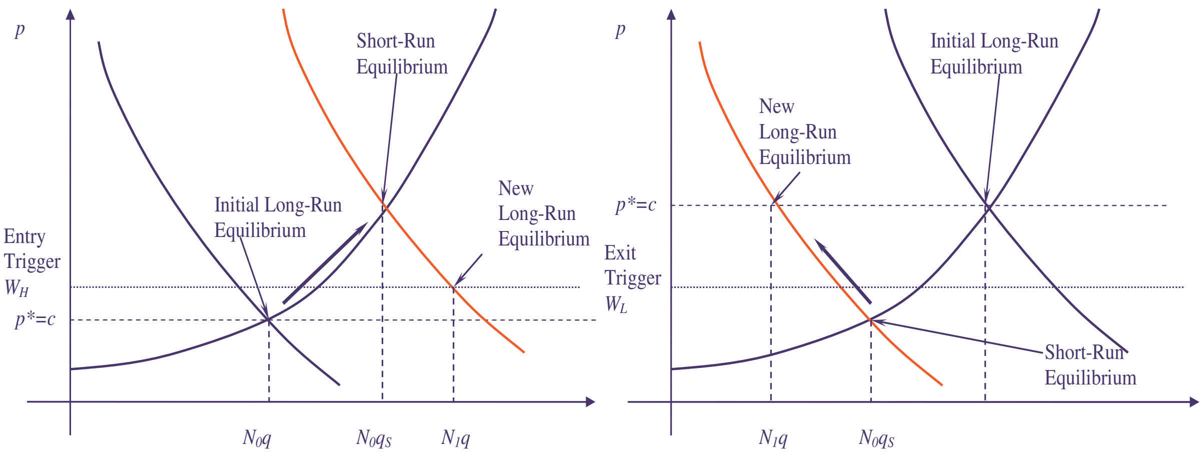


Figure 5.1: **Impact of trigger points on Entry and Exit**

Consider an industry initially in a long-run equilibrium position, which assumes number N_0 of operating firms and long-run cost *c (Figure 5.1, a)*. Suppose that demand shifts upward, then the industry will immediately move to a new short-run equilibrium position. The shock in demand causes an increase in prices to p_S and the output per firm increases to q_S; this can influence the investment decision of firms. Because firms' profits increase, operating firms earn more in the short-run (due to $p_S>c$) and can even be induced to make investments to expand; inactive firms can be induced to invest in entry.

In the long run, firms enter in response to the increase in profit, with the number of firms increasing to $N_1>N_0$; the industry will then move to the right along a new demand curve until it reaches the new long-run equilibrium.

The graph *(b)* demonstrates the change in the number of firms as a result of the exit of firms as an adjustment to the new long-run equilibrium after a fall in demand or prices. In the long run, firms exit in response to the decrease in profit, with the number of firms falling to $N_1<N_0$.

Now, consider that a firm's profit-maximising investment decision is to enter or to remain inactive. A firm has to invest a lump sum *k* and will have a variable cost *w* for the production of output. In the case of an exit decision, it must also pay a lump sum *l,* which it loses due to the exit of the firm, and a variable cost *w* will be saved. The goal of the firm is to maximise expected net present value (NPV). The standard Marshallian theory (Marshall, 1920) postulates that a firm will invest (and enter) if expected NPV is greater than zero, and in the case of an operating firm a decision to exit will be undertaken when NPV is negative.

Then for the entry investment of a firm, the trigger point W_H is Marshall's long run cost (when NPV>0), which is the sum of the variable cost and the interest on the sunk costs:

$$W_H \equiv w + \rho k \tag{1}$$

where ρ is interest rate.

The Marshallian trigger point for exit disinvestment of a firm (NPV<0) becomes:

$$W_L \equiv w - \rho l \tag{2}$$

The recent developments described in articles of Dixit (1989), Dixit and Pindyck (1994) introduced a discussion concerning a difference between Marshallian trigger points and Real Option trigger points. The difference can be explained by the presence of uncertainty that causes a firm to consider the option of waiting. In Dixit (1989) we find the following relationships for the Real Option entry P_H and exit P_L trigger points:

$$P_H > w + \rho k \equiv W_H \tag{3}$$

$$P_L < w - \rho l \equiv W_L \tag{4}$$

In the same article, the author analytically derives a closed form solution for trigger points that take into account uncertainty *(Appendix 5.1)* and the effect of changes in expectation of output prices (μ), uncertainty (σ^2) and interest rate (ρ) on trigger points. Dixit makes analytical calculations to examine the behaviour of trigger points when parameters change. He shows that in the presence of positive expectations concerning price trends, a firm will enter at a lower threshold and will remain despite temporarily unfavourable prices. Analysing the effect of changes in prices, Dixit concludes that "even a little uncertainty matters a lot". The increase in interest rate causes trigger points to increase because the firm expects a higher return on alternative investment and prefers neither to enter nor to exit. The importance of sunk costs is also underlined in the study of Dixit because they influence the gap between Marshallian and Real Option trigger points.

5.2.2. Empirical model

From equations *(1-2)* we can numerically calculate Marshallian entry and exit thresholds.

In the case of Entry, firms consider parameters of a potential sector to enter, consequently ρ is an average value indicating the current profitability of the sector as perceived by a potential entrant. w, k are operating costs in the first year and the costs of capital; they represent the sunk costs of entrant firms. These individual characteristics of a firm are also important, because when the firm decides on entry it takes into account the level on which it is going to operate.

In the case of Exit, ρ is the same as for entry firms, but w and l are operating costs of the previous year and irreversible costs of capital; this represents sunk costs of the exit of firm j. To calculate losses l due to exit, we also include loss of profit because the firm no longer operated.

The changes in the number of entering or exiting firms indicate investment (or disinvestment) decisions of firms. According to the empirical model represented in *Equations 5-6,* we estimate the impact of investment trigger points on entry *(5)* or exit *(6)* decisions:

$$Entry^t = \gamma_1 TR_H^t + \eta^t \quad (5)$$

$$Exit^t = \gamma_1 TR_L^t + \eta^t \quad (6)$$

where TR_H^t is the calculated average threshold for entry in time *t,* and TR_L^t is the calculated average threshold for exit in time t. Marshallian trigger points *(* W_H and W_L *)* are calculated as shown in *Equations 1-2*; Real Option trigger points *(* P_H and P_L *)* are calculated as shown in *Appendix 5.1*. Additional variables, following Real Option theory, have an impact on trigger points and perception about the profitability of the sector. They are the trend rates of growth of the market price of output μ and its variance σ^2.

$Entry^t$ is the number of firms entering in the year *t*; $Exit^t$ is the number of firms that were previously observed to be in operation in the year *t*. η^t - is an error term and γ - is the parameter to be estimated.

As a possible modification of the model based on Marshallian trigger points, we include μ, σ^2, ρ as additional variables in the *Equations 5-6*, thereby assuming that these parameters have an impact on the firm's decision concerning entry/exit, but have no impact on the threshold as assumed by Real Option theory.

5.2.3. Econometric model

Since the dependent variable in the entry (exit) equation is the number of firms entering (exiting), this can take only nonnegative integer values. A count is understood as the number of times an event occurs. The ordinary least squares (OLS) method for even count data results in biased, inefficient, and inconsistent estimates (Long, 1997). Thus, varaious nonlinear models that are based on the Poisson distribution were developed for this type of "count data".

The Poisson regression is

$$y_i \sim Poisson\,(\mu_i) \tag{7}$$

$$\mu_i = \exp(x_i) \tag{8}$$

for observed count y_i with covariates for the *i*-th observation.

The Poisson model assumes that its mean is equal to its variance, which is unlikely in reality. This leads to a problem of overdispersion, i.e. that the observed variance is greater than the mean ($\text{var}(y_i) > E(y_i)$). One reason for this is the omission of relevant explanatory variables. Estimates of a Poisson model for overdispersed data are unbiased, but inefficient with standard errors biased downward (Cameron and Triverdi, 1998; Long, 1997). The most common alternative is the Negative Binomial model, which introduces an individual, unobserved effect into the conditional mean.

$$y_i \sim Poisson\,(\mu_i^*) \tag{9}$$

$$\mu_i^* = \exp(x_i\beta + u_i) \tag{10}$$

$$e^{u_i} \sim Gamma\,(1/\lambda, \lambda)$$

λ is the overdispersion parameter. The larger λ is, the greater the overdispersion. If $\lambda = 0$ then the model converges to the Poisson model. A more detailed description of the Poisson model and the negative binomial model can be found in Cameron and Triverdi (1998: p. 59), Greene (2003: p. 744).

5.3. Classification of entry and exit

5.3.1. Definition of types of entry and exit

Besides genuine entry, when a new firm is organised, and traditional exit when a firm disappears, there are other options. First, a firm can split into two firms for different reasons (e.g. different locations, branches, or divided ownership). Second, by contrast, some firms can coalesce into one organisational form. Other entry and exit cases can be explained by diversification and a change in specialisation of firms. A firm might originally be an agricultural firm, for example, and later become a horticulture firm, and be registered as such. In that case, it can be considered to be an exit from one sector and an entry into another. The nature of exit and entry can also be different due to administrative decisions. For instance, if a farmer received compensation (because of the establishing of a residential area, road construction, organisation of a recreation zone, for example) and stopped operating, then his decision to enter the same sector could be triggered by other reasons compared with new firms. Although much discussion has taken place in recent years in research (e.g. Buddelmeyer *et al.*, 2006, Brandt, 2004, Miller and Folta, 2002) regarding entry and exit, and changes in firm size, the classification of entry and exit is not investigated in the literature. We distinguish some characteristics that can help us to differentiate entry and exit. These are given in *Table 5.1*.

The entry decision assumes an investment in capital that can be considered as a structural entry barrier (Siegfried and Evans, 1994), but there is also an "institutional" barrier that includes the registration of a firm and the organisation of production. We characterize a firm's entry in time *t* by a set $(S_t; L_t)$, where S_t is a registration status, which also includes characteristics of ownership and management and L_t is an area under glass, which is the crucial source for producing production. S_t can be considered as a proxy for "institutional" investments, L_t as a proxy for capital investments. It is also possible to compare set $(S_t; L_t)$ with a set of characteristics of a firm in time *t-1,* before entry. All possible combinations are presented in "Entry box" of *Table 1* and include:

1) a set of (0;0) indicating a new start of a firm at time *t*. The firm made an investment in capital (in the case of glasshouse horticulture this would include investments in land, glasshouses, installations) and an investment in establishing the firm (registration, organisation of production, marketing, hiring labour);

2) a set of $(S_t;0)$ indicating that there was no change in the registration status of a firm, but there was no land under glass; consequently this firm was operating in time *t-1*, but not in the glasshouse horticulture sector. The firm made an investment only specifically to glasshouse production capital and entered the sector at time *t*;

3) a set of $(S_{t-1};L_t)$ giving the information that at time *t* a firm had the same area under glass in operation as at time *t-1*; but due to the changes in the registration status, this firm was first registered at *t* as a horticulture firm. This indicates the "institutional" investments of the firm.

Table 5.1: **Matrix of firm life**

Changes in Registration status *(Institutional Investment)*	**Changes in Land under glass *(Investment in Capital)***					
	L_{t-1}	L_t	L_{t+s}	…	L_T	L_{T+1}
S_{t-1}	(0;0)	$(S_{t-1};L_t)$	←		*Entry box*	
S_t	$(S_t;0)$	$(S_t;L_t)$	$(S_t;L_{t+s})$			
S_{t+s}		$(S_{t+s};L_t)$	$(S_{t+s};L_{t+s})$			
⋮				⋱		
S_T					$(S_T;L_T)$	$(S_T;0)$
S_{T+1}		*Exit box*	→		$(S_{T+1};L_T)$	(0;0)

Note: $(S_t;L_t)$ and $(S_T;L_T)$ *represent the present state of glasshouse horticulture firm in year t or T*

We assume that during the firm's life, it is possible to observe some changes in the set, but we are able to trace these and confirm that they belong to the same firm. When we observe the exit of the firm, it can also be demonstrated by analysing "Exit box" in Table 1. If set $(S_T;L_T)$ demonstrates the characteristics of a firm which was previously observed in time *T*, then we can gain information about this firm in the period *T+1*. The changes in the set will provide us with characteristics for the classification of the exit. Following the same structure of analysing "Exit box" as was done for "Entry box", we can distinguish three possible exits:

1) a set of (0;0) indicating a real end of firm that interrelates with capital and institutional disinvestments;

2) a set of $(S_T;0)$ indicating that there was no change in registration status of a firm in time *T+1*, but there is no land under glass anymore; consequently this firm continues to operate, but not in the glasshouse horticulture sector. The firm disinvested (e.g. by selling or demolishing glasshouses) in the area under glass;

3) a set of $(S_{T+1}; L_T)$ giving the information that at time T a firm has the same area under glass in operation as at time *T+1*, but due to the changes in the registration status, this firm is no longer registered. This indicates "institutional" disinvestments.

Summarising then, we classify three different entries based on the combination of entry investments: the new start of a firm (the genuine or real[26] entry), the entry into the horticulture sector, and the transformation entry. Consequently we classify exit as: the genuine (real) exit, the exit from the horticulture sector, and the transformation exit. This classification of entry and exit is an important factor for our analysis: on the one hand, genuine entry-exit decisions can differ in magnitude of entry and exit investment barriers (trigger points) compared to other types of entry-exit; and on the other hand, the changes in the level of the trigger points can have a different impact on changes in the population of firms.

5.3.2. Empirical Classification of Entry and Exit

The next step in the classification of entry and exit can be the empirical implementation of the classification, which is represented in *Figure 5.2*. In practice, firms are registered in the registration data-set, by giving a firm an individual and unique number *n*.

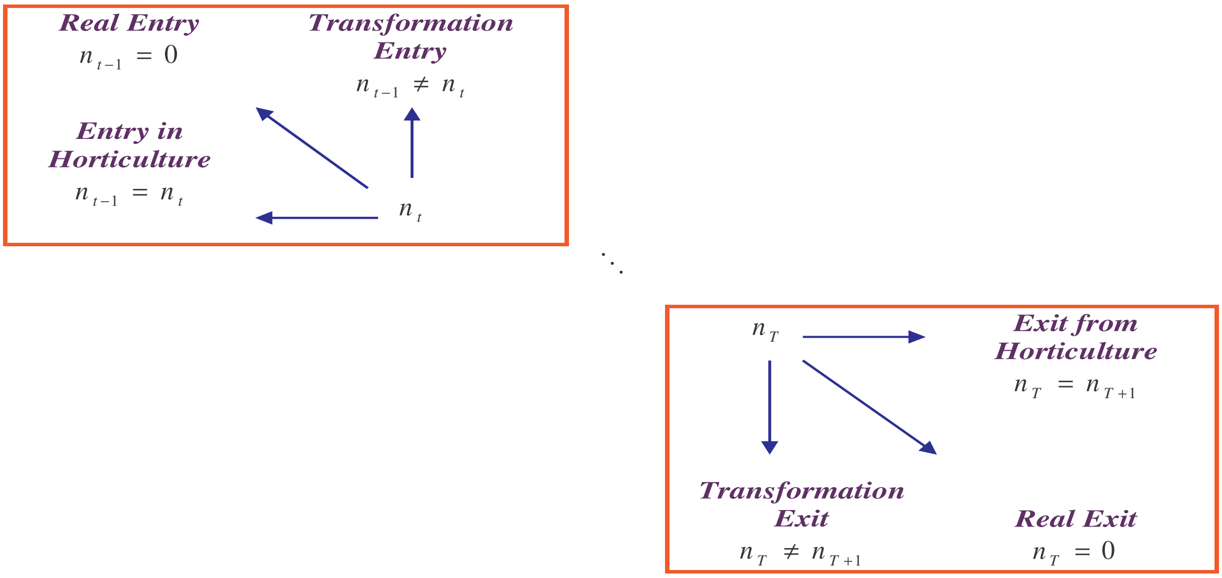


Figure 5.2: **Classification of Entry and Exit**

The "Entry box" in *Figure 5.2* demonstrates the empirical implementation of the theoretical classification of entry discussed above. The use of identification numbers makes the implementation easier if information about land or registration form is hidden. If the

[26] We use terms "genuine" and "real" interchangeably for the definition of one of the types of entry or exit.

identification number n_t is observed at time *t*, then the information about the number of a firm in the previous year assists in classifying the type of entry: 1) if identification number n_{t-1} did not exist in the previous year, it is a genuine entry; 2) if a firm did not change an identification number compared with the previous period, but is observed for the first time in the glasshouse horticulture, we can assume that this concerns an entry into horticulture of an existing (probably arable) firm; 3) the case of a firm having a different identification number compared to the previous year ($n_{t-1} \neq n_t$) can indicate entry after registration changes due to a merger or split, or inheritance. This type is more difficult to explain without assessing more qualitative information, which is usually not available.

In the same way it is possible to classify exit as: 1) real (or genuine) exit, if there is no identification number in period *T+1*, but there was a number in the previous period; 2) exit from horticulture can be indicated if a firm continues to exist under the same identification number, but is not registered in the population of glasshouse horticulture firms; 3) transformation exit can be classified when a firm changed its identification number in the last year of observation.

5.4. Data

5.4.1. Empirical evidence on entry-exit in Dutch glasshouse horticulture

The analysis of entry and exit of Dutch agriculture firms is quite rare. Consequently, there is very limited information available from central statistic sources. To obtain empirical information about the situation in the Dutch glasshouse horticulture sector, we analysed the demography of firms in the period 1975 – 2004. Following the general classification given in the previous sub-section, we can distinguish *(e.g. Figure 5.4)* three types of entry-exit, but we will concentrate on the first two types, since the "Transformation" type, which relates to the "institutional" investments, requires additional information in order to perform a reliable analysis. The Graphs below are based on the "Meitelling data" provided by LEI[27].

By analysing 29-year dynamics of established and terminated firms, we can conclude from *Figure 5.3* that the number of exiting firms was mostly in excess of those entering, except in 1976 and 1989. The largest net exit, which is defined as the number of exit firms minus the number of entry firms, occurred in 1996 and 2001, 345 and 578 firms respectively. From the graph we can see the wave-shape of entries with the peak in 1979, 1990 and 1999. After 1990 there is a steep decrease in the number of entry firms, with 1996 being one of the most "unattractive" years for glasshouse horticulture. In 2002 the highest number of entries

[27] LEI is the Agricultural-Economics Research Institute, the Netherlands; www.lei.nl.

was accompanied by the highest number of exits, which could be related to the substantial drop in firm's income (from 40,800 euros in 2001 to 13,200 euros in 2002)[28]. The predominance of the net exit of firms results in a decline in the total number of glasshouse horticulture firms from 17,265 in 1976 to 9,946 in 2004.

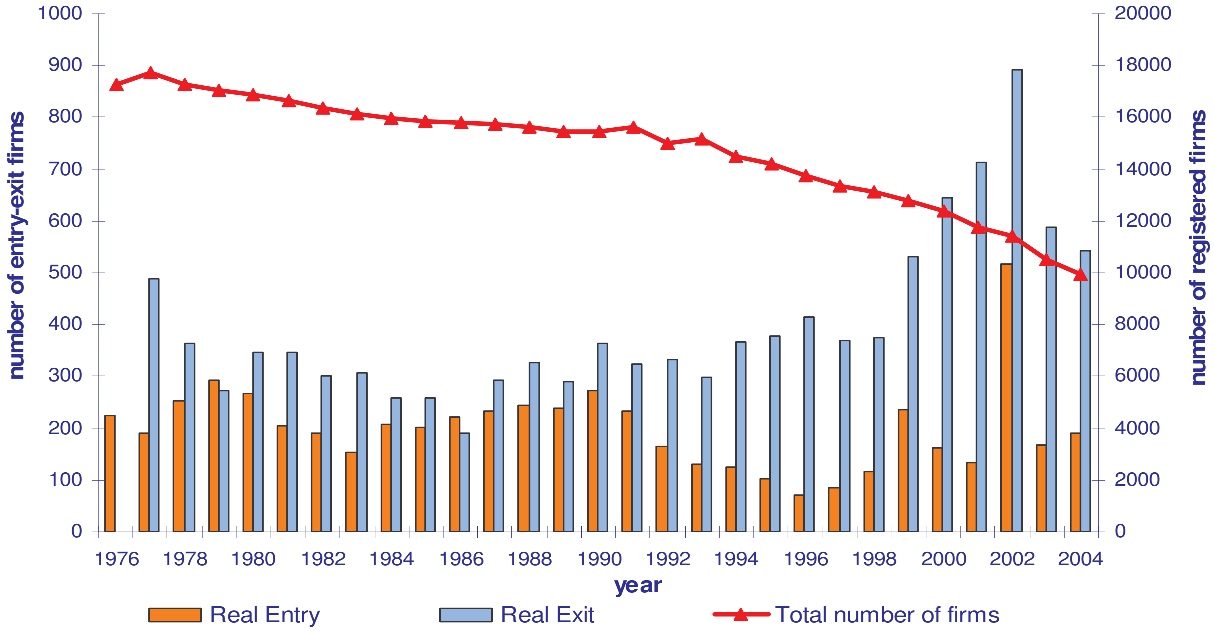


***Figure 5.3:* Real Entry and Exit of firms in Dutch glasshouse horticulture**

From the first brief overview of changes in number and size of horticulture firms, we can formulate the following questions: What are the real changes in the horticulture sector due to the entry and exit of firms? What kind or type of firms entered and left the sector? What are the reasons for the entry and exit of firms? To answer these questions, we need to analyse the dynamics of entry and exit at the micro-level. Following the proposed classification of entry and exit, the entry and exit firms are classified, and a structure of different types of entry-exit firms is represented in *Figure 5.4*.

From the graph, it can be observed that entry into glasshouse horticulture through a change in specialisation of existing firms is dominant. The exit is mostly observed as the real exit or the transformation exit (which is related to the changes in registration form). The real entry and exit fluctuate in the same pattern as the whole sample of entering and exiting firms, and can be used for further analysis as a good approximation of entry or exit investment decisions.

One of the common approaches for analysing entry and exit is through the use of duration models (e.g. Buddelmeyer *et al.*, 2006), which answer the questions concerning the length of operational life of firms, and factors influencing the survival of firms. We provide only the

[28] www.lei.nl

descriptive analysis of the survival of firms in Dutch glasshouse horticulture, but we consider the length of the operation of firms in the context of different types of entry and exit.

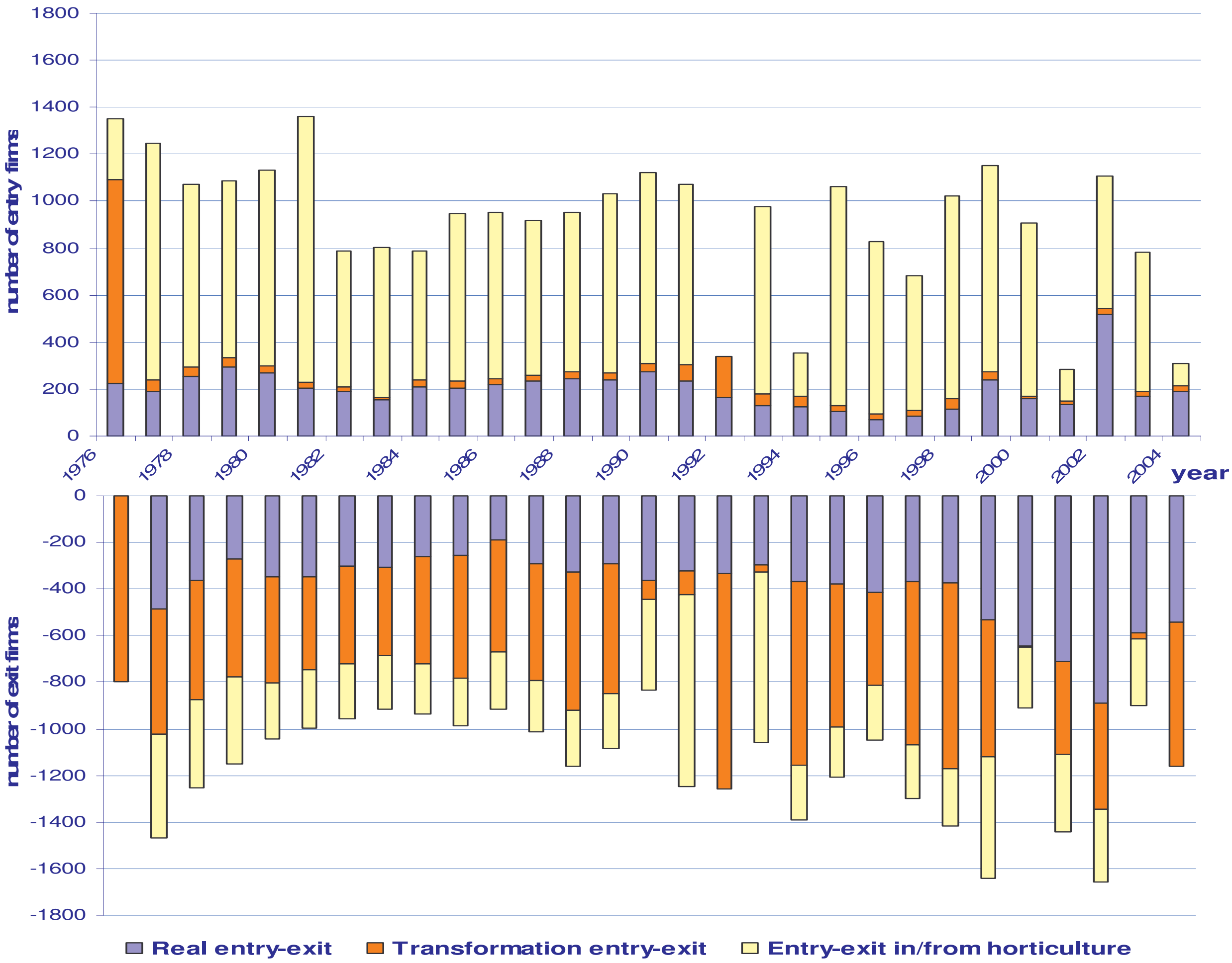


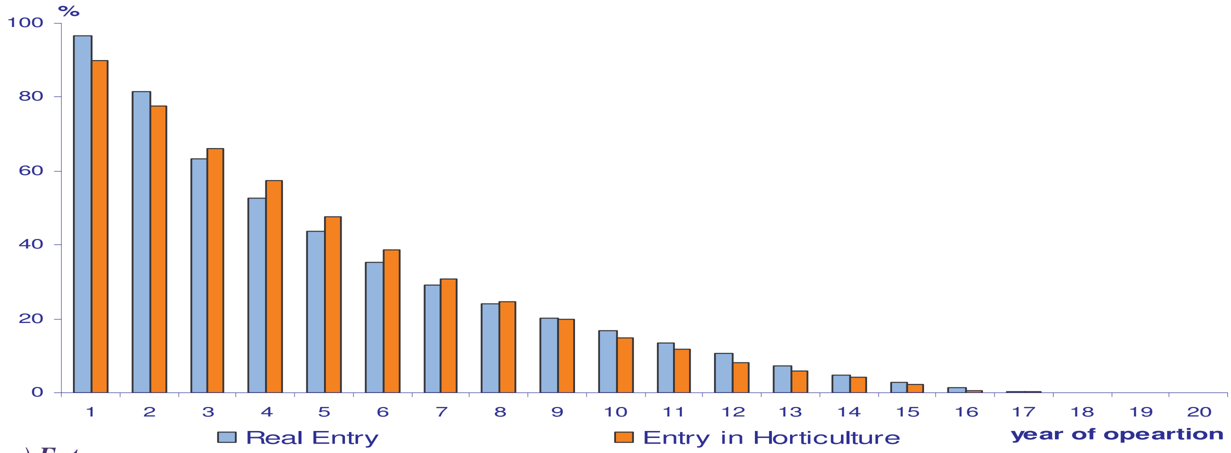
***Figure 5.4:* Different types of Entry and Exit**[29]

As can be seen from *Figure 5.5(a),* after five years only 50% of the firms were still in existence. In the first two years, the newly-established firms have a higher survival rate than the firms that change specialisation, but during the 3rd-8th years of operation, the latter group survives better; in the 10th year of operation, only 20% of entering firms survived for both types of entry. Thus it is possible to assume that different types of entry can have an impact on the survival chances of firms during the first years of operation.

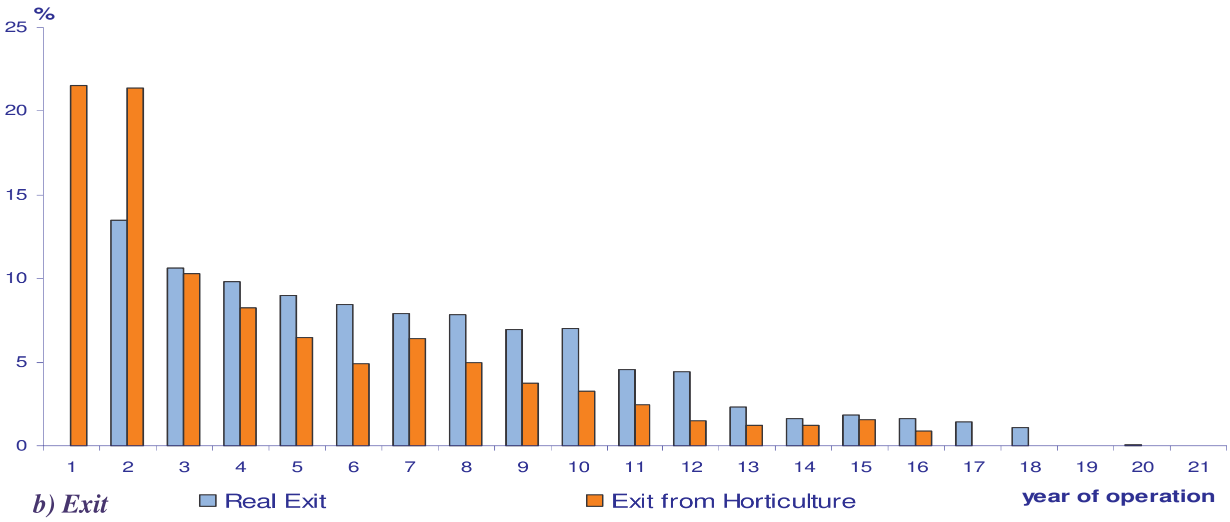
From *Figure 5.5(b),* we can see the difference in pattern of exits for different types of exiting firms. Exiting firms that leave the horticulture sector, but continuing to operate (probably in arable farming), typically leave in the first two years (about 50% of all exits into

[29] The data on transformation and horticulture entry-exit in 1992 suffer from changes in legislation. Due to this, there is no entry-exit due to the changes in the specialisation of firms, but a very large number of transformation changes.

horticulture). Real exits show a decrease over the years, but exit is spread over the period: from 13% of firms ceasing operation after two years, to 7% of firms after 10 years. From this analysis we can assume that the length of a firm's operational life can influence the choice of exit decision for firms.



a) Entry



b) Exit

***Figure 5.5:* Survival time after Entry (a) and prior to Exit (b)**

5.4.2. Data description

This section first gives a description of the data used in estimation and then presents an analysis of calculated trigger points, which are used as independent variables in the model.

We combine two data sets: FADN (Farm Accountancy Data Network) and "Meitelling" data[30], provided by the LEI. Both data sets concern Dutch glasshouse horticulture: FADN

[30] Meitelling is the Register of Enterprises and Establishments of agriculture firms in the Netherlands. The register covers all firms with a size equal to or bigger than 2 nge (Dutch Size Units). For details see: www.lei.nl.

covers the period 1975-1999, "Meitelling" covers the period 1975-2004. The variables used for estimating thresholds, and the econometric specification of the model are represented in *Table 5.2*.

Table 5.2: **Descriptive Statistics for Glasshouse Firms, Thresholds and Number of Entry and Exit**

Variable	Description of Variable	Mean	Standard Deviation
Ha_tot	Land per firm, ha	2.31	0.33
Ha_glass	Land under glass per firm, ha	0.62	0.11
Profit_ha	Profit per ha, 1000 Euros*	59.0	17.7
Cost_mat_ha	Material cost per ha, 1000 Euros*	234.8	44.3
Lab_tot	Number of workers per firm, annual workers	3.4	5.4
Cost_lab	Labour cost per annual worker, 1000 Euros*	20.3	0.5
Inv_ha	Investments per ha, 1000 Euros*	26.9	8.3
μ	Trend rate of growth of output prices	0.06	0.01
σ	Standard deviation of output prices	0.14	0.02
ρ	Interest rate, %	7.63	1.67
$Entry_K$	Number of entering firms		
	K=1 as real entry	194.4	62.1
	K=2 as entry in horticulture	767.9	143.5
$Exit_K$	Number of exiting firms		
	K=1 as real exit	339.0	73.6
	K=2 as exit from horticulture	278.8	89.8
$W_{H,K}$	Marshallian entry threshold, calculated for entering firm, 1000 euros*		
	K=1 as real entry	437.3	153.1
	K=2 as entry in horticulture	190.1	77.8
$W_{L,K}$	Marshallian exit** threshold, calculated for exiting firm, 1000 euros*		
	K=1 as real exit	-235.6	61.1
	K=2 as exit from horticulture	-66.1	23.3

* *Monetary values are normalised by 1985 prices*

** *Exit thresholds were used for estimation as absolute values for the simplicity of the interpretation of results of the econometric model*

"Meitelling" data provide us with information about all firms in the sector during these years. If a firm exited and entered during these time periods then we have the complete record of the "firm's life": from "birth" to "death". Some description of the data is provided in *Section 5.4.1.* Although the coverage of glasshouse horticulture firms is good (427,501 observations), the data content is fairly small. Basically, only the land and the numbers of employees are available.

The FADN is an unbalanced panel data set, amongst others, on glasshouse horticulture firms. Due to the rotation of firms, firms stay in the sample for an average of 3-5 years. These data provide a wide range of individual characteristics of firms such as revenue, capital, investments, variable costs, which we used for the estimation of the annual level of these variables and consist of 6,905 observations on 1,500 firms. For the calculation of the trigger points, we used variables from both data sets; however, due to the time period of FADN data, the further estimation is limited by the period 1975-1999.

We calculate Marshallian entry trigger points as the sum of operational costs of the first year and an interest on invested capital, which are investments in the first operating year. A detailed description of the calculation of trigger points by combining of two data sets is provided in *Appendix 5.2*. To calculate the Marshallian exit trigger point we need to know the losses due to the irreversibility of capital. It is not possible from our data set to obtain a salvage price (Johnson, 1956) of capital of exiting firms and then to calculate gains or losses that a firm incurs. We assume that the firm can sell capital at its book value, so there are no gains or losses. When the firm decides to exit, it saves on operational costs, which we calculate in the same way as for the entry firms. So, it can be counted as a gain for the exiting firm. The main loss, which we include in the calculation of Marshallian exit trigger point, is the loss of profit. Due to the exit, the firm does not get a profit in the year of exit and cannot immediately reallocate sources to gain a profit in another activity.

The variables represented in *Table 5.2* are used for the calculation of trigger thresholds. These variables characterise the average glasshouse firm, which earns 59,000 euros profit through the use of 2.3 ha of land (0.6 ha under glass) and employs 3.4 workers per year. The average firm invests 26900 Euros per ha in capital (such as land, glasshouses and installations). The salient characteristic of Dutch glasshouse firms is that they remain small-scale family firms (68.8% of family labour) with respect to labour and land, but they are highly capital-intensive, with an average capital per firm of 383,000 euros (at 1985 price levels).

The next step, as an extension of the conventional approach, will be to calculate Real Option trigger points *(Appendix 5.1)* and compare them with Marshallian ones. As can be seen, the investment thresholds (*Table 5.3*) vary over the years with the common tendency of growth. The gap between Marshallian and Real option trigger points varies and becomes bigger: if at the beginning of the analysed period the difference for entry was about 5,000 euros and for exit about 2,000 euros, then at the end it had risen to 30,000 and 14,000 euros respectively.

Table 5.3: **Marshallian and Real Option trigger points**

Year	Real Entry Trigger Points, 1000 euros		Real Exit Trigger Points, 1000 euros		Horticulture Marshallian Trigger Points, 1000 euros	
	Marshallian	Real Option	Marshallian	Real Option	Entry	Exit
1976	201.6	206.4	na	na	17.1	na
1977	222.8	228.6	-117.0	-119.2	91.8	-48.5
1978	224.7	230.3	-154.1	-156.6	110.3	-52.9
1979	274.1	280.9	-179.8	-182.9	140.4	-58.4
1980	431.3	441.4	-243.0	-247.5	178.3	-68.1
1981	544.5	557.5	-275.6	-280.8	164.3	-70.7
1982	315.8	324.0	-242.0	-246.8	206.6	-86.3
1983	344.3	354.4	-243.3	-248.9	175.8	-87.7
1984	475.5	488.2	-179.0	-182.3	173.8	-64.8
1985	342.6	352.5	-209.7	-213.7	184.6	-53.7
1986	358.0	369.0	-251.0	-255.7	181.1	-41.5
1987	385.0	400.1	-176.4	-181.8	191.8	-63.1
1988	305.0	317.0	-168.1	-173.2	161.8	-43.8
1989	366.2	380.6	-207.1	-213.9	235.3	-69.1
1990	429.4	443.9	-158.5	-162.9	220.8	-16.9
1991	521.9	539.7	-279.3	-287.4	243.4	-84.6
1992	555.9	575.5	-354.7	-365.1	na	na
1993	666.1	696.4	-284.1	-295.5	312.1	-43.9
1994	659.2	688.4	-264.2	-274.8	42.9	-72.8
1995	600.0	626.5	-254.8	-265.1	241.3	-65.3
1996	762.1	797.7	-344.2	-358.7	284.2	-90.3
1997	388.7	407.8	-252.2	-263.3	196.1	-60.7
1998	590.2	621.8	-292.8	-306.4	310.9	-134.5
1999	529.7	558.1	-286.9	-300.4	306.9	-76.8
Total	437.3	453.6	-235.6	-242.7	190.1	-66.1

** Trigger points represent the annual average level*
*** na – not possible to calculate due to the absence of reliable data on horticulture entry/exit*
**** Calculated in 1000 euros equivalent in 1985*

Following the discussion in Dixit (1989), the difference between thresholds is caused by uncertainty. So the years with the biggest gap, namely 1981, 1987, 1993, and 1996 possibly exhibit the effect of "hysteresis", when firms prefer to wait and would need to overcome a higher threshold to make investments (in the case of entry) or disinvestments (in the case of exit). It can be also noted that the difference between entry trigger points is bigger than for exit trigger points; although in both cases the difference between Marshallian and Real Option thresholds is affected in the same years. Additionally, we can observe that exit investment thresholds exhibit smoother patterns compared to entry investment thresholds. Firms classified as either real entry- or real exit firms have their main specialisation in glasshouse horticulture, with the share of land under glass more than 50% (e.g., 70% in 1999); but firms entering the horticulture sector from other sectors have a lower share of land under glass (less than 50%) and those exiting from horticulture into another sector have only a 5-10% glasshouse area. This can help to better understand *Figure 5.5 (Section 5.4.1)*: on the one hand, in the initial years these firms have an additional option to return to the previous specialisation and to cease glasshouse horticulture production; on the other hand, if these firms continue, they survive better in later years than firms that carried out a real entry. An existing firm that enters (exits) glasshouse horticulture has to overcome lower impediments compared to the real entry (exit). This is demonstrated by the difference in the investment trigger points: an existing firm that enters the horticulture sector should invest (on average, over the years) 190.1 thousand euros, but for a real entry a firm should invest almost twice as much, on average 437.3 thousand euros. For the real exit, a firm should overcome (on average) losses of 235.6 thousand euros, which is three times the threshold for the exit from the horticulture sector (loss of 66.1 thousand Euros).

5.5. Results of estimation econometric models

The change in the level of trigger points can encourage or discourage exit and entry into glasshouse horticulture, as is shown in *Tables 5.4-5.5*. These tables give the negative binomial estimation results for entry and exit. The results lend support to the negative binomial model, since the λ parameter is significantly different from zero. This is confirmed by the Likelihood-ratio test. The significance of overdispersion parameter λ confirms the presence of an individual, unobserved effect that means non constant mean and variance in the data. By this fact, the outperforming level of Log-Likelihood for Negative binomial regression over the Poisson model can be explained. The exit barriers were included in the model as the positive values for the purpose of easier interpretation.

The difference among models is in the explanatory variables: *Model 1* includes Marshallian trigger points, *Model 2* includes Real Option trigger points, which are corrected for the effect of expectation of prices, uncertainty, and interest rate; and *Model 3* explicitly incorporates the expectation of prices, uncertainty and interest rate in *Model 1,* that deviates from the specification of Dixit (1992).

Table 5.4: **Effect of Trigger Points on Real Entry and Exit**

Variable	Real Entry			Real Exit		
	Model 1	***Model 2***	***Model 3***	***Model 1***	***Model 2***	***Model 3***
	Trigger point $W_{H,1}$	*Trigger point* $P_{H,1}$	*Trigger point* $W_{H,1}$	*Trigger point* $W_{L,1}$	*Trigger point* $P_{L,1}$	*Trigger point* $W_{L,1}$
Dependent variable:		*Entry1*			*Exit1*	
Independent variables:						
TR	-0.002*** (0.0004)	-0.002*** (0.0004)	-0.001*** (0.0006)	-0.001* (0.0006)	-0.001* (0.0006)	-0.002*** (0.001)
μ			12.269* (6.776)			-19.020*** (3.785)
σ			1.459 (5.087)			-7.300*** (2.554)
ρ			0.095** (0.046)			0.012 (0.023)
Constant	5.372*** (0.203)	5.371*** (0.203)	3.402*** (1.142)	5.253*** (0.154)	5.245*** (0.152)	7.405*** (0.629)
λ	0.093 (0.028)	0.091 (0.027)	0.057 (0.018)	0.034*** (0.011)	0.034*** (0.011)	0.014 (0.357)
Likelihood-ratio test of λ = 0: Chi2(01)	334.79***	324.01***	183.13***	198.40***	199.20***	70.52***
Log likelihood:						
- Poisson model	-299.12	-293.37	-217.81	-227.44	-227.87	-154.24
- Negative binomial regression	-131.72	-131.37	-126.24	-128.24	-128.27	-118.98
Pseudo R2	0.06	0.06	0.10	0.01	0.01	0.08
N	24	24	24	23	23	23

1) t-statistics in parentheses
*2) *** denotes coefficient significant at 1% level, ** at 5% and * at 10% level*

Based on Pseudo R2, it can be concluded that the Model 3 provides the best explanation of the variation of entry and exit out of three specifications. Although it should be acknowledged that the low Pseudo R2 in all models and the small sample size are limitations of the results.

Table 5.5: **Effect of Trigger Points on Entry into and Exit from Horticulture**

Variable	Entry into Horticulture			Exit from Horticulture		
	Model 1	***Model 2***	***Model 3***	***Model 1***	***Model 2***	***Model 3***
	Trigger point $W_{H,2}$	*Trigger point* $P_{H,2}$	*Trigger point* $W_{H,2}$	*Trigger point* $W_{L,2}$	*Trigger point* $P_{L,2}$	*Trigger point* $W_{L,2}$
Dependent variable:		*Entry2*			*Exit2*	
Independent variables:						
TR	-0.002*** (0.0007)	-0.002*** (0.0006)	-0.001 (0.001)	-0.007*** (0.003)	-0.007* (0.003)	-0.007*** (0.002)
μ			-5.950 (4.682)			-17.941*** (7.048)
σ			-3.115 (3.958)			-15.797*** (4.265)
ρ			0.049* (0.028)			-0.066* (0.039)
Constant	7.639*** (0.148)	7.626*** (0.144)	6.433*** (0.813)	6.600*** (0.210)	6.597*** (0.205)	9.070*** (1.186)
λ	0.039*** (0.012)	0.039*** (0.012)	0.025 (0.008)	0.093*** (0.030)	0.092*** (0.030)	0.042 (0.014)
Likelihood-ration test of $\lambda = 0$: Chi2(01)	577.62***	574.98***	347.79***	487.20***	483.66***	210.08***
Log likelihood:						
- Poisson model	-424.10	-422.76	-304.86	-360.69	-358.84	-214.43
- Negative binomial regression	-135.29	-135.27	-130.97	-117.09	-117.00	-109.38
Pseudo R2	0.03	0.04	0.05	0.02	0.02	0.07
N	21	21	21	20	20	20

[1)] *t-statistics in parentheses*
[2)] **** denotes coefficient significant at 1% level, ** at 5% and * at 10% level*

As can be seen from the estimation results, a higher level of entry thresholds has a negative impact on the number of firms that decide to enter. Increasing exit thresholds deters firms from exiting the sector. In agreement with the theory, positive expectations about the trend of output prices induce more firms to enter and fewer firms to cease operation.

Higher interest rate, which is an indicator of the profitability of a sector, has a positive connection on entry, and a negative one for exit (except a real exit, which is not significant). Uncertainty (σ) has a positive (and not significant) result for real entry, but a negative one for entry into horticulture.

This can be explained by the statement of Wennberg *et al.* (2007) that the negative effect of uncertainty on the likelihood of entry will turn positive at a high level of uncertainty for real entry but not for the entry of existing firms. Therefore the results can be understood as an indication of higher uncertainty for the real entry, compared to the entry into horticulture. The higher variation of input prices deters firms from exits; this effect is larger for exiting due to a change in specialisation. This means that firms prefer to delay the decision to exit, because of expectations of positive changes in prices.

The presence of investment thresholds predetermines a certain number of firms that are able to overcome these thresholds and that decide to invest and enter (or to disinvest and exit). Changes in investment thresholds affect firms and change their behaviour in such a way that an additional number of firms will enter or exit. This effect of changes in trigger points can be demonstrated by analysing elasticises (*Table 5.6*).

Table 5.6: **Marginal effects for trigger points after Negative Binomial Estimation (Model 3[31])**

	Real Entry	Real Exit	Entry in Horticulture	Exit from Horticulture
Dependent variable:	*En1*	*Ex1*	*En2*	*Ex2*
Independent variable:	$TR_{H,1}$	$TR_{L,1}$	$TR_{H,2}$	$TR_{L,2}$
- trigger point *W*	-0.270 (0.11)	-0.530 (0.18)	-0.733 (0.82)	-1.977 (0.64)

** standard errors in parentheses*

The establishment of a new firm can be expected if the real entry threshold decreases by 3,700 euros. The real exit investment threshold should decrease by 1,900 Euros to induce an additional firm to cease trading. The difference in elasticises demonstrates the fact that existing firms respond more to changes in trigger points, because it is easier for these firms to overcome investment barriers. The changes in entry barriers should be bigger than for exit barriers to have an impact on a firm's decision as can be seen from smaller values of elasticities for entry compared to exit thresholds.

[31] *Model 3* is represented in *Table 5.6*, because, as is shown in *Tables 5.3, and 5.4*, *Model 3* outperforms other specifications.

Another observation from the table is that the existing firms that enter or exit the horticulture sector are more sensitive to the changes in investment thresholds. It can be expected that with a 2,700 Euro decrease in the horticulture investment threshold ($TR_{H,2}$), two more firms will enter the horticulture sector, while to encourage the establishment of the two additional firms the threshold ($TR_{H,1}$) should decrease by 7,400 Euros. The same holds true for the exit: we can expect the exit from the horticulture sector of the two additional firms if the investment threshold ($TR_{L,2}$) is bigger in absolute value by an amount of 1,000 euros; but for real exit $TR_{L,1}$ should change by 3,800 euros.

***Table 5.7:* Predicted and Actual mean of Number of Entry and Exit firms**

	Real Entry	Real Exit	Entry into Horticulture	Exit from Horticulture
Number of Entry or Exit:				
- actual	194.4 (62.1)	339.0 (73.6)	767.9 (143.5)	278.8 (89.8)
- predicted by:				
Model 1	197.6 (46.1)	339.6 (37.5)	803.7 (133.5)	289.4 (56.7)
Model 2	197.4 (46.4)	339.5 (36.7)	802.5 (129.8)	289.1 (55.8)
Model 3	194.8 (46.9)	339.0 (57.5)	785.1 (86.7)	277.7 (51.3)

** standard errors in parentheses*

By analysing the *Table 5.7,* we can compare how close the prediction can be compared to the actual average of events. It can be seen that real entry and exit events have closer predicted values than horticulture entry and exit. This can be related to the slower reaction to changes in investment thresholds, as discussed above. As a comment to the discussion about the real option approach, we can see that the use of RO trigger points only slightly improves the prediction of entry and exit, while assuming that characteristics of the sector influence the firm's decision instead of changing trigger points *(Model 3)* gives the most accurate prediction. The preference for *Model 3* can be also supported by the differences in values of Log-likelihood and *Pseudo R2* provided in *Tables 5.4-5.5.*

5.6. Discussion

We have examined empirically the entry-exit process in Dutch glasshouse horticulture as an investment decision of a firm that should overcome an investment threshold. This chapter has demonstrated that investment trigger barriers have an impact on a firm's decision to invest and enter, or to disinvest and exit. An increase in the barriers discourages firms from taking any action; they prefer to delay the decision, which is associated with irreversible investments.

The models that include Marshallian and Real Option trigger points were compared. The explicitly calculated investment thresholds provide insights into the barriers that a firm should overcome and shows the increase of competition in the sector, partially due to the use of capital-intensive technology in glasshouse horticulture.

For the first time, the heterogeneity of entry and exit decisions was examined and classified. The theoretical classification, based on institutional and capital investments of firms, was applied to Dutch glasshouse horticulture data. We distinguished three types: real (or genuine) entry-exit; glasshouse horticulture sector entry-exit; entry-exit due to transformations in the registration of firms. This last aspect was not further investigated in this chapter, due to the need to add more (qualitative) information, which is not available.

The heterogeneity of entry and exit investments has two consequences. First, firms will overcome different thresholds that can induce or deter firms from entry or exit. Second, the change in thresholds results in a different number of entering or exiting firms, e.g. existing firms whose specialization changes, resulting in them entering horticulture are more sensitive to the change in investment thresholds compared to firms, which potentially can enter the sector and which are considering establishing a new business. The difference in degree of irreversibility of the different types of entry and exit can be one of the reasons for this.

The impact of thresholds can be a confirmation of the effect of irreversibility on an investment decision: if a threshold (as a sum of operational and fixed costs) is possible to be reversed, a firm will not take it into account.

The empirical results do not provide reasonably strong support to real option theory, while the model that suggests the direct impact of the sector-characterizing variables, such as expectation of output prices, uncertainty and interest rate, explains entry-exit decision better. The effect of these variables is larger for the real entry and exit compared to the change in specialization entry-exit. Moreover, uncertainty has a negative impact on exit and entry into horticulture, but turns out to be positive for the real entry. One of the possible suggestions, which can be further explored in future research, is that for a higher level of uncertainty, the negative effect of uncertainty on the likelihood of entry can turn positive.

Further research can be conducted on deepening the knowledge of the individual firm's decision for entry and exit which differentiates the heterogeneity of entry and exit. Thus it can have an important impact on the length of survival of firms, and on their post-entry performance. The entry-exit investments associated with changes in management or ownership of a firm (classified as "transferred entry-exit") needs further investigation and assumes acquiring additional (qualitative) information.

Appendix 5.1. Real Option trigger points

Real Option trigger points (Dixit, 1989) for Entry P_H and Exit P_L investments.

$$P_H = \frac{\rho - \mu}{\rho} \frac{\beta}{\beta - 1} W_H$$

$$P_L = \frac{\rho - \mu}{\rho} \frac{\alpha}{\alpha + 1} W_L$$

where:

$$\alpha = \frac{\sigma^2 - 2\mu - ((\sigma^2 - 2\mu)^2 + 8\rho\sigma^2)^{1/2}}{2\sigma^2} < 0$$

$$\beta = \frac{\sigma^2 - 2\mu + ((\sigma^2 - 2\mu)^2 + 8\rho\sigma^2)^{1/2}}{2\sigma^2} > 1$$

μ - is the trend rate of growth of the market price of output and σ^2 – its variance.

Appendix 5.2. Empirical calculation of Marshallian trigger points for different types of entry and exit, based on the combination of two data sets

We will calculate Marshallian entry trigger points as the sum of fixed cost (i.e. interest rate on investment of first operating year) and operational cost of first year. We obtain an average investment per hectare of land in a particular year from FADN data, then multiply this by the size of land at entry in year *t,* thereby getting an approximation of fixed costs for the *i*-th firm. Operating costs include material costs and labour costs. In the same way we obtain average values from FADN data and then we can find an approximation of operational costs for firm *i* entering in year *t*.

Real Entry:

$$W_{H,1} = \left[LandTot_i^t * \frac{MatC^t}{LandTot^t} + Labour_i^t * \frac{LabourC^t}{Labour^t} \right] +$$
$$+ \left[\rho * LandTot_i^t * \frac{Inv^t}{LandTot^t} \right]$$

Entry in horticulture sector from other sectors:

$$W_{H,3} = \left[LandGlass_i^t * \frac{MatC^t}{LandTot^t} + ShareGlass_i^t * Labour_i^t * \frac{LabourC^t}{Labour^t} \right] +$$
$$+ \left[\rho * LandGlass_i^t * \frac{Inv^t}{LandTot^t} \right]$$

To calculate Marshallian exit trigger points we need to know the losses due to the irreversibility of capital. It is not possible from our data set to obtain a salvage price of capital of exiting firms and then calculate gains or losses of a firm. We assume that the firm can sell capital goods at book value. When the firm decides to exit, it saves operational costs, which we calculate in the same way as for the entry firms. So, it can be counted as a gain for the exiting firm. The main loss for the exit firm is the loss of an expected profit.

Real Exit:

We arbitrarily choose 3 years to calculate losses of profit, using for estimation in *Equation (12)* s = 1,2,3.

$$W_{L,1} = \left[\Delta LandTot_j^t * \frac{MatC^t}{LandTot^t} + \Delta Labour_j^t * \frac{LabourC^t}{Labour^t} \right] -$$

$$- \left[\frac{1}{(\rho - 1)^{s-1}} \Delta LandTot_j^t * \frac{PROF^t}{LandTot^t} \right]$$

Exit from horticulture sector (land under glass = 0 ha):

$$W_{L,3} = \left[\Delta LandGlass_j^t * \frac{MatC^t}{LandTot^t} + \Delta Labour_j^t * \frac{LabourC^t}{Labour^t} \right] -$$

$$- \left[\Delta LandGlass_j^t * \frac{PROF^t}{LandTot^t} \right]$$

All variables with only superscript t indicate that the values are averages and are calculated from FADN data across all firms. Variables that also have a subscript i and j indicate values obtained for "Landbouwtelling" data for an individual entry (i) or exit (j) firm.

For calculation we use variables:

$W_{H, L}$ – Marshallian trigger point, H = entry, L = exit

LandTot – land in operation, ha

LandGlass – land under glasshouses, ha

Inv – Investment in capital.

MatC – Material Costs,

Labour – number of workers,

LabourC – labour costs,

Δ – is indication of difference operator (with previous year),

PROF – profit in sector.

Appendix 5.3. Difference of different types of entry and exit trigger points and specialisation of firms

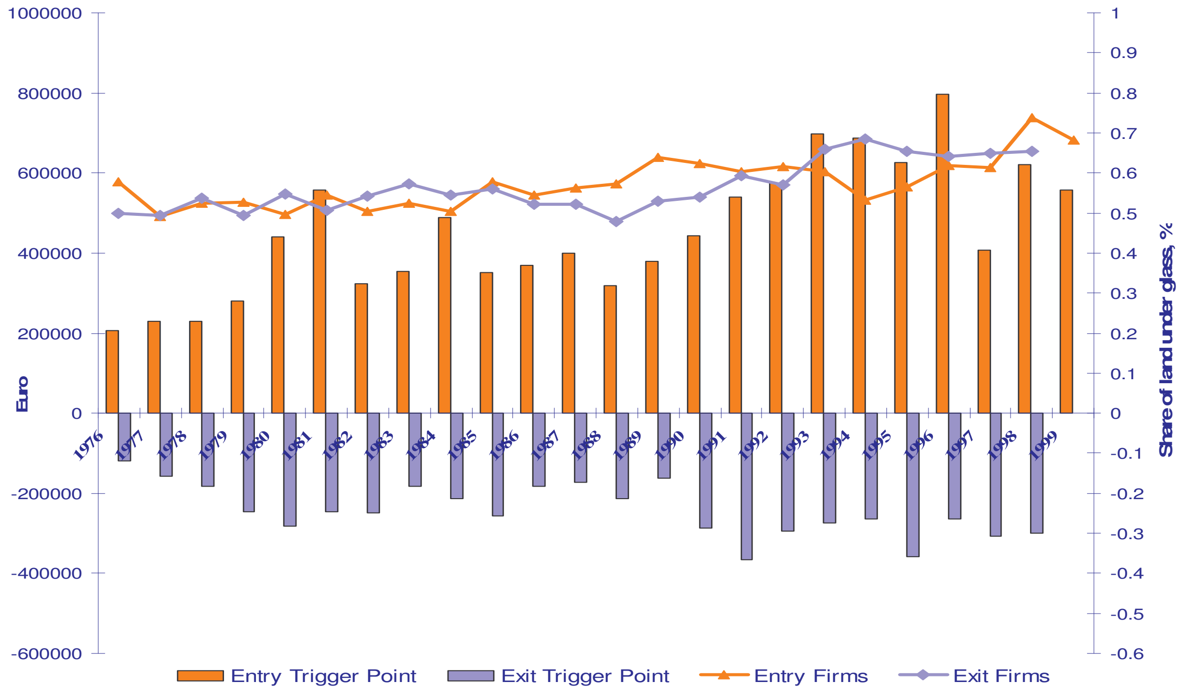


Figure 5.A: **Real Entry and Exit Trigger Points and specialisation in glasshouse horticulture of Entry and Exit firms**

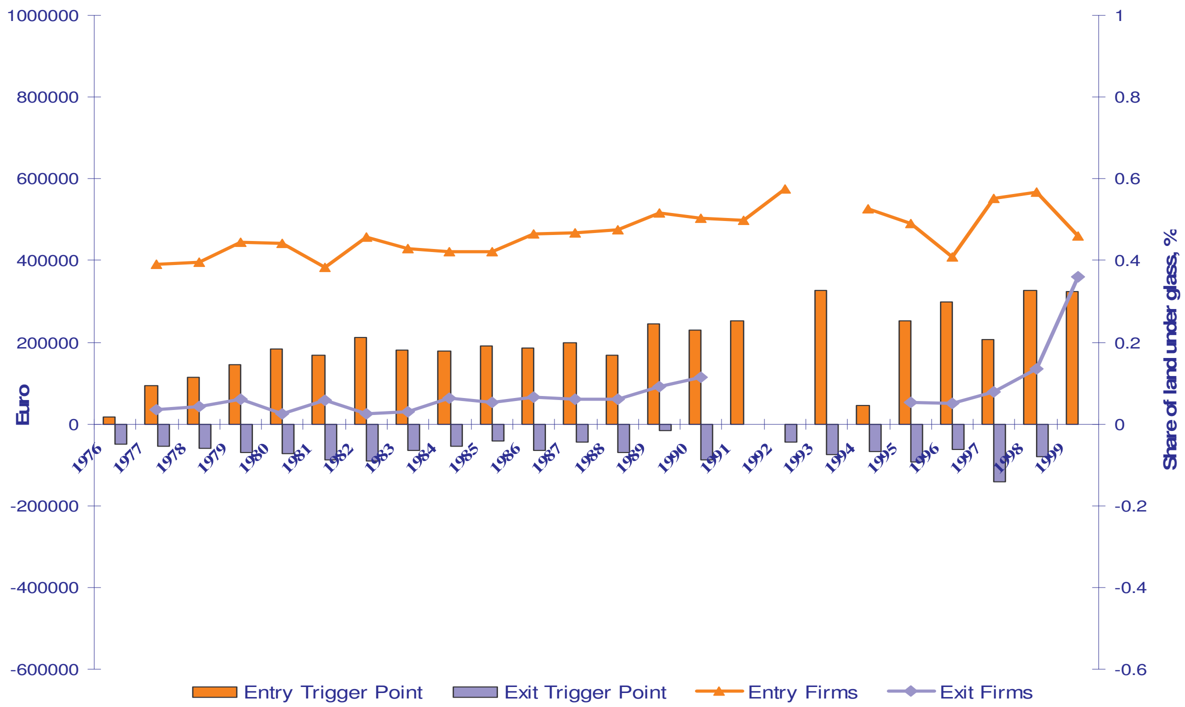


Figure 5.B: **Entry into and Exit from Horticulture sector RO Trigger Points and specialisation in glasshouse horticulture of Entry and Exit firms**

Chapter 6

Discussion and Conclusions

"The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them."

Sir William Bragg

6.1. Introduction

In this thesis the investment decision has been the central focus of the study. The main objective was to reflect on investment theory by applying it to the particular case of Dutch glasshouse horticulture.

From this broad objective, as described in *Chapter 1,* specific research questions were identified:

1. What are the factors underlying investment decision? What are the effects of these factors on the firm's decision to invest and on the decision of how much to invest? What are dynamic changes and the main characteristics of the Dutch glasshouse horticulture sector, which influence investments?
2. Does investment in the Dutch glasshouse horticulture sector reveal a smooth or a lumpy pattern? How can the lumpy and intermittent pattern of investment be explained? What defines the time duration between investment spikes? What is the time duration for Dutch glasshouse horticulture?
3. What is risk and what is uncertainty in relation to investments? How can risk and uncertainty be incorporated in a theoretical model of investment behaviour in relation to input demand and output supply? What is the effect of risk and uncertainty on investment?
4. What is the link between investment pattern and change in the number of operating firms in horticulture? What is the classification of entry and exit as an investment decision? What is the level of investment trigger points that a firm should overcome for entry and exit? What is the impact of changes in trigger points on the number of entry and exit firms? What is the effect of the uncertainty on the number of entry and exit firms?

This chapter reviews the findings aimed at answering the research questions, and presents a discussion on the theoretical, methodological and empirical issues, followed by general conclusions and recommendations for future research.

6.2. Conceptual issues

A conceptual framework has been developed to answer the research questions. Within the framework, the investment decisions and concepts underlying investment decisions are specified *(Figure 6.1).* The grey-coloured elements (on the left) in *Figure 6.1* represent investment thresholds, adjustment costs, irreversibility, and risk and uncertainty. Although they are latent aspects of in investment decisions—and therefore not observable—they are important for the understanding of investments. Another part of *Figure 6.1* (on the right) indicates what can be observed and studied. The realised investment is considered as a conjunction of three decisions: participation, level and timing of investments. The important link between observable and unobservable parts is the indirect study of underlying investment decisions' concepts through the exploration of three dimensions of investment decisions.

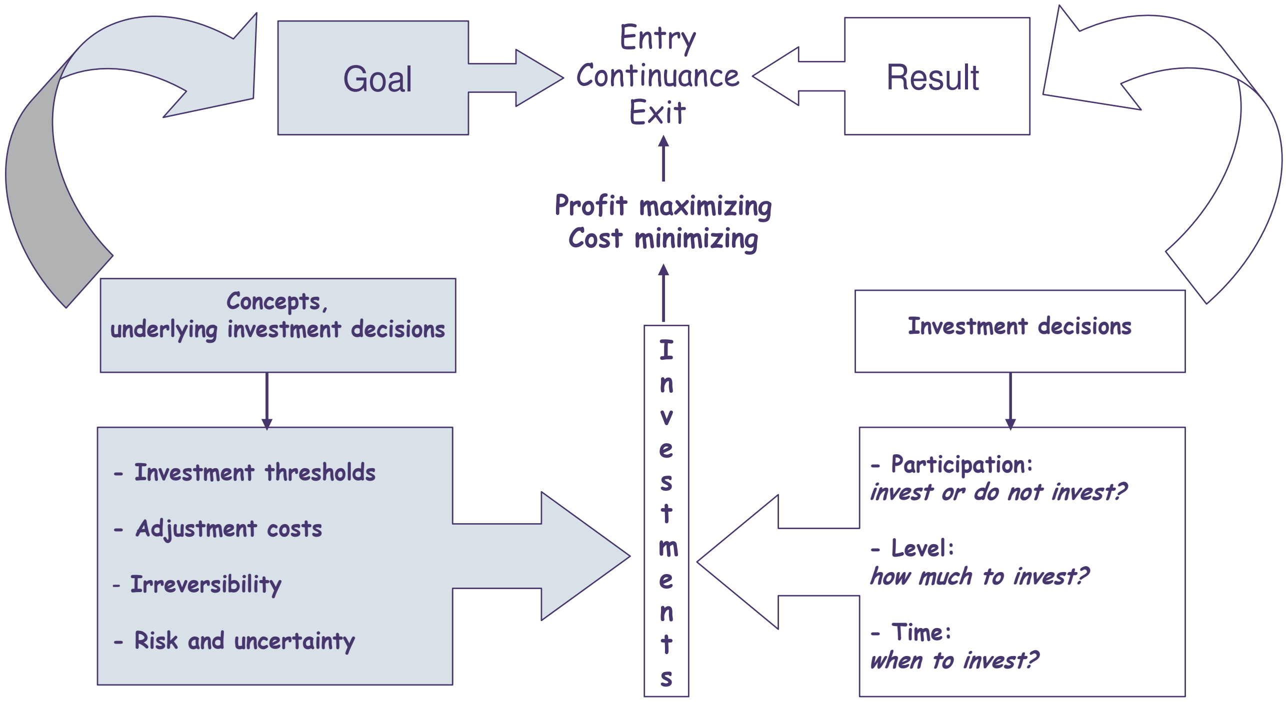


***Figure 6.1:* Framework of investment decision-making on a micro-level**

"The final goal of any firm is to continue to exist"

The life span of any firm can be marked by three steps: entry, continuance, exit. Every step can be considered as a goal of a firm, which is not observable, and as a result, which can be observed. Achieving the goal can be realised through profit maximisation (or cost minimisation), which is considered as a primary goal of the firm in microeconomics[32]. Therefore, the role and objective of a firm's investments are assumed to achieve the profit-maximising goal.

6.2.1. Investment decisions

Participation

The participation decision is the first decision that should be made by a potential investor and should be distinguished from other investment decisions.

[32] Remarks on the objectives of the firm can be found in Mas-Colell *et al.*, 1995: p.152.

In *Chapters 2 and 5* the "participation" investment decision is considered from a different perspective. The traditional framework does not distinguish investment decision as a combination of three decisions, which can be affected by different factors. In *Chapter 2,* the participation- and level-decisions are analysed in one framework by using the Heckman selection model. This allowed testing the correlation between two investment decisions, which was not significant. The difference in set of significant variables (e.g. energy- and land prices are not significant for the level decision), combined with the fact that some of the variables exhibited a contrasting sign (e.g. debts, revenue, labour cost), confirmed the difference between "participation" decisions and "level" decisions. Changes in variables that increase the profitability of firms, together with limited financial constraints and a younger head of the firm, make the decision to invest more probable. Nevertheless, with rising land- and energy prices, a firm is more willing to invest; e.g. higher energy prices lead to a higher investment level in equipment as a substitute for variable inputs (energy).

In *Chapter 5,* the entry and exit is considered as a participation decision. The contribution to the literature is that this chapter has demonstrated to what extent investment trigger barriers have an impact on a firm's decision to invest and enter or to disinvest and exit. The raising of the barriers discourages firms from taking action, they prefer to delay a decision that is associated with irreversible investments. Another contribution of this thesis to the literature is that Marshallian and Real Option trigger points were compared. The effect of uncertainty on the level of investment following Real Option theory (Dixit and Pindyck, 1994) can be observed through the changes in investment threshold. The empirical results of this thesis do not provide strong support to Real Option theory, while the model suggests that the direct impact of the sector-characterizing variables, such as expectation of output prices, interest rate and uncertainty, explains entry-exit decision better.

Level of investments

The estimation of the level of investment was made in *Chapter 2* by considering this decision as a second-step investment decision after a firm has already decided to invest. The variables that were found to influence the investment level positively are wealth, firm size, debts, and growth of output- and capital prices. Compared to the participation decision, as demonstrated by the Heckman selection model, a smaller set of significant variables predetermines the decision concerning the level of investment; some of these variables exhibit a contrasting sign.

The descriptive part of *Chapter 2* revealed the lumpiness of investment that indicates a high investment level, which was elaborated in *Chapter 3* from the perspective of time in relation to investment spikes. The variable indicating entry investment was included in the model of *Chapter 3*. The coefficient was positive and significant, which indicates that an entering firm concentrates investment in a short period within the first 1-2 years. This effect was not revealed by the Heckman selection model in *Chapter 2*, which shows that entry is important for participation but not for the level of investment decision. Further investigation of entry investment was done in *Chapter 5* by studying the participation decision.

The most extensive study of level of investment was conducted in *Chapter 4*. The analysis has been extended to risk and uncertainty, also using a dynamic approach. The investment demand was estimated first as an equation of the system, which also includes equations of input demand and output supply (as in Elhorst, 1993, Vasavada and Ball, 1988). The estimation using 3SLS, which allows for endogeneity and correlation between equations in the system, provides a good explanation for demand and supply equations, but not for the investment one. Endogeneity is introduced by the investment variable, which is a dependent variable in the investment demand equation, but an explanatory variable in output supply and input demand equations. Assumption the correlation between equations indicates that all three decisions, which are represented by three equations, are related to each other. An important contribution of this thesis is the clarification of the role of risk and uncertainty in the system. By the estimation of three equations, we also obtained richer information on the influence of investments on the economic system through output supply and input demand. In the year in which a firm introduces investments, its demand and supply are lower, because production factors (e.g. financial, labour sources) are used to get investments operational. This is demonstrated by negative coefficients of investment variables in the output supply and input demand equations.

The dynamic structure of the panel data was exploited for estimating the investment demand as a single equation by a GMM estimator, which allows us to overcome problems with heterogeneity and endogeneity, as well as possible omitted variables. The GMM provides a consistent estimation without the need to specify the distribution of the data (2005). Compared to previous studies of level of investment (e.g., Elhorst, 1987) the three types (output, input, and capital goods) of price uncertainty and risk were included in the model. This leads to the conclusion that the different price risk and uncertainty play an important, but different role in the investment decision. In this thesis a first attempt is made to take into account the asymmetry in the effect of uncertainty on investment. The difference between effects of negative and positive (with respect to the firm's profit) uncertainty is confirmed. Another contribution of this thesis in explaining the level of investment is that risk and uncertainty each have a different, sometimes contrasting effect, as in the case with capital prices, and should be distinguished for future research.

Time of investments

In *Chapter 2,* the intermittent pattern of investments was revealed. This means that investments are not spread smoothly over time but punctuated with periods of no- or low-investments. The empirical investigation of investments, which were grouped by size in 10 groups, led in *Chapter 2* to the provisional assumption about the presence of an investment cycle. Ignoring the investment cycle can lead to errors in prediction of investment fluctuations.

These findings were further explored in *Chapter 3*, by studying the time span between large investment periods. The fact that 16.5% of horticulture firms experience an investment spike, but that these account for 67.7% of total investment emphasises the importance of understanding this phenomenon. Duration analysis was used to investigate the factors determining the variation in timing between investment spikes. Conventional statistical approaches are not able to capture the effects of time-varying determinants and length of time-span between investment spikes. The results at firm level demonstrate the lowest probability of lumpy investment just after an investment spike, followed by a sharp increase in the sixth year. The finding in this thesis of an increasing probability of observing an investment spike with the years in other words, an upward-sloping shape of hazard) is comparable to the results of Cooper *et al. (*1999) and of Nilsen and Schiantarelli (2003), but contradict findings of Gelos and Isgut (2001). The results at average-firm level confirm the findings at the firm level about the presence of a 6-year investment cycle. Reasons for this length of investment cycle can be assumed to be the life-span of capital goods, the technology development, and business cycle, but these need further investigation. The existence of specific investment cycles implies that new policy instruments to increase the adoption of new, for example energy-saving, technologies will not necessarily lead to an immediate increase in investments, but will depend on other factors associated with the degree of obsolescence of the installed technologies.

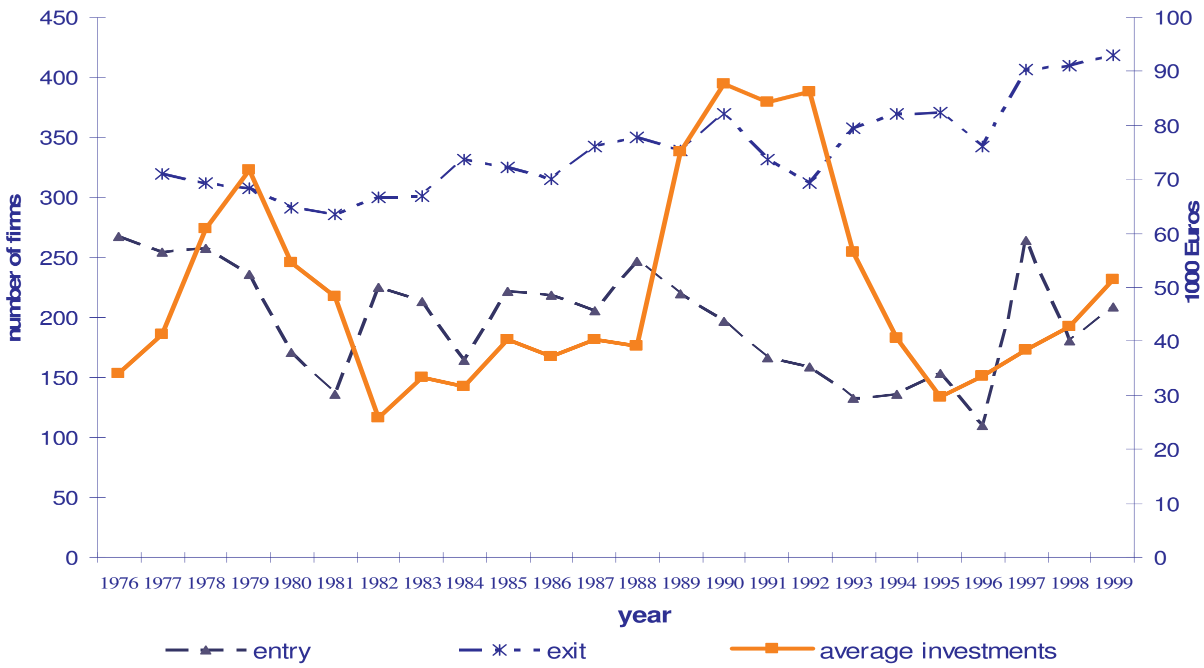


Figure 6.2: **Predicted numbers of entry-exit firms and timing of investment spikes**

In this thesis, a first attempt was made to estimate the effect of firms' entry investments on the occurrence of the investment spike. The indicator of an entry *(Table 3.2)* shows a positive effect that assumes that entering firms prefer to invest in a short period, rather than to spread investment over the years. In *Figure 6.2,* the timing of investment spikes *(from Table 3.5)* is compared with the probability of entry and exit predicted by the Negative Binomial model of *Chapter 5 (Table 5.4)*.

The co-movement of the predicted number of entry firms confirms the possible contribution of entry investment to the time of observation of investment spikes. So, the high predicted number of entries in 1977-1978 might have contributed to the investment spike in 1979, the increase in the number of entering firms in 1982, 1985, 1988 and 1997 might have had impact on the growth of investment level in 1982, 1985, 1989 and 1999. The large investment during 1990-1992 cannot be explained by the entry investment; but the low probability of exit during 1991-1992 can indicate that, during these years, the existing firms made large investments.

6.2.2. Concepts, underlying investment decisions

Adjustment costs

Firms incur costs in adjusting their capital; these costs are adjustment costs that firms face for a given investment. The assumption about the shape of the adjustment costs plays a crucial role in the literature that has attempted to improve understanding of capital investment in recent decades. The traditional assumption of a linear quadratic (convex) shape of the adjustment cost (Gould, 1968, Nickell, 1978) function does not provide a good explanation for lumpy and intermittent patterns of investments. Beyond some pioneering work (Cooper *et al.*, 1999, Nilsen and Schiantarelli, 2003, Cooper and Haltiwanger, 2006), the empirical documentation of capital adjustment cost patterns remains limited. The contribution of this thesis to this discussion is the providing of empirical evidence of nonconvexity of adjustment costs. The 6-year investment cycle found is in line with the work of Davidson and Harris (1981), where they postulated that in the presence of a fixed cost component in adjustment costs, one of the optimal long-run policies is a sequence of investment cycles with a constant period, each cycle involving a period of investment followed by a period of no investment.

As discussed by Caballero and Leahy (1996), fixed costs yields lumpiness of investment, thus, as it was suggested in *Chapter 2,* adjustment cost can mostly be influential for the decision regarding the level of investment. Estimation of a duration model for investments, as discussed in *Chapter 3*, provides an indirect method for deducing the form of the adjustment cost function, because the shape of the hazard function is related, as was shown by Cooper *et al.* (1999), to the shape of the firm's adjustment cost function. In this thesis, the increasing probability of observing an investment spike is found, which reflects the presence of the fixed component in adjustment costs. This result is comparable to that of Fennema *et al.* (2006) in exploring the timing of investment episodes of Dutch manufacture firms. A comprehensive approach to the study of adjustment cost function is demonstrated by Gardebroek (2001). His findings that the adjustment cost pattern differs for different type of capital can be related to the discussion in the descriptive part of the *Chapter 2*, but it was not exploited further in this thesis.

Irreversibility

If symmetry of the adjustment costs function is assumed (Gould, 1968, Nickell, 1978), this implies that investment can be reversed. Under this assumption, negative and positive gross investments follow the same decision rule. But this contradicts the Dutch glasshouse horticulture data. When investments are irreversible, firms usually cannot disinvest without incurring large costs, affecting their decision about the timing of investment: firms can postpone their investments. Investments are partly or completely irreversible due to incomplete markets for used capital goods, and the time- and firm-specific nature of capital goods. The presence of the irreversibility effect can be indicated by the rare occurrence of negative investment (0.7% of all observation of investment in Dutch horticulture) and high frequency of zero-investment (54% respectively). Irreversibility implies that investment becomes intermittent, that is the observation of periods with no investment, followed by periods with investment. This thesis contributes to the study of irreversibility by revealing the higher probability to invest in the 6th year. This is in line with Bertola (1998), who showed that irreversibility can explain the occurrence of investments at distinct times, which could possibly generate a fairly regular cycle in a macroeconomic model, although a relationship with a micromodel has not been further determined.

In *Chapter 2,* the assumption is made that irreversibility can also be important for the explanation of the participation decision, because it can entail a firm to postpone investment if the firm is not able to overcome an investment threshold. The negative impact of investment threshold on the decision to invest, confirmed in this thesis in *Chapter 5*, can indicate the effect of the irreversibility of an investment decision.

Irreversibility can also contribute to the effect of uncertainty on investment. As is postulated by Real Option theory, uncertainty is only relevant in the presence of irreversibility. Therefore, finding the effect of uncertainty on investment can indirectly confirm that investments at least are partly irreversible. In *Chapter 5*, the difference in the effect of uncertainty on an entry-exit investment decision can be explained by the difference in the degree of irreversibility. In this thesis the found effect of uncertainty on entry and exit confirms the suggestion about the irreversibility of the investment decision. But the effect of uncertainty on different types of entry-exit decisions is ambiguous. This is also suggested by

Folta and O'Brien (2004), who found an effect of irreversibility of entry investments on uncertainty.

Investment thresholds

In *Chapter 2,* the impact of different variables on the decision to invest was estimated. Although this estimation was not linked to the presence of investment trigger points (which is developed in *Chapter 5*), it provides insights into the factors that are contained in the concept of investment trigger points. For example, variables such as capital price growth or debts, which are related to the costs of investment and explain the increase of investment triggers, or limited possibility to overcome the investment threshold due to financial constraints, have a negative impact on the decision to invest. Variables, such as revenue, wealth, and output prices, have a positive impact. This means that their increase stimulates the decision to invest by making it possible to overcome an investment threshold.

Chapter 5 is dedicated to the study of investment trigger points. In this thesis a first attempt is made to explicitly calculate investment thresholds and to estimate their effect on the investment participation decision. Following the conventional approach, Marshallian trigger points for entry and exit are calculated for the period 1975-1999. Entry thresholds are higher than the exit thresholds; the thresholds for the real entry and exit are higher than the thresholds for entry and exit due to the changing specialization. Additionally, it was observed that exit thresholds have a smoother pattern compared to entry thresholds, which might be explained by the fact that the entry decision is more sensitive to changes in sector characteristics. This can be because the entry decision is based more on future expectation of some parameters than the exit decision, in other words, a firm possesses less information. For example, before entry, a firm calculates a cash flow based on the average profit in the sector, but before exit, a firm calculates a future cash flow based on the firms results, which is also compared with the average profitability of the sector.

Risk and uncertainty

There is quite some theoretical discussion about the impact of risk and uncertainty on investment, although in empirical applications often these phenomena are not distinguished. It can be explained that both components influence the ability (or rather, inability) to precisely predict what the future holds. *Chapter 4* is dedicated to the study of the effect of risk and uncertainty on investment. A contribution of this thesis to this discussion is that we estimated and compared the difference in the impact of risk and uncertainty using firm-level data. This is consistent with the competence hypothesis postulated in Heath and Tversky (1991), which shows that the effect of uncertainty on investment should differ depending on the source of uncertainty. A new framework for uncertainty estimation is proposed, which distinguishes between risk and uncertainty as respectively predictable and unpredictable derivations of predicted prices from actual prices. This result can be connected with the findings of Bell and Campa (1997) that firms react stronger to uncertainty, to which they have only recently been exposed, than regarding uncertainty, with which they have been confronted over the years. The research results make clear that distinguishing risk and uncertainty contributes to a better understanding of investment behaviour.

Another contribution of this thesis is that the asymmetry of uncertainty shocks was assumed and implemented in the models as two separate variables, showing the difference in impact of negative shock, which is usually stronger, compared to positive ones, for output-price uncertainty, and weaker for input- and capital-price uncertainty. The presence of asymmetry of reactions on uncertainty can explain the ambiguity of the results of other studies that were often reported (Abel and Eberly, 1999,Bloom *et al.*, 2006). By testing, the assumption about asymmetry of uncertainty was confirmed in *Chapter 4,* which can be due to the difference in the aversion of positive and negative shocks by firms as is discussed in a “Theory of Disappointment” (Gul, 1991)

The growth of risk suppresses investments in the case of capital goods and output prices, and increases investments in the case of input prices. The positive effect of “input-prices risk” can be explained by the fact that firms are motivated to invest to decrease costs.

The effect of an output price uncertainty shock, regardless of whether it is profitable for the firm or not, is to suppress investments. Input-price uncertainty influences investment positively. An unexpected growth of capital prices decreases the level of investments, but lower than expected capital prices have a stimulating effect.

The empirical study in *Chapter 5* provided a good case to test the relation of uncertainty with the participation investment decision, by comparing models with and without uncertainty, and with different specifications of the relation between uncertainty and the number of participation firms. Results indicated that the model that assumes the direct impact of uncertainty, which is captured by variables of expectation of prices, variation of prices and interest rate, outperforms other specifications. The positive expectations about trends in output prices induce more firms to enter and fewer firms to cease operation. A higher interest rate, which from a macro perspective indicates a particular part of a business cycle and can be related to the profitability of business, had a positive impact on entry and a negative one for exit. The bigger variation of output prices has a negative effect for exit from horticulture and a positive effect for real exit and any type of entry. This can indicate that the effect of uncertainty is nonmonotonic – greater uncertainty might decrease the likelihood of an investment participation decision, but beyond some critical level it might increase the likelihood of entry-exit investments. This result is comparable to that of Folta and O’Brien (2004) found by testing the effect of uncertainty on entry, and can be explained by the fact that the growth opportunities are also enhanced with greater (up to some level) uncertainty.

6.3. Methodological issues

The methodological issues relate to the application or implementation of the theoretical framework into empirical studies.

Application of theory and empirical methods to the data

Several empirical methods, based on the different theoretical models were applied to the different data sets to meet the objectives of the chapters. This combination of theoretical approaches, empirical methods and data sets can be considered as one of the important methodological issues of this thesis and is demonstrated in *Table 6.1*. The combination is necessary due to the intricacy of the study of investment decisions that is reflected in *Figure 6.1*.

The dominating theory used in all chapters is Capital Budgeting, which exploits the profit maximization objective of a firm. The firm-level data over 1975-1999 of Dutch glasshouse horticulture firms, provided by LEI, was used in every chapter. The construction of a 10-groups data-set by size in Chapter 3 provided an additional possibility to test the conclusion about time patterns of investment over a longer period than can be made at firm-level, because of rotation in the panel. The possibility of conducting the analysis on grouped data was first proposed by Deaton (Deaton, 1985). To construct a pseudo-panel, the size and homogeneity of the cohort was taking into account, because as was shown in Verbeek and Nijman (1992), ignoring these conditions will lead to a large bias in the estimation.

The investment trigger points in *Chapter 5* were calculated from the FADN data and incorporated as the annual average in Meitelling data. The price variables from CBS are used for an estimation of risk and uncertainty in Chapter 4 and Chapter 5.

The wide range of empirical models that fits data best is exploited. The Principal Component Analysis *(Chapter 2)* by generating the factors, which explain as much of the variance in these factors as possible, revealed the variables underlying investment. The Heckman selection model was chosen due to the high frequency of zero-investment that can lead to selection bias in the inference of the model. The important issue is that the participation- and level investment decisions are considered in one framework.

The duration model in *Chapter 3* is used for the analysis of the time pattern of investment. The important issue is that different specifications were estimated: one is based on a theoretical model and another enlarged by firm-specific variables and year dummies. Although the latter model improves the understanding of the investment pattern, the former one provides useful insights into the probability of observing an investment spike, which also contributes to the better explanation of underlying adjustment costs patterns.

Table 6.1: Applied Theoretical and Empirical Models to achieve Objectives of the chapters

Chapter	Data	Theoretical Model	Empirical Method	Objective of analysis
2	FADN (1975-1999) - firm-level Price-indexes (CBS) - macro-level	- Capital Budgeting (Profit Maximisation) - Behavioural economics	- Descriptive - Principal Component Analysis - Heckman Selection model	- Contribution of investments in changes in Dutch glasshouse horticulture sector - Investigation of factors underlying investments, analysis data structure - Decision to invest - Decision about the level of investment
3	FADN (1975-1999) - firm-level - grouped data set	- Capital Budgeting (Profit Maximisation) - Adjustment Cost	- Duration model	- Lumpy and intermittent pattern of investment - Time between investment spikes
4	Price-indexes (CBS) -macro-level	- Efficient market	- Moving window ARIMA	- Risk - Uncertainty
	FADN (1975-1999) - firm-level	- Capital Budgeting (Profit Maximisation) - Adjustment Cost	- 3SLS - Dynamic panel GMM-estimator	- Effect of risk and uncertainty on level of investments
5	Meitelling (1975-2004) - firm-level - average annual level FADN (1975-1999) - average annual level Price-indexes (CBS) -macro-level	- Capital Budgeting (Profit Maximisation) - Real Option	- Descriptive - Negative binomial	- Classification of Entry and Exit as investment decisions - Estimation of Entry/Exit Investment Trigger points - Effect of trigger points on number of firms investing in entry/exit - Effect of uncertainty on number of entry/exit firms

** FADN (Farm Accountancy Data Network) is unbalanced panel data, provided by LEI for glasshouse horticulture firms*
*** Meitelling is the Register of Enterprises and Establishments data, provided by LEI for glasshouse horticulture firms*
**** CBS is Central Bureau of Statistics (processed data)*

The correction of the model on heterogeneity, which is important for the inference on results, is another important issue of the thesis. As was demonstrated, taking into account unobserved heterogeneity of firms yields the different estimation of probability of observing investment spikes, which diverged most in the first and sixth years.

The level investment in *Chapter 4* was estimated: first, in the system of equations (input demand, output supply and investment demand) by 3SLS, second, as a single equation by a GMM dynamic panel data estimator. The 3SLS estimator, which allows for endogeneity and correlation between equations in the system, provides a good explanation for demand and supply equations and influence of investment on an economic system, but not for the investment one. With the estimation of investment by Arellano-Bond estimator, the dynamic nature of investment decision-making was taking into account.

Due to the fact that the dependent variable in *Chapter 5* can take only nonnegative integer values, the Poisson regression model was proposed. The assumption of the Poisson model about equal mean and variance is unlikely to be observed in real data. This was confirmed by the use of the Negative Binomial model, which, in the Poisson model, introduces an individual unobserved affect into conditional mean and was preferred due to the Loglikelihood-ratio test results.

Main variables affecting the investments

The application of theoretical and empirical models discussed above contributed to the selection of the main explanatory variables. The synthesis of the effect of explanatory variables used in the thesis on investment decision is represented in *Table 6.2*. It can be seen that participation and time decisions have the same signs for the variables; by contrast, some variables have the opposite signs to the level decision. The relation of the explanatory variables with the level of investment in *Chapter 2* is in the same direction as was found in *Chapter 4*.

Overall, it is possible to draw conclusions about the negative impact of accumulated *Capital* on any type of investment decision. The high *Debt* (at the beginning of the year) shows a negative impact on participation and time decisions, but a positive impact on the level, presumably distinguishing conservative and progressive firms. The higher *Profitability* (represented in different models as revenue, profitability shock, or interest rate) induce firms to invest, but a negative sign for the level of investment can indicate a concern of firms about adjustment costs, particularly internal ones, which imply a reduction in production. *Output price* has a positive impact on investment in all chapters, because it implies a positive expectation about future revenue. Growth of *Capital goods price* will deter a firm from the decision to invest, but a positive sign for the level can be related to the business cycle effect.

The increase of *Input price* can be due to the possible substitution effect, when the investment decision is driven by cost minimisation goals (e.g. replacing labour by capital, or old installations by new, more efficient ones). The same cost minimisation goal can explain the negative impact of input price growth on the level of investment. *Firm size* exhibits opposite signs. It can have a plausible explanation as a bigger firm invests infrequently, but once it has made the decision to invest, it induces a bigger investment compared to smaller firms. The impact of firm size is taken into account in other models. For example, the duration model of *Chapter 4* was corrected by an assumption about the presence of the fixed effect. In the GMM dynamic panel data estimator of the *Chapter 5,* the individual effect of a firm (which is broader than only size and can also include specialisation, location or management characteristics) is removed by first-differencing.

Table 6.2: The effect of explanatory variables on investment decision

Variables	Investment decision				
	Participation	Level	Time	Level	Participation
	Chapter 2 Table 2.7	*Chapter 2 Table 2.7*	*Chapter 3 Table 3.2*	*Chapter 4 Table 4.5*	*Chapter 5 Table 5.4*
Capital	-	-	-	-	
Debt	-	+	-		
Profitability	+	-	+	-	+
Output price	+	+		+	+
Capital price	-	+		+	
Input price	+	-		-	
Firm Size	-	+	√	√	

1) + means a positive impact
2) – means a negative impact
3) √ means that it is taking into account

The important overall conclusion is the consistency of the found results through the whole thesis.

Empirical definition of zero-investment

The first methodological issue, addressed in *Chapter 2*, was the definition of zero-investment. We defined “zero” investment if the ratio of investment to accumulated capital is higher than -0.05 but lower than 0.05. The use of nominally zero-level of investment hides the real distribution of negative, positive and zero-investments. The introduction of the proposed definition, based on relative importance of investment, represents an empirically plausible result *(Table 2.2).*

Risk and Uncertainty

In this thesis we proposed the framework in *Chapter 4* for an estimation of uncertainty that is distinguished from risk. Risk is defined as estimated standard deviation of residuals from ARIMA(0,1,0) estimation of prices. In most studies (e.g. Abel and Eberly, 1994, Ghosal and Loungani, 1996, Leahy and Whited, 1995) the standard deviation of prices is used as an uncertainty variable. Uncertainty in this thesis represents outcomes in the tails of distributions of prices and is calculated as a distance from expected interval estimation of prices to the realised prices.

Classification of Entry Exit investment decisions

The high heterogeneity of entry and exit decisions can lead to ambiguous inferences about underlying factors. The important contribution of this thesis is the elaboration of the classification of entry-exit decision as a combination of institutional and capital investments in time. The institutional investment includes a registration of a firm and organisation of production that characterise the ownership and management of the firm. Capital investment characterises fixed assets, which are essential for production. We classified three different entry-exit: real (or genuine) entry-exit; entry-exit by changing specialisation; transformation entry-exit. In this thesis the empirical implementation of the theoretical classification is proposed, which is based on changes in an individual registration number of a firm. Because the information about a firm's changes in institutional and capital investments in time is difficult to observe, the elaborated empirical methodology provides an accurate classification of different types of entry and exit investments.

6.4. Future research options

Consideration of theoretical issues, current results and future developments indicates challenges for future research.

The effect of heterogeneity of capital goods on investment, which was not explored in this thesis, can be interesting to evaluate, because the heterogeneity of capital goods can contribute to the aggregated investment patterns in two ways. On the one hand, the different capital goods have a different life-cycle, which can change the length of the investment cycle. On the other hand, the complimentarity of capital goods (for example, land and glasshouse) can lead to synchronization of time-spans between investments. The difference in the adjustment cost pattern of fixed capital can be further explored by the estimation of duration models for different types of capital.

Reasons for a 6-year investment cycle (revealed in this thesis), which contributes to the lumpy and intermittent pattern of investment, were not investigated in this thesis and remains an interesting subject for further study. Moreover, recent study by Gourio and Kashyap (2006) found that investment spikes are highly pro-cyclical, which led them to the suggestion of the relation of investment lumpiness to the business cycle. This suggestion would be interesting to test in further research.

The entry and exit investments, as indicated in this thesis, contribute to the investment pattern, which should be further explored. The most promising direction is an estimation of the impact of entry and exit on the level of investment and timing of investment spikes. Therefore, it would be interesting to study the correlation between investment cycle and industry dynamics. The length of survival of firms, which is one of the characteristics of the industry dynamics, might depend on the level of entry and exit investment thresholds, although this needs to be explored.

This thesis has made clear that distinguishing risk and uncertainty contribute to the better understanding of the level of investments. It can be interesting to investigate and compare the effect of risk and uncertainty with respect to other aspects of the investment decision. For example, the variables of risk and uncertainty can be included in the participation investment decision in a framework of entry-exit decisions (as in *Chapter 5*). The knowledge about effect of uncertainty on investments can also be improved by taking into account the difference in specialisation of firms that can better capture the fluctuation of market prices for the vegetable, cut-flowers and pot-plants sectors and can include substitution effect both across and between sectors.

6.5. Final conclusions

The proposed combination in this thesis of different approaches, which focus on certain aspects of the investment behaviour is a flexible tool that improves the understanding of the investment pattern. The following main conclusions can be drawn from the framework used in this thesis:

1) A new paradigm for the empirical analysis of investment patterns, introduced in this thesis, contributes to the understanding of the relevance of variables and their effect on an investment decision by elaboration of the three aspects of an investment decision: participation, level and timing of investment.
2) Accumulated capital has a negative impact on any aspect of investment decision. Variables of debt and profitability are important determinants, but have a different impact depending on the aspect of investment decision. Prices and price-related risk and uncertainty are variables that have a relevant effect on investment.
3) The proposed classification of entry-exit, based on organisational and specialisation aspects of a firm, helps to identify three types of entry and exit investment decisions. This

was useful for modelling the participation investment decision and recognizing the effect of uncertainty on entry and exit of firms.

4) The raising of investment thresholds discourages firms from actions due to the irreversibility of the investment decision, but their effect can differ because of the difference in degree of irreversibility, which is related to the type of entry and exit.
5) The analyses of investment spikes revealed the existence of a 6-year investment cycle in Dutch glasshouse horticulture. Knowledge of the investment cycle contributes to a better understanding of observed changes in investment.
6) The presence of a fixed component of adjustment costs is important for explaining investment spikes that imply the lumpiness of investment patterns
7) The observed periods of zero-investment in Dutch glasshouse horticulture at firm level can be explained by the irreversibility of investment, which restrains firms from taking action and leads to the postponing of investment.
8) Firms respond more strongly to risk than to uncertainty. An increase in the risk of changes in capital- and output-prices suppresses investment; but risk, related to the input-prices, stimulates investment. Uncertainty that increases the value of a firm shows a bigger investment response than uncertainty that decreases the firm's value. The estimated effect of negative input-price uncertainty and the positive output-price uncertainty give unexpected results in sign.
9) The assumption about the asymmetry of the uncertainty effect was confirmed, which contributes to the discussion in theoretical literature about the ambiguity of effect of uncertainty on investment.
10) Analysis of entry-exit in Dutch glasshouse horticulture does not provide strong support to real option theory as it is defined in the model of Dixit (1989), while the model that suggests the direct impact of the sector characterising variables, such as interest rate, expectation and variance of output prices, explains entry-exit decisions better.

References

"Science is a capital or fund perpetually reinvested; it accumulates, rolls up, is carried forward by every new man. Every man of science has all the science before him to go upon, to set himself up in business with."

John Burroughs, 1913

Abbring, J.H. and van den Berg, G.J., (2003). The Unobserved Heterogeneity Distribution in Duration Analysis. *Working paper:* Free University Amsterdam.

Abel, A.B. and Eberly, J.C. (1994). A Unified Model of Investment under Uncertainty. *The American Economic Review*. 84(5): 1369-1384.

Abel, A.B. and Eberly, J.C. (1997). An Exact Solution for the Investment and Value of Farm Facing Uncertainty, Adjustment Costs, and Irreversibility. *Journal of Economic Dynamics and Control*. 21: 831-852.

Abel, A.B. and Eberly, J.C. (1999). The Effect of Irreversibility and Uncertainty on Capital Accumulation. *Journal of Monetary Economics*. 44: 339-377.

Abel, A.B. and Eberly, J.C., (2002). Investment and q with Fixed Costs: an Empirical Analysis. *Working paper:* Warton School, University of Pennsylvania.

Agbola, F.W. and Harrison, S.R. (2005). Empirical Investigation of Investment Behaviour in Australia's pastoral region. *The Australian Journal of Agricultural and Resource Economics*. 49: 47-62.

Amemiya, T. (1974). Multivariate Regression and Simultaneous Equation Models when Dependent Variables are Truncated Normal. *Econometrica*. 42(6): 999-1012.

Amemiya, T. (1984). Tobit models: A survey. *Journal of Econometrics*. 24(1-2): 3-61.

Arellano, M. and Bond, S.R. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *Review of Economic Studies*. 58: 277-297.

Asano, H. (2002). An Empirical Analysis of Lumpy Investment: the Case of US Petroleum Refining Industry. *Energy Economics*. 24(6): 629-645.

Barry, P.J., Ellinger, P.N., Baker, C.B. and Hopkin, J.A. (2000). *Financial Management in Agriculture*. Danville: Interstate Publishers.

Bell, G.K. and Campa, J.M. (1997). Irreversible Investments and Volatile Markets: A Study of the Chemical Processing Industry. *The Review of Economics and Statistics*. 79(1): 79-87.

Bellman, R. (1957). *Dynamic programming*. Princeton: University Press.

Bertola, G. (1998). Irreversible Investment. *Research in Economics*. 52: 3-37.

Bertola, G. and Caballero, R.J. (1994). Irreversibility and Aggregate Investment. *Review of Economic Studies*. 61: 223-246.

Bloom, N., Bond, S.R. and Van Reenen, J., (2006). The Dynamics of Investment under Uncertainty. *Working paper:* NBER, No 12383.

Brandt, N., (2004). Business Dynamics in Europe. *Working Paper:* STI, OECD Publications, Paris, France.

Buddelmeyer, H., Jensen, P.H. and Webster, E., (2006). Innovation and the Determinants of Firm Survival. *Discussion paper:* IZA, No2386.

Caballero, R.J. and Engel, E.M.R.A. (1999). Explaining Investment Dynamics in U.S. Manufacturing: A Generalized (S,s) Approach. *Econometrica*. 67(4): 783-826.

Caballero, R.J. and Leahy, J.V., (1996). Fixed Costs: the Demise of Marginal q. *Working paper:* NBER, No 5508.

Cameron, A.C. and Triverdi, P.K. (1998). *Regression Analysis of Count Data*. Cambridge: Cambridge University Press.

Campbell, J.Y., Lo, A.W. and MacKinlay, A.C. (1997). *The Econometrics of Financial Markets*. Princeton: Princeton University Press.

Cassimon, D., Engelen, P.-J., Meersman, H. and Van Wouwe, M., (2002). Investment, Uncertainty and Irreversibility: Evidence from Belgian Accounting Data. *Working paper:* National Bank of Belgium, No 23.

Cattell, R.B. (1966). The Scree Test for the Number of Factors. *Multivariate Behavioral Research*. 1: 245-276.

Cook, S. (2004). Finite-Sample Properties of the GLS-Based Dickey-Fuller Test in the Presence of Breaks in Innovation Variance. *Austrian Journal of Statistics*. 33(3): 305-314.

Cooper, R. and Haltiwanger, J.C. (2006). On the Nature of Capital Adjustment Costs. *Review of Economic Studies*. 73: 611-633.

Cooper, R.W., Haltiwanger, J.C. and Power, L. (1999). Machine Replacement and the Business Cycle: Lumps and Bumps. *The American Economic Review*. 89(4): 921-946.

Davidson, R. and Harris, R. (1981). Non-Convexities in Continuous-Time Investment Theory. *Review of Economic Studies*. 48(2): 235-253.

de Bont, C.J.A.M., van Everdingen, W.H. and Koole, B., (2003). Standard Gross Margins in the Netherlands. *Eurostats Agricultural Typology:* LEI, The Hague.

Deaton, A. (1985). Panel Data from Time Series of Cross-Sections. *Journal of Econometrics*. 30(1-2): 109-126.

Diederen, P., van Tongeren, F. and van der Veen, H. (2003). Returns on Investments in Energy-Saving Technologies under Energy Price Uncertainty in Dutch Greenhouse Horticulture. *Environmental and Resource Economics*. 24: 379-394.

Dixit, A. (1989). Entry and Exit Decisions under Uncertainty. *The Journal of Political Economy*. 97(3): 620-638.

Dixit, A. (1992). Investment and Hysteresis. *Journal of Economic Perspectives*. 6(1): 107-132.

Dixit, A.K. and Pindyck, R.S. (1994). *Investment under Uncertainty*. Princeton: Princeton University Press.

Dixit, A.K. and Pindyck, R.S. (2001). *The Options Approach to Capital Investment*. In: Real Options and Investment under Uncertainty: Classical Readings and Recent Contributions E.S. Schwarz and L. Trigeorgis (Editors). Cambridge, Massachusetts: The MIT Press.

Doms, M. and Dunne, T. (1998). Capital Adjustment Patterns in Manufacturing Plants. *Review of Economic Dynamics*. 1: 409-429.

Eisner, R. and Strolz, R.H. (1963). *Determinants of Business Investment*. In: Impacts of Monetary Policy. New York: Prentice-Hall Inc.

Elhorst, J.P., (1987). De Investeringen in Kapitaalgoederen en het Financieringsvraagstuk in de Nederlandse Landbouw. *Onderzoeksverslag:* Landbouw Economish Instituut (LEI-DLO), No 31, Den Haag.

Elhorst, J.P. (1993). The Estimation of Investment Equations at the Farm Level. *European Review of Agricultural Economics*. 20: 167-182.

Elliott, G., Rothenberg, T.J. and Stock, J.H. (1996). Efficient Tests for an Autoregressive Unit Root. *Econometrica*. 64(4): 813-836.

Ellsberg, D. (1961). Risk, Ambiguity, and the Savage Axioms. *The Quarterly Journal of Economics*. 75(4): 643-669.

Epstein, L.G. (1981). Duality Theory and Functional Forms for Dynamic Factor Demands. *Review of Economic Studies*. 48: 81-95.

Fama, E. (1970). Efficient Capital Markets: A Review of Theory and Empirical Work. *Journal of Finance*. 25: 1043-4053.

Fama, E. (1991). Efficient Capital Markets: II. *Journal of Finance*. 46: 1575-1617.

Fennema, J., Letterie, W. and Pfann, G.A. (2006). The Timing of Investment Episodes in the Netherlands. *De Economist*. 154: 373-388.

Folta, T.B. and O'Brien, J.P. (2004). Entry in the Presence of Dueling Options. *Strategic Management Journal*. 25: 121-138.

Gardebroek, C. (2001). *Micro-Econometric Models for Analysing Capital Adjustment on Dutch Pig Farms*. PhD-thesis. Wageningen University.

Gardebroek, C. (2004). Capital Adjustment Patterns on Dutch Pig Farms. *European Review of Agricultural Economics*. 31(1): 39-59.

Gelos, G. and Isgut, A. (2001). Fixed Capital Adjustment: Is Latin America Different? *Review of Economics and Statistics*. 83(4): 717-726.

Ghosal, V. and Loungani, P. (1996). Product Market Competition and the Impact of Price Uncertainty on Investment: Some Evidence from U.S. Manufacturing Industries. *The Journal of Industrial Economics*. 44: 217-228.

Gijsberts, L. (1987). *Achtergronden van toen en nu*. In: 100 jaar veilingen in de tuinbouw (1887-1987) P. Plantenberg (Editor) Centraal Bureau van de Tuinbouwveilingen in Nederland.

Gollier, C. (2001). *The economics of risk and time*. Cambridge, Massachusetts: MIT Press.

Gould, J.P. (1968). Adjustment Costs in the Theory of Investment of the Firm. *Review of Economic Studies*. 35: 47-55.

Gourieroux, C. (2000). *Econometrics of Qualitative Dependent Variables*. Cambridge University Press.

Gourio, F. and Kashyap, A.K., (2006). Investment Spikes: New Facts and a General Equilibrium Exploration. *Working paper:* Boston University.

Granger, C.W.J. (1981). Some Properties of Time Series Data and Their Use in Econometric Model Specification. *Journal of Econometrics*. 16: 121-130.

Greene, W.H. (2003). *Econometric Analysis*. Upper Saddle River, New Jersey: Prentice Hall.

Grenadier, S.R. and Weiss, A.M. (1997). Investment in Technological Innovations: an Option Pricing Approach. *Journal of Financial Economics*. 44: 397-416.

Grossman, S.J. and Stiglitz, J.E. (1980). On the Impossibility of Informationally Efficient Markets. *American Economic Review*. 70: 393-408.

Grzegorz, P. and Kort, P.M. (2001). Investment under Uncertainty and Policy Change. *Working paper No.2001-05. Center for Economic research, Tilburg University*: 1-22.

Gul, F. (1991). A Theory of Disappointment Aversion. *Econometrica*. 59(3): 667-686.

Hair, J.F.J., Anderson, R.E., Tatham, R.L. and Black, W.C. (1998). *Multivariate Data Analysis*. New York / London: Macmillan Publishing Company.

Hall, A.R. (1994). Testing for a Unit Root in Time Series with Pretest Data-Based Model Selection. *Journal of Business & Economic Statistics*. 12: 461-470.

Hall, A.R. (2005). *Generalized Method of Moments. Advanced Texts in Econometrics*. Oxford: Oxford university press.

Hasset, K.A. and Metcalf, G.E. (1998). Investment with Uncertain Tax Policy: Does Random Tax Policy Discourage Investment? *Economic Journal*. 109(457): 372-393.

Heath, C. and Tversky, A. (1991). Preference and Belief: Ambiguity and Competence in Choice under Uncertainty. *Journal of Risk and Uncertainty*. 4: 5-28.

Heckman, J.J. (1979). Sample Selection Bias as a Specification Error. *Econometrica*. 47: 153-161.

Hsiao, C., Hammond, P. and Holly, A. (2002). *Analysis of Panel Data*. Cambridge University Press.

Hsu, S.-H. and Chang, C.-C. (1990). An Adjustment-Cost Rationalization of Asset Fixity Theory. *American Journal of Agricultural Economics*. 72(2): 298-308.

Hugget, M. and Ospina, S. (2001). Does productivity fall after the adoption of new technology? *Journal of Monetary Economics*. 48: 1973-1995.

Jenkins, S.P. (2005). Survival Analysis with Stata. http://www.iser.essex.ac.uk/teaching/degree/stephenj/ec968/.

Johnson, G.L. (1956). *Agricultural Adjustment Problems in a Growing Economy*. In: E. Heady (Editor) Iowa State University Press.

Jovanovic, B. (1998). Vintage Capital and Inequality. *Review of Economic Dynamics*. 1(2): 497-530.

Kahneman, D. and Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*. 47: 263-291.

Kaiser, H.F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement*. 20: 141-151.

Keynes, J.M. (Editor), 1921. *A Treatise on Probability*. London: Macmillan.

Keynes, J.M. (1936). *General Theory of Employment, Interest and Money*. London: Macmillan.

Knight, F.H. (1921). *Risk, Uncertainty and Profit*. Boston: Houghton Miffin.

Kort, P.M. (1987). The Firm's Investment Policy under a Concave Adjustment Cost Function. *Engineering Costs and Production Economics*. 12(1-4): 57-63.

Kuiper, W.E., Pennings, J.M.E. and Meulenberg, M.T.G. (2002). Identification by full Adjustment: Evidence from the Relationship between Futures and Spot Prices. *European Review of Agricultural Economics*. 29: 67-84.

Lancaster, T. (1990). *The Econometric Analysis of Transition Data.* Cambridge: Cambridge University Press.

Leahy, J.V. and Whited, T.M. (1995). The Effect of Uncertainty on Investment: Some Stylized Facts. *Journal of Money, Credit, and Banking*. 28(1): 64-83.

LEI (2000a). *Agricultural Economic Report 2000 of the Netherlands: Summary*. The Hague, The Netherlands: Agricultural Economic Research Institute LEI.

LEI (2000b). *Landbouwcijfers*. ‘s Gravenhage/Voorburg/Heerlen, The Netherlands: Landbouw Economisch Instituut/Centraal Bureau voor de Statistiek.

LEI (2004). *Landbouwcijfers*. ‘s Gravenhage/Voorburg/Heerlen, The Netherlands: Landbouw Economisch Instituut/Centraal Bureau voor de Statistiek.

LEI (2005). *Perspectieven voor de agrarishe sector in Nederland: Achtergrond rapport bij "Kiezen voor Landbouw"*. Den Haag: LEI.

Levene, H. (1960). *In Contributions to Probability and Statistics: Essays in Honor of Harold Hotelling*. In: I. Olkin and *et al.* (Editors).

Long, J.S. (1997). *Regression Models for Categorical and Limited Dependent Variables. Advanced Quantitative Techniques in the Social Sciences*. Sage Publications.

Lucas, R.E. (1967). Optimal Investment Policy and the Flexible Accelerator. *International economic review*. 8(1): 78-85.

Lught, F.H. (1988). *Wet investeringsrekening*. FED's Fiscale Brochures. Den Haag: Uitgeverij FED BV.

Maddala, G.S. and Kim, I.M. (1998). *Unit roots, cointegration, and structural change*. Themes in modern econometrics Cambridge: Cambridge University Press.

Marshall, A. (1920). *Principles of Economics*. Macmillan, New York.

Mas-Colell, A., Whinston, M.D. and Green, J.R. (1995). *Microeconomic Theory*. Oxford: Oxford University Press.

Methodology of the Farm Accountancy Data Network (FADN). http://ec.europa.eu/agriculture/rica/index_en.cfm.

Meyer, B.D. (1990). Unemployment Insurance and Unemployment Spells. *Econometrica*. 58(4): 757-782.

Miller, K.D. and Folta, T.B. (2002). Option Value and Entry Timing. *Strategic Management Journal*. 23: 655-665.

MLNV (2005). *Kiezen voor Landbouw: Een visie op de toekomst van de Nederlandse agrarishe sector (in Dutch).*

Muth, J.F. (1961). Rational Expectations and the Theory of Price Movements. *Reprinted in The new classical macroeconomics*. Volume 1(1992)(International Library of Critical Writings in Economics, vol. 19. Aldershot, U.K.: Elgar.): 3-23.

Neumann, G.R. (1997). *Search Models and Duration Data*. In: Handbook of applied econometrics M.H. Pesaran and P. Schmidt (Editors).Vol. II, Microeconomics: 300-351. Oxford: Basil Blackwell.

Ng, S. and Perron, P. (1995). Unit Root Test in ARMA Models with Data Dependent Methods for the Selection of the Trancation Lag. *Journal of American Statistical Association*. 90: 268-281.

Nicholson, J. (1994). *The Dutch Glasshouse Industry: An Economic History*. Wye College Press.

Nickell, S.J. (1978). *Cost of adjustment*. In: The investment decisions of firms. England: Cambridge University Press.

Nilsen, O. and Schiantarelli, F. (2003). Zeros and Lumps in Investment: Empirical Evidence on Irreversibilities and Nonconvexities. *The Review of Economics and Statistics*. 85(4): 1021-1037.

OECD (2003). *The Sources of Economic Growth in OECD Countries*. Paris, OECD.

Onatski, A. and Williams, N., (2002). Modelling Model Uncertainty. *Working paper No.169:* European Central Bank.

Ostbye, S. (1997). A real Option Approach to Investment in Factor Demand Models. . *Applied Econometrics Letters*. 4: 153-157.

Oude Lansink, A. and Pietola, K. (2002). *Modelling Energy Saving Technology Choices in Dutch Glasshouse Horticulture*. In: Economics of Sustainable Energy in Agriculture E.C. Ierland and A. Oude Lansink (Editors).Vol. 24, Economy & Environment. Dordreht, the Netherlands: Kluwer Academic Publishers.

Oude Lansink, A. and Pietola, K. (2005). Semi-parametric Modelling of Investments in Heating Installations: The Case of the Dutch Glasshouse Industry *Journal of Agricultural Economics*. 56(3): 433-448.

Oude Lansink, A. and Stefanou, S.E. (1997). Asymmetric Adjustment of Dynamic Factors at the Firm Level. *American Journal of Agricultural Economics*. 79: 1340-1351.

Oude Lansink, A.G.J.M., Verstegen, J.A.A.M. and van den Hengel, J.J. (2001). Investment Decision Making in Dutch Greenhouse Horticulture. *Netherlands Journal of Agricultural Science*. 49: 357-368.

Pfann, G.A. (1996). Factor Demand Models with Nonlinear Short-Run Fluctuations. *Journal of Economic Dynamics and Control*. 20: 315-331.

Pietola, K.S. and Myers, R.J. (2000). Investment Under Uncertainty and Dynamic Adjustment in the Finish Pork Industry. *American Journal of Agricultural Economics*. 82(4): 956-967.

Plantenberg, P. (Editor), 1987. *100 jaar veilingen in de tuinbouw (1887 - 1987)*. Hardenberg: Centraal Bureau van de Tuinbouwveilingen in Nederland.

Pravda (2 July 2004). Russians left without Dutch flowers.

Purvis, A., Boggess, W.G., Moss, C.B. and Holt, J. (1995). Technology Adoption Decisions under Irreversibility and Uncertainty: An *Ex Ante* Approach. *American Journal of Agricultural Economics*. 77: 541-551.

Richards, T.J. (1996). Economic Hysteresis and the Effects of Output Regulation. *Journal of Agricultural and Resource Economics*. 21: 1-17.

Robison, L.J. and Barry, P.J. (1996). *Present Value Models and Investment Analysis*. Northport, Alabama: The Academic Page.

Rosinski, J. and Yen, S.T., (2004). A Note on the Conditional Moments of Limited Dependent Variable Models with a Transformed Dependent Variable. *Working paper:* The University of Tennessee, Knoxville.

Roy, A.D. (1952). Safety First and the Holding of Assets. *Econometrica*. 20: 431-449.

Savage, L.J. (1954). *The Foundation of Statistics*. New York: Wiley.

Schlagheeke, G.J.C. (1988). Na de WIR. *Het Financiele Dagblad, 1 maart*, p. 11.

Siegfried, J.J. and Evans, L.B. (1994). Empirical Studies of Entry and Exit: A Survey of the Evidence. *Review of Industrial Organization*. 9: 121-155.

STATA (2003). *Arellano-Bond linear, dynamic panel-data estimation*. In: Cross-Sectional Time-Series. Reference Manual. Release 8. Texas: A Stata Press Publication, Stata Corporation.

Stevens, J.P. (1992). *Applied Multivariate Statistics for the Social Sciences (2nd edition)*. Hillsdale, NJ: Erlbaum.

Tauer, L.W. (2006). When to Get In and Out of Dairy Farming: A Real Option Analysis. *Agricultural and Resource Economics Review* 35: 1-6.

Taylor, R.A.M. (2005). On the Use of Sub-Sample Unit Root Tests to Detect Changes in Persistence. *Journal of Time Series Analysis*. 26(5): 759-778.

The New York Times (19 October, 1994). The Plight of Dutch Tomatoes and Cheese, p. 9.

Tomek, W.G. and Querin, S.F. (1984). Random Processes in Prices and Technical Analysis. *The Journal of Future Markets*. 4: 15-23.

Trigeorgis, L. (1997). *Real Options. Managerial Flexibility and Strategy in Resource Allocation*. MIT Press, Cambridge.

Van den Berg, G.J. (2001). *Duration Models: Specification, Identification and Multiple Durations*. In: Handbook of Econometrics J.J. Heckman and E. Leamer (Editors).Vol. 5, Chapter 55. Amsterdam: North-Holland.

Van der Knijff, A., Benninga, J., Reijnders, C. and Nienhuis, J., (2006). Energie in de glastuinbouw van Nederland: Ontwikkelingen in de sector en op de bedrijven tot en met 2004. *LEI-Rapport 3.06.02*, Den Haag.

Van Meijl, H., van Horen, L. and Wolters, A., (1999). Een wereld te winnen. Strategishe keuzes in de glastuinbouwtoelevering. LEI, Den Haag.

Vasavada, U. and Ball, E.V. (1988). A Dynamic Adjustment Model for U.S. Agriculture: 1948-79. *Agricultural Economics*. 2: 123-137.

Vasavada, U. and Chambers, R.G. (1986). Investment in U.S. Agriculture. *American Journal of Agricultural Economics*. 68: 950-960.

Verbeek, M. and Nijman, T. (1992). Can Cohort Data be Treated as Genuine Panel Data? *Empirical Economics*. 17: 9-23.

VNO (1980). *WIR Wijzer*. Den Haag.

Vrolijk, H.C.J. and Cotteleer, G.C., (2004). Non-respons en Rotatie in het Bedrijven - Informatienet. Kwantitatieve en Kwalitatieve analyse van de effecten. *Rapport:* LEI, Den Haag.

VROM (1999). *The Netherlands' Climate Policy Implementation Plan, Part I: Measures in the Netherlands*. The Hague (in Dutch and English): Ministry of VROM.

Wen, Y. (1998). Investment Cycles. *Journal of Economic Dynamics and Control*. 22: 1139-1165.

Wennberg, K., Folta, T.B. and Delamr, F. (2007). Real Option Model of Stepwise Entry into Self-Employment. Proceedings of the conference: *Entrepreneurship Research Conference*, University of Maryland.

WIR (1988). Wet Investeringsrekening, Het Financiele Dagblad, pp. 13.

Summary

"Vigorous writing is concise."

William Strunk Jr.,
"The Elements of Style", 1919

This study reflects on investment theory by applying it to the specific case of Dutch glasshouse horticulture. Starting from the management theory of capital budgeting and incorporating elements of adjustment cost theory and options theory, the empirical contribution of different approaches have been investigated. Investment is one of the fundamental decisions of a firm. Many factors may influence these decisions, which fulfil a role in growth, efficiency, productivity and profitability of a firm. Some aspects have been investigated more than others. In particular, the timing of investments, reactions to risk and uncertainty, and the entry and exit of firms have received ample attention. The starting point of this thesis is a theoretical background, and focuses on conceptual and empirical items.

The Dutch horticulture sector is an interesting case for studying investment behaviour. Glasshouse horticulture firms are often family-owned. In particular, the smaller firms make extensive use of family labour. But firms are relatively capital intensive. And they are in a continuous state of flux, trying to meet societal demands while at the same time retaining their competitive position. Investments set the scene for such changes.

During the research, a conceptual framework was developed to answer the research questions that were posed in the introductory chapter. Three aspects of the investment decision were distinguished: (1) whether or not to invest: the *participation* decision; (2) the *level* of investment and (3) the *timing* of investment. The three concepts were analysed consecutively or in combination by using different theoretical and empirical approaches. The results make possible a better understanding of the concepts and underlying investment decisions, giving an opportunity to reflect on investment theory.

The focus of *Chapter 2* is to reveal the main determinants of firm investment. For this purpose, the FADN data (Farm Accountancy Data Network) from 1975 till 1999 were used, thereby allowing a longer term overview to be studied. The descriptive analysis of firm investment reveals that years with high investment levels are typically followed by years with low investment levels. Moreover, investment patterns appear to differ between capital goods and between subsectors in glasshouse horticulture. To explore interrelationships among variables, a Principal Component Analysis was used, which shows that investments are largely autonomous. Comparing subsamples of zero and positive investments (focusing on the participation decision), we observe that investing firms have a bigger scale: implying a higher level of revenue, wealth and capital. Additionally, the investing firm is run by a younger entrepreneur. Is the level of investment determined by the same factors? This has been investigated using a two-step Heckman model, which makes it possible to focus both on the participation decision and the level of investment. Factors behind those steps often differ and are sometimes contrasting. Debt, and growth of capital-, energy- and land prices show clearly

opposite signs with respect to participation and level, while more wealth and higher output prices strongly encourage the decision to invest and also increase the investment level.

The timing of an investment decision was further analysed in *Chapter 3*. Here the concepts of investment spikes (period with high investment, also called periods with lumpy investment) and investment spells (the period between two successive investment spikes) are central. Capital adjustment exhibits periods of relative low or zero investment punctuated by lumpy investments. The periods between investment spikes were studied in a discrete-time proportional hazard framework by estimating a probability of observing lumpy investment and factors underlying lumpy and intermittent patterns of investment. The presence of investment cycles demonstrates the long-term policy of firms to invest in particular periods (investment spikes) with lower or zero investment levels in between, which contradict the smooth pattern predicted by a convex adjustment model. The panel-data models are augmented with a gamma distribution to account for unobserved heterogeneity among firms, which turned out to be a useful model extension. Duration models were estimated on two data sets: on an unbalanced panel and on average data of ten 'firm size' groups of Dutch greenhouse firms over the period 1975-1999. The 'firm size' groups (or average firm data) allow analyses over a longer period. Two specifications of the model were estimated: one includes only theoretically-based variables, while another specification is extended by empirically-based variables. Theoretically-based models can explain the occurrence of investment spikes adequately. Both specifications of models show an investment cycle of 6 years. This is also confirmed for the average firm, which exhibits a higher hazard ratio in the 6^{th}, 12^{th}-13^{th} and 21^{st} years of duration.

In *Chapter 4*, risk and uncertainty are explicitly incorporated in the theoretical model of investment behaviour in relation to input demand and output supply. The novel approach of the empirical investigation of uncertainty as an unpredictable part of price changes is explored. Moreover, positive and negative uncertainties are distinguished by classifying them according to their expected effect on the value of the firm. This approach provides the opportunity to test assumptions about asymmetric effects of uncertainty and difference in effects of risk and uncertainty of input-, output- and capital prices on investment decisions. Time series analysis of prices shows that all three prices can be characterized by means of a random walk model, which implies that prices increase every year with a (fluctuating) 'constant' term, also called 'price drift'. The analysis uses a moving window with a span of 25 years. Input prices and capital prices grow faster than output prices, indicating strong productivity growth. Two different investment models were used. In a system approach, investment is estimated together with input demand and output supply. The other model puts all emphasis on the investment equation. We follow the latter model with respect to the results. Risk and uncertainty related to output prices suppresses investments, but the coefficient of risk is not significant. Input-price risk and uncertainty stimulate investments. The increase in capital-price risk and negative (with respect to the value of firm) uncertainty decrease investments, but positive uncertainty has a positive impact on investments of Dutch glasshouse horticultural firms. Distinguishing risk and uncertainty gives new perspectives on the investment decision.

The entry and exit decisions, considered as participation investment decisions, are investigated in *Chapter 5*. The first target was a classification of entry and exit. Three types of entry-exit are distinguished: real (related to establishing or closing of a firm), entry-exit to another specialisation of the firm, and transformation to registration (due to the changes in ownership or management). Entry into glasshouse horticulture through a change in specialisation of existing firms is dominant. The exit is mostly a real exit or a transformation exit (which is related to the changes in registration of the firms). A real entry-exit and changes of specialisation were further investigated. Although not fully exploited, the analysis gives interesting survival rates for different firms. The main focus was on the thresholds to either enter or exit glasshouse horticulture. From a theoretical perspective, thresholds are represented by so-called trigger points. The estimation exploited the negative binomial model to investigate the role of Marshallian trigger points on the observed number of entry or exit firms in Dutch glasshouse horticulture over a period of 25 years. Firms have to overcome different levels of thresholds depending on types of entry and exit. Moreover, the effect of the changes in threshold over time will have a different effect for different types of entry-exit investment decisions. The estimation of the model, which takes into account an expectation of output prices, uncertainty and interest rate, explains better the changes in the numbers of firms that decided to invest and enter, or disinvest and exit. An assumption that these variables can influence the entry-exit decisions through the increasing or decreasing of trigger points, which is in line with real option theory, was not clearly supported by empirical results.

Together, *Chapters 2-5* demonstrate that the combination of different approaches proposed in this thesis, focusing on certain aspects of investment behaviour, is quite useful for understanding investment patterns. *Chapter 6* synthesises the results of the various chapters into a proposed paradigm of analysing investment behaviour: participation, level and timing. These observable concepts are influenced by unobservable or implicit concepts like investment thresholds, adjustment costs, irreversibility, and risk and uncertainty. The connection between these two sets of concepts gives new insights. The discussion is developed first along the lines of the observable concepts and then by the unobservable concepts. The coherence of the results is analysed and discussed, placing it against the background of available literature. Results are quite similar in the different chapters of the

thesis, using different approaches and methods. The main intention was to develop additional approaches in analysing investment behaviour, starting from the theory and bringing it up to the empirical level. The different approaches and the resulting insights have been put in an overview table. Chapter 6 contains recommendations for future research and gives number of conclusions on the main results of the thesis.

Samenvatting

“Schrijven is schrappen.”

Godfried Bomans,
Nederlandse schrijver, 1913-1971

Dit proefschrift werkt aan de ontwikkeling van investeringstheorie door het toe te passen in een specifieke context: de Nederlandse glastuinbouw. Het proefschrift start vanuit de managementtheorie van ‘capital budgeting’, incorporeert elementen van de ‘adjustment cost theory’ en ‘real options theory’ en bestudeert vervolgens in welke mate de verschillende benaderingen empirische observaties kunnen verklaren. De investeringsbeslissing is een van de belangrijkste beslissingen van een bedrijf. Vele factoren hebben invloed op deze beslissing en daarmee op de groei van een bedrijf, de efficiëntie, de productiviteit en de rentabiliteit. Sommige van deze factoren hebben in dit proefschrift extra aandacht gekregen, waaronder, de ‘timing’ van de investeringen, de invloed van risico en onzekerheid en de start- en beëindigingsbeslissing van ondernemers. Het startpunt van dit proefschrift is een theoretische verhandeling met een uitwerking naar conceptuele en empirische items.

De Nederlandse glastuinbouw is een interessante context om investeringsgedrag te onderzoeken. Glastuinbouwbedrijven zijn vaak familiebedrijven waarbij, met name de kleinere bedrijven, veel gebruik maken van eigen arbeid. Tegelijkertijd zijn glastuinbouwbedrijven relatief kapitaalintensief. Bedrijven bevinden zich in een continu veranderingsproces om tegemoet te komen aan de wensen vanuit de maatschappij en om tegelijkertijd hun concurrentiepositie in de markt te behouden. Investeringen zijn hierbij belangrijke aanjagers van verandering.

Gedurende het onderzoek is een conceptueel raamwerk ontwikkeld om de onderzoeksvragen, zoals gesteld in het introductiehoofdstuk, te kunnen beantwoorden. Drie aspecten van investeringsbeslissingen zijn daarbij onderscheiden: (1) wordt er wel of niet geïnvesteerd op een bepaald moment, ook wel de *participatie*beslissing genoemd, (2) als er geïnvesteerd wordt, wat is dan de *omvang* van de investeringen, en (3) de ‘*timing*’ van de investering. Deze drie aspecten zijn los van elkaar en in samenhang onderzocht door gebruik te maken van verschillende theoretische en empirische benaderingen. Het resultaat van deze exercitie zijn vernieuwde inzichten met betrekking tot de betekenis van deze aspecten bij investeringsbeslissingen.

Hoofdstuk 2 gaat in op het bepalen van de determinanten van investeringbeslissingen door bedrijven. Voor dit doel zijn bedrijven van het LEI Bedrijven-Informatienet gebruikt van 1975 tot 1999. Daarmee is het mogelijk om investeringen over een langere tijdsspanne te bestuderen. De beschrijvende analyse van de investeringen op bedrijfsniveau laat zien dat jaren met hoge investeringsniveaus meestal gevolgd worden door jaren met lage investeringsniveaus. Bovendien wordt duidelijk dat investeringspatronen bij diverse kapitaalgoederen van elkaar verschillen en dat tevens tussen subsectoren in de glastuinbouw aanzienlijke verschillen zijn. Een principale-componentenanalyse is uitgevoerd om zicht te krijgen op de relaties tussen diverse variabelen. Dit laat zien dat investeringen redelijk autonoom plaatsvinden ten opzichte van andere variabelen. De vergelijking tussen observaties zonder investeringen en observaties met investeringen (de participatiebeslissing) laat zien dat bedrijven die investeren vaak groter zijn en meer inkomsten, vermogen en kapitaal hebben. Bovendien worden deze bedrijven vaker geleid door een jongere ondernemer. Wordt de hoogte van de investeringen bepaald door dezelfde factoren? Deze vraag is onderzocht met behulp van een tweestaps-Heckman-model, dat het mogelijk maakt om gelijktijdig de participatiebeslissing (wel of niet investeren) en de hoogte van de investering te analyseren. De factoren die ten grondslag liggen aan deze twee beslissingen zijn vaak verschillend. Bijvoorbeeld, de coëfficiënten zijn tegengesteld voor de schuldpositie en toename in kapitaal-, energie- en grondprijzen, terwijl een toename in vermogen en hogere productprijzen zowel de beslissing om te investeren als de hoogte van de investering positief beïnvloeden.

De timing van de investering is verder onderzocht in *hoofdstuk 3*. Allereerst worden enkele concepten toegelicht: investeringspieken (*spikes* oftewel *periods with lumpy investment*) en de periode tussen twee opeenvolgende investeringspieken (*investment spells)*. De tijdlijn van veranderingen in de kapitaalgoederenvoorraad laat perioden zien met relatief weinig of geen investeringen, die worden onderbroken door perioden met relatief hoge investeringsniveaus. De periode tussen twee opeenvolgende investeringspieken is bestudeerd met behulp van een zogenaamd ‘discrete-time proportional hazard’-model Hiermee wordt de kans op het waarnemen van een investeringspiek geschat alsmede de factoren die bepalend zijn voor het investeringspatroon met perioden van veel en weinig investeringen. De aanwezigheid van investeringscycli met piekinvesteringen en perioden van relatieve rust daartussenin, geeft aan dat het langetermijninvesteringbeleid van bedrijven niet verklaard kan worden met een zogenaamd ‘convex adjustment’-model omdat dan een gelijkmatiger investeringspatroon te zien zou zijn.

De gebruikte paneldata-modellen zijn vervolgens uitgebreid met een gamma-verdeling om rekening te kunnen houden met onverklaarde heterogeniteit tussen bedrijven; dit bleek een waardevolle uitbreiding te zijn. Tenslotte zijn zogenaamde ‘duration’-modellen geschat op twee datasets: één op een ongebalanceerde panel-dataset en één op een dataset waarbij de tuinbouwbedrijven zijn ingedeeld in tien bedrijfsgrootteklassen waarbij wordt gewerkt met gemiddelden per klasse over de periode 1975-1999. Deze aanpak met ‘bedrijfsgrootteklassen’ maakt het mogelijk om gegevens over een langere periode te analyseren. Twee specificaties van het model worden vervolgens geschat: één met enkel op basis van de theorie geselecteerde variabelen en één waarbij de vorige specificatie is uitgebreid met empirisch-bepaalde variabelen. Geconcludeerd wordt dat bij de ongebalanceerde panel-dataset de theoriegebaseerde specificatie de aanwezigheid van investeringspieken goed kan verklaren.

Beide specificaties van het model laten een investeringscyclus van 6 jaar zien. Dit wordt ook bevestigd in het model waarbij gebruik gemaakt wordt de bedrijfsgrootteklassen. Dit model laat zien dat de kans op een investeringspiek het hoogst is in het 6^e^, 12^e^ of 13^e^ en 21^e^ jaar in een tijdreeks.

In *hoofdstuk 4* worden risico en onzekerheid expliciet opgenomen in het theoretisch model van investeringsgedrag. De onzekerheid in deze nieuwe aanpak van empirisch onderzoek bestaat uit onvoorspelbare prijsveranderingen. Risico geeft ook onzekere uitkomsten, maar daarvan zijn de verwachting en de variatie wel bekend. Bij onzekerheid wordt een onderscheid gemaakt tussen positieve en negatieve onzekerheid door ze te classificeren naar het verwachte effect op de opbrengst van de bedrijven. Deze benadering biedt de mogelijkheid tot het testen van hypothesen over asymmetrische effecten van onzekerheid en het verschil in effect van risico en onzekerheid (van de prijzen van input, output en kapitaal) op investeringsbeslissingen. Tijdreeksen van prijzen laten zien dat de prijsschommelingen kunnen worden aangeduid met een zogenaamd ‘random walk’-model. Dit impliceert dat de prijzen ieder jaar stijgen met een (fluctuerende) constante hoeveelheid, ook wel aangeduid als prijsdrift. In de analyse wordt daarom gebruik gemaakt van een voortschrijdend blikveld met een reikwijdte van 25 jaar. De prijzen van inputs en kapitaal stijgen sneller dan de outputprijzen, hetgeen aangeeft dat er sprake is van een sterke productiviteitsstijging. Twee verschillende modellen zijn gebruikt. In het ene model zijn middels een systeembenadering de investeringen geschat samen met de vraag naar inputs en de productie van outputs. In het andere model is alle nadruk gelegd op de investeringen. Hieronder bespreken we de resultaten van dit laatste model. Risico en onzekerheid bij de outputprijzen remmen investeringen, alhoewel de risicocoëfficiënt niet significant is. Risico en onzekerheid van inputprijzen stimuleren daarentegen investeringen. Een toename van het risico van de kosten van kapitaal, en negatieve onzekerheid met betrekking tot de opbrengsten van het bedrijf, remmen de investeringen. Positieve onzekerheid daarentegen heeft een positieve invloed op de investeringen van Nederlandse glastuinbouwbedrijven. Geconcludeerd kan worden dat het meenemen van risico en onzekerheid in de analyses nieuwe inzichten geeft bij investeringsbeslissingen.

De beslissingen om een bedrijf te starten of te stoppen, zijnde een soort van participatiebeslissingen, zijn onderzocht in *hoofdstuk 5*. Hierbij zijn drie typen van ‘starten’ of ‘stoppen’ onderscheiden: *daadwerkelijk* (starten of stoppen met een bedrijf), *veranderen van specialisatie* van het bedrijf, en *veranderen van registratie* (door veranderingen in eigendom of bedrijfsleiding). Meest voorkomend is het starten van een glastuinbouwbedrijf door een verandering in specialisatie bij een bestaand bedrijf. Een beslissing om te stoppen is meestal het definitief stoppen van het bedrijf of een verandering in registratie. Het daadwerkelijke starten en stoppen alsmede de veranderingen in specialisatie worden onderzocht in dit proefschrift. Alhoewel er nog meer analyses te bedenken zijn, biedt de huidige analyse al een interessante kijk op de 'overlevingskansen' van de bedrijven. De meeste nadruk ligt hierbij op drempelwaarden om te starten of te stoppen met een glastuinbouwbedrijf. Deze drempelwaarden worden in de theorie aangeduid met omslagpunten. Met behulp van een negatief binomiaal model is de rol van zogenaamde 'Marshallian' omslagpunten op de waargenomen aantallen start- en stop-beslissingen in de glastuinbouw van de afgelopen 25 jaar onderzocht. Hierbij gelden verschillende drempelwaarden, afhankelijk van het type 'start' of 'stop'. Bovendien veranderen deze drempelwaarden in de loop van de tijd en dit heeft een verschillende uitwerking voor de verschillende 'start' en 'stop'-typen. De schattingsresultaten, waarbij de verwachtingen in productprijzen, onzekerheid en rentepercentages zijn meegenomen, laten zien dat het model een betere verklaring geeft voor de investerings- en 'start'-beslissingen, dan voor de desinvesterings- en 'stop'-beslissingen. Een veronderstelling op basis van de 'real option'-theorie dat verwachte productprijzen, onzekerheid en rentepercentages invloed hebben op de omslagpunten en daarmee op de 'start'- en 'stop'-beslissingen, wordt door onze empirische resultaten niet duidelijk ondersteund.

Samengevat, de hoofdstukken 2 tot en met 5 van dit proefschrift laten zien dat de combinatie van verschillende benaderingen, bij verschillende aspecten van het investeringsgedrag, een zinvolle aanpak is om investeringspatronen te leren begrijpen. *Hoofdstuk 6* synthetiseert de uitkomsten van de vorige hoofdstukken en presenteert een paradigma om investeringsgedrag te analyseren, waarbij participatie, niveau en timing de belangrijkste concepten zijn. Deze waarneembare concepten worden beïnvloed door niet-waarneembare concepten, zoals investeringsdrempels, aanpassingskosten, onomkeerbaarheid van investeringsbeslissingen en risico en onzekerheid. De verbinding tussen de waarneembare en niet-waarneembare concepten geeft nieuwe inzichten. De discussie in dit proefschrift ontwikkelt zich allereerst langs de lijn van de waarneembare concepten om vervolgens daar de niet-waarneembare concepten bij te betrekken. De coherentie van de resultaten is geanalyseerd en bediscussieerd tegen de achtergrond van de beschikbare literatuur. De resultaten in de verschillende hoofdstukken van dit proefschrift, gebruikmakend van diverse benaderingen en methodieken, sluiten goed op elkaar aan. Het belangrijkste doel van dit proefschrift was om nieuwe aanpakken te ontwikkelen om investeringsgedrag te analyseren en om dit vanuit de theorie naar een empirisch niveau te tillen. Het resultaat van deze verschillende benaderingen is samengevat in een overzichtstabel. Hoofdstuk 6 bevat daarnaast aanbevelingen voor toekomstig onderzoek en presenteert de conclusies bij de belangrijkste resultaten van dit proefschrift.

Completed Training and Supervision Plan

"Never regard study as a duty, but as the enviable opportunity to learn to know the liberating influence of beauty in the realm of the spirit for your own personal joy and to the profit of the community to which your later work belongs."

Albert Einstein, 1879 – 1955

Description	Institute / Department	Year	Credits[1)]
General courses:			***7.4***
Career Assessment	Wageningen Graduate Schools, Meijer&Meijaard	2006	0.2
Scientific Publishing	Wageningen Graduate Schools	2004	0.2
Scientific Writing	Wageningen University	2003	1.5
Written English	Wageningen University	2003	1.5
Techniques for Writing and Presenting a Scientific Paper	Mansholt Graduate School of Social Sciences (MG3S)	2002	1
Mansholt Introduction course	MG3S	2002	1
Research Methodology	MG3S	2002	2
Discipline-specific courses			***31***
The Econometrics of Risk and Return	CEMFI, Madrid, Spain	2006	0.5
Recent Developments in International Finance	CEMFI, Madrid, Spain	2006	0.5
Economic Organisation Theory	NAKE	2005	2
Simulation-Based Econometric Methods	NAKE	2005	2
General method of moments: Theory and Practice	MG3S	2005	2
Econometrics of Panel Data	NAKE	2004	2
Bayesian Methods in Theory and Practice	MG3S	2003	2
Bayesian Statistics	Wageningen University	2003	1
Financial Risk Management	NAKE	2002	2
Behavioural Economics	MG3S	2002	3
Models in Agricultural Economics	MG3S	2002	5
Advanced Econometrics	MG3S	2002	3
Econometrics I	Wageningen University	2002	3
Horticulture Production Chains: Hortonomy	Wageningen University	2002	2

38th NAKE Workshop	NAKE	2005	1
Badi Baltagi on "Econometric Analysis of Panel Data"			
Giuseppe Bertola on "Distribution in Macroeconomic Models"			
John D.Wilson on "Intergovernmental Competition for Capital and Labour"			
Eyal Winter on "Incentives in Organisations"			
Presentations at conferences and workshops			***3***
26th conference of International Association of Agricultural Economists	Gold Coast, Australia	2006	
NAKE Research Day, the Dutch Central Bank	Amsterdam, the Netherlands	2006	
XVth International Symposium on Horticultural Economics and Management	Berlin, Germany	2004	
Mansholt PhD Day: "The Impact of Social Sciences on Decision- Making in Governments, Business and Consumer Organisations"	Wageningen, the Netherlands	2004	
The Agricultural Economic Society Conference	London, UK	2004	
Total (minimum 20 credits)			***41.4***

[1)] *One credit point represents 40 hours of course work*

* MG3S stands for Mansholt Graduate School of Social Sciences
** NAKE stands for Netherlands Network of Economics
*** CEMFI stands for Centre of Financial and Monetary Study, Bank of Spain

Curriculum Vitae

"The achievement of your goal is assured the moment you commit yourself to it."

Mack R. Douglas

Natalia GONCHAROVA was born on July 12th, 1970 in Stavropol, Russia. She completed mathematical school with distinction. In 1987 she passed her entrance exams for the Stavropol State Agrarian University (StGAU), where she obtained a degree with distinction in "Economics and Management in Agriculture" in 1991. In the period 1992-1996 she worked as a chief accountant for a private firm in Rostov-on-Don, Russia. In 1996 she started teaching economics at the Stavropol State Agrarian University, first as assistant professor, then as lecturer, and later as associate professor. During this period she also provided consultancy to private firms on economic issues.

As well as teaching, she conducted research, for which she received individual grants from the Economics Education and Research Consortium (Eurasia Foundation, World Bank, Global Development Network (GDN) *et al*). In 1999 she was awarded a grant from TACIS (EU) for a 2-month training in economics at the New School of Economics (Moscow, Russia), which she completed successfully (rated 3rd out of 60 participants).

She obtained her Doctoral degree from the Stavropol State Agrarian University in 2000, with a thesis entitled "The role of the part-time individual farms in the transition period (the case of Stavropol region)".

In 2001 she gained a junior research grant from the Mansholt Graduate School and started her PhD at Wageningen University and Research Centrum in the Business Economics group in June 2002. From July 2005 she continued her PhD in the Agriculture Economics and Rural Policy group. During her PhD she completed the educational programme of Mansholt Graduate School of Social Sciences and presented her work at several international conferences.

Publisher

Ponsen & Looijen BV, Wageningen

Cover design

Elements from the painting “We are all different” by Darya Goncharova

Financing organisations

Financial support from Agricultural Economics and Rural Policy Group

Financial support from Business Economics Group

Mansholt Graduate School of Social Science Junior Research Grant, Wageningen University

LEB fund financial support for conference attendance, Wageningen University