The Impact of Innovation, Firm Growth and Perceptions on Technical and Scale Efficiency

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Abstract

This paper uses a two-stage approach to analyse efficiency and productivity of Dutch glasshouse firms over the period 1991-1998. The first stages uses DEA to determine productivity growth and technical and scale efficiency; the second stage applies a TOBIT model to explain technical and scale efficiency; OLS is used to explain productivity change. The main explanatory variables are structural changes (innovation and firm growth), socio-economic variables and perceptions classified according to the SWOT-analysis. Variables that are stable over time, i.e. socio-economic variables of the firm and perceptions of the entrepreneur explain the level of technical and scale efficiency. Innovation and firm growth are important factors in the explanation of productivity growth.

Key words: *firm growth, innovation, panel data, productivity growth scale efficiency, socio-economic structure, technical efficiency*

Introduction

The explanation of firm performance has been the subject of numerous studies in the agricultural economics literature. Studies focusing on efficiency form a major category among these studies. Technical efficiency reflects the ability of a firm to obtain a maximum level of outputs from a given bundle of inputs or to use a minimum level of inputs to produce a given bundle of outputs (Coelli *et al*., 1999)[1].

In the literature, a large number of studies explain efficiency using a two-stage approach. The first stage computes the efficiency level whereas the second stage explains efficiency from a set of socio-economic variables. Ideally, all variables representing input and output are included in the first stage. Differences in technical efficiency between firms are then attributed to differences in the level of knowledge, skills and motivation of the entrepreneur. Therefore, inefficiency reflects all known and unknown factors that cause a sub-optimal level of production compared to firms which produce under equal circumstances.

The previous literature has used a variety of socio-economic variables to explain the level of efficiency and Table 1 provides an overview. Bravo-Ureta and Rieger (1991) find that firm size and extension on technical efficiency have a positive effect on technical efficiency and find no impact of the farmer's experience and education. Hallam and Machado (1996) report a positive impact of firm size on efficiency. Andreakos *et al*. (1997) find a positive impact on efficiency from farmer's age, formal education and ac-

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cess to credit. Also, they find that the presence of a successor and location of the firm have significant negative impacts; no significant effect is found from firm size and specialization. Wilson *et al*. (1998) report a negative effect of the farmer's experience and a positive effect of firm size on technical efficiency; geographical location has no significant impact. Alvarez and Gonzalez (1999) find a negative effect of firm size on efficiency in dairy farming. They suggest that a manager has a constant management capacity and farms in the largest size category are experiencing limits to a manager's span of control over the farm operation. Amara *et al*. (1999) also find a negative impact of firm size on efficiency in Canadian arable farming and a positive effect of the number of years with farming experience. No relationship is found between the farmer's perception of environmental degradation and efficiency; adoption of conservation practices, had a positive impact on efficiency.

Table 1. Overview of studies explaining efficiency

	Bravo-Ureta and Rieger (1991)	Hallam and Machado (1996)	Adreakos et al. (1997)	Wilson et al. (1998)	Amara et al. (1999)	Alvarez and Gonzalez (1999)
Used technique						
First stage	SFA	SFA	SFA	SFA	SFA	SFA
Second stage	ANOVA/ Kruskal Wallis	OLS	OLS	Jointly estimation	OLS	OLS
Socio-economic variables						
Age/experience	0	ni	+	–	+	+
Successor present	Ni	ni	–	ni	ni	ni
Education	0	ni	+	ni	0	ni
Credit access	Ni	ni	+	ni	ni	ni
Firm size	+	+	0	+	–	–
Specialization	Ni	–	0	ni	ni	ni
Location[a]	Ni	+	+	0	0	0
Degree of mechanization	Ni	0	Ni	ni	ni	ni

+ Significant positive relationship[a]
- Significant negative relationship
0 No significant relationship
ni Not included
[a] for location, the sign has no significance

The socio-economic variables discussed above are weak indicators for the farmer's knowledge level. Better data reflecting the farmer's knowledge could improve the explanation of the level of efficiency. Moreover, the socio-economic variables as described above are rather stable over time. These variables are more suitable for explaining differences in efficiency between firms rather than changes in efficiency (and productivity) over the years.

This paper contributes to literature on efficiency and productivity analysis by extending the explanation of efficiency and productivity change with socio-economic variables about the firm operator's perceptions of firm and environment reflecting his knowledge and motivation. Also, variables reflecting strategic changes such as innovation and firm growth are accounted for. The focus of the application is on FADN data of Dutch horticulture under glass. The available economic data from the FADN have been extended with survey data with information about strategic changes, innovations and a SWOT-analysis.

The remainder of this paper is structured as follows. The conceptual model is discussed in section 2. This is followed by a description of branch characteristics of horticulture under glass. Data are discussed in section 4 and section 5 presents the results. The paper concludes with a discussion and future outlook.

Conceptual model

The studies summarized in Table 1 explain the level of technical efficiency from socio-economic variables. This section uses concepts derived from strategic management literature to develop a conceptual model that relates performance to a set of socio-economic variables, innovation and growth and the firm operator's perceptions (i.e. knowledge). Figure 1 presents a graphical outline of the conceptual model used in this study.

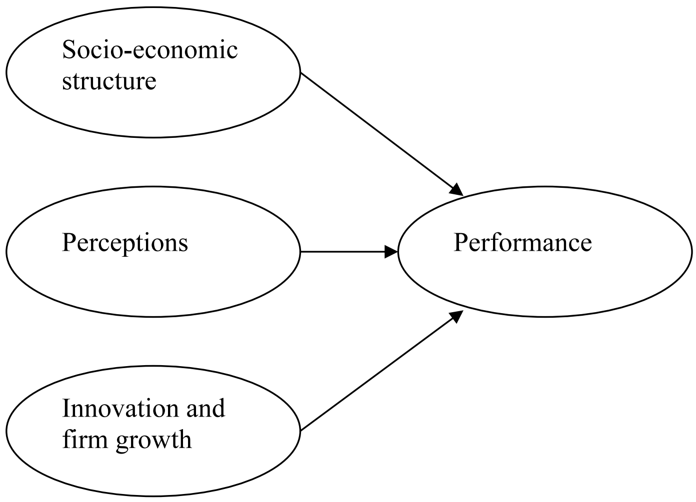

Figure 1. Graphical outline of the conceptual model

Performance

This study employs several measures of the firm's performance, i.e. technical and scale efficiency and productivity growth. Technical efficiency reflects the ability of a firm to obtain maximum output from a given set of inputs or minimum input to produce a given set of outputs (Coelli *et al*., 1999)[1]. The production frontier reflects the minimum input levels to obtain a certain output level. The efficient input-output levels are based on observations reflecting the best agricultural practice under the assumption of variable returns to scale (VRS). Firms producing on the production frontier are technically efficient. Scale efficient firms operate at an optimal firm size, i.e. at constant returns to scale.

Productivity reflects the ratio of the produced output to the used input (Coelli, *et al.,* 1999). Productivity growth is the relative increase of the productivity over time and is composed of technical change and efficiency change.

Socio-economic variables

To elaborate existing models, variables representing the socio-economic variables are at the basis of the conceptual model. The socio-economic variables refer to all those characteristics of the entrepreneur and the firm, which are assumed to influence firm performance. Examples are age of the entrepreneur, location, solvency etc.

Perceptions

Lack of knowledge or motivation of the firm operator are generally assumed to be an important factors, explaining why firms produce inefficiently. The conceptual model accounts for these factors through the firm operator's knowledge of internal (firm characteristics) and external factors (e.g. policy environment). The perception of the firm operator about internal and external factors may have negative or positive impacts on the firm's performance. A SWOT-analysis can be used to measure perceptions of external and internal factors. Perceptions of the firm operator are at the basis of strategic decisions.

Innovation and firm growth

To understand changes in efficiency and productivity over time, strategic changes have been included in the conceptual model. Two types of strategic changes have been distinguished: innovation and firm growth. Innovation has been broadly defined as any idea, practice or object that is perceived as new by the entrepreneur (Rogers, 1995). Because of the emphasis on adoption versus development of innovations, firm developments like diversification and integration are included in this definition. Firm growth refers to an expansion of the production capacity that increases the managerial burden.

Adoptions of innovations result in an upward shift of the production frontier, which is measured as technical change. Moreover, firm growth enables the entrepreneur to change the size of the firm and improve scale efficiency. Therefore, it is likely that innovation and firm growth have an impact on efficiency change and technical change. However, innovations demand for additional knowledge, whereas firms expansion requires a spread of the available management capacity over a larger firm. Therefore, innovation and expansion of the firm may not increase productivity and efficiency.

In conclusion, data on knowledge, innovation and firm growth may contribute to a better understanding of the dynamic aspects of efficiency and productivity change.

Characteristics of Dutch horticulture under glass

This section describes characteristics and developments of Dutch horticulture under glass, the focus of this study. In most strategic management handbooks, the relationships between strategic changes and performance have been based upon case studies. Empirical studies that statistically investigate these relationships are rare. The agricultural economics literature is no exception to this. However, the atomistic structure of agriculture implying a simple management structure and the availability of a large number of homogeneous firms make this branch attractive for empirical research. The empirical application in this study focuses on Dutch glasshouse horticulture. Unlike many other sectors in Dutch agriculture, horticulture under glass is not subject to production, market or price regulations.

Three main categories of marketable outputs are distinguished in Dutch horticulture: (1) vegetables with main products like tomatoes, cucumbers and peppers, (2) cut flowers like roses, chrysanthemum, tulips and lilies and (3) potted plants. Geographical advantages of horticulture in the Netherlands are relatively low temperatures in summer, mild winters, a high light intensity along the coast and the vicinity of large markets for vegetables and flowers. These factors contribute to the national and international success of Dutch horticulture. The strong position has been further strengthened by a trading system with auctions and a balanced system of research, extension and education (Vijverberg, 1996).

However, several developments violate the leading position of Dutch horticulture under glass. Lack of available land in the traditional specialized glasshouse regions, high labour costs and stringent environmental legislation increase the costs of production. Furthermore, vegetable production faces increasing competition of Mediterranean countries having higher temperatures and more sunshine in spring, winter and autumn, a larger availability of land and lower labour costs. However, competition with producers in these regions triggers the development of innovations. During the early nineties, vegetable producers suffered from a bad environmental image in Germany, the main market for Dutch horticultural products. Prices of vegetables are more sensitive to changes in supply and demand than prices of ornamental products like flowers and potted plants, making the production of vegetables more risky. The very low prices forced many growers to terminate the firm or to shift to other products. Table 2 presents a number of characteristics of Dutch horticulture and variables that illustrate he importance of horticulture for the Dutch economy.

Innovations in production and marketing and a decreased supply of vegetables resulted in high profits during the late nineties. These developments explain both the high annual decrease in the number of firms and the high annual increase in firm size (Table 2). Cut flower production is faced with increasing competition from countries like Israel, Kenya and Ecuador, although this competition is less severe than in vegetables. The supply of these products in wintertime is complementary to Dutch production. A large share of these products is also traded by the Dutch auctions. The innovative character of this branch, the decreasing number of firms, the increasing scale of production as well as the dynamic developments in the environment makes Dutch horticulture under glass attractive for this research.

Table 2. Characteristics of Dutch horticulture under glass

	Vegetables	Cut flowers	Potted plants
Sector data			
Total production value*10^6 Euro, 2001	1,155	2,078	1,214
Number of specialized firms in 2001 Annual change in number of firms, 1990 – 2001	2,457 -4.8%	4,884 [a] -1.9%[a]	
Firm data			
Firm size (standard firm units)[b] in 2001	248	211	243
Greenhouse area per firm (ha), 2001 Annual change in greenhouse area per firm in 1990 – 2001	1.65 4.8%	1.13[a] 3.1%[a]	
Profitability, 1990 – 2000 (revenues/costs *100%)	97	95	99
Total man year per firm in 2001	6.87	5.44[a]	

Source: Anonymous, 2002; Anonymous 1990-2000
[a] The data source does not provide figures for cut flowers and potted plants separately
[b] one standard firm unit represents € 248 standardized net added value

Methods and Data

A two-stage approach is used to test the conceptual model presented in section 2 (Thiele and Brodersen 1999). The first stage determines the firm's technical and scale efficiency and productivity growth, i.e. performance (Figure 1). Productivity growth is further decomposed in technical change and technical efficiency change (Coelli et al., 1999).

Data envelopment analysis (DEA) has been used to determine productivity growth and technical and scale efficiency. DEA is more flexible than Stochastic Frontier Analysis (SFA) as it does not require a functional specification for the production frontier, and it avoids distributional assumptions for the inefficiency (Coelli et al., 1999). A disadvantage of DEA is the vulnerability for measurement errors in the variables. Outliers of firms producing on the frontier may have a large impact on the efficiency of other firms. The impact of outliers is tested in a sensitivity analysis using super-efficiency DEA models. In this approach, firms under evaluation are excluded from the reference set. A large difference between an efficient firm and the production frontier after exclusion may indicate measurement errors (Zhu, 2003).

Productivity growth has been computed using the Malmquist TFP (total factor productivity) index (input-oriented). Furthermore, Malmquist TFP index has been decomposed in efficiency change and technical change (Coelli, et al., 1999).

The second stage employs a TOBITmodel to explain technical and scale efficiency; OLS-regressions to explain changes in productivity.

First stage: computing efficiency and productivity with DEA

Panel data of firms in horticulture under glass covering the period 1991-1998 are obtained from a rotating panel of farms that participate in the Dutch Farm Accountancy Data Network (FADN). The FADN is a stratified sample of Dutch agriculture and horticulture and contains an abundance of high quality data on firm structure, investments, and performance etc., which have been collected by the Agricultural Economics Research Institute. The firms typically remain in the panel for a maximum of about eight years, so the panel is incomplete. Firms rotate in and out the sample to avoid a selection bias, which arises when firms improve their performance by their presence in the accounting system. The data set used for calculating technical efficiency contains 1,821 observations from 481 firms.

One output and six inputs (energy, materials, services, structures, machinery and installations and labour) are distinguished. Output consists of vegetables, fruits, potted plants and flowers. Energy consists of gas, oil and electricity, as well as heat deliveries by electricity plants. Materials consist of seeds and planting materials, pesticides, fertilisers and other materials. Services are activities provided by contract workers and from storage and delivery of outputs. Fixed inputs are structures (buildings, glasshouses, land and paving), machinery and installations and labour. Labour is measured in quality-corrected man-years, and includes family as well as hired labour. Labour is assumed to

Table 3. Variables and Descriptive Statistics of FADN Data (compared with the subsamples)

Firm type	Variable	Dimension	Mean	Standard dev.
Vegetables	Output	1000 Guilders	1076 (1177)	837 (735)
	Energy	1000 Guilders	155 (182)	132 (128)
	Materials	1000 Guilders	135 (143)	106 (87)
	Services	1000 Guilders	92 (106)	64 (61)
	Structures	1000 Guilders	842 (1017)*	688 (649)
	Machinery	1000 Guilders	316 (384)*	302 (287)
	Labour	Man year	6.60 (7.44)	4.33 (3.80)
Cut Flowers	Output	1000 Guilders	1177 (1360)	930 (931)
	Energy	1000 Guilders	155 (180)	126 (129)
	Materials	1000 Guilders	204 (293)*	264 (270)
	Services	1000 Guilders	131 (155)*	100 (89)
	Structures	1000 Guilders	814 (1201)*	704 (978)
	Machinery	1000 Guilders	439 (565)*	520 (506)
	Labour	Man year	7.07 (6.60)	4.85 (2.94)
Potted plants	Output	1000 Guilders	1455 (1189)	1168 (870)
	Energy	1000 Guilders	143 (137)	128 (92)
	Materials	1000 Guilders	392 (313)	346 (266)
	Services	1000 Guilders	188 (167)	156 (150)
	Structures	1000 Guilders	935 (729)	932 (455)
	Machinery	1000 Guilders	461 (404)	540 (326)
	Labour	Man year	7.55 (5.79)*	5.78 (3.39)

* Different at Significancy level of 5% (Independent samples T-test)

be a fixed input because a large share of total labour consists of family labour. Flexibility of hired labour is further restricted by the presence of permanent contracts and by the fact that hiring additional labour involves search costs for the firm operator. The quality correction of labour is performed by the LEI and is necessary to aggregate labour from able-bodied adults with labour supplied by young people (e.g., young family members) or partly disabled workers. Capital in structures, machinery and installations is measured at constant 1990 prices and is valued in replacement costs[2].

Tornqvist price indexes are calculated for output and the three composite variable inputs with prices obtained from the LEI/CBS. The price indexes vary over the years but not over the firms, implying differences in the composition of inputs and output or quality differences are reflected in the quantity (Cox and Wohlgenant, 1986). Implicit quantity indexes are generated as the ratio of value to the price index. A more detailed description of the data is found in Table 3. Differences between firm types are relatively small. Vegetable producers have the lowest costs and output per firm, potted plant production has the highest costs and output per firm.

Second stage: TOBIT and OLS-regression

Technical and scale efficiency have been regressed on the variables listed in Table 4. A TOBIT model is used because the dependent variables are restricted to the interval [0,1] (Greene, 1997). The likelihood ratio test has been used to test whether blocks of related variables are significant at the critical 5% level. Insignificant blocks are excluded from the further analysis. OLS is used to regress productivity change and its decomposition in technical change and efficiency change on the same set of regressors.

Most socio-economic variables have been derived from the available FADN data set. Time horizon has been included as a dummy variable that takes the value of 1 for firms with a long time horizon, i.e. firm entrepreneurs with a successor or aged below 50. Data about the education level of the entrepreneur were not available from the FADN. Firm structure is reflected by: firm type, location, firm size, solvency and the modernity of durable goods. Two dummy variables are included in the regression to account for three firm types, i.e. specialised vegetables, flowers and potted plant producers. A regional dummy is included, taking the value one for firms located in the glasshouse district (in the western part of the country), and zero for firms in other regions. Standardized firm units reflect firm size, a measure based upon the net added value per ha (Welten, 1997). This criterion allows for comparing sizes of activities between different branches like the production of roses and tomatoes. Solvency is measured as the percentage equity capital in total capital. The modernity of durable goods has been calculated as the ratio of the book value of all durable goods and their replacement value[3].

The panel data set used for computing technical efficiency is not balanced as firms rotate in and out. The efficiency measures may be affected by this rotation scheme, particularly when efficient firms are removed from the sample. In order to account for the impact of the rotation on efficiency, a set of year-dummy variables has been included in the model. The year-dummies also account for year-specific effects like weather and market conditions.

An additional survey among a selection of FADN farms was conducted to gather data about perceptions and innovation and growth. The selection of firms from the FADN was restricted to firms that have participated for at least four years, with the last year of participation 1996 or later. [4]In the year 2000, the selected firms have been re-

Table 4. Descriptive statistics of the sample (n=222)

Variable	Mean	St. dev.	Description
Innovation and firm growth			
INACT	0.149	0.357	1 if firm renewal occurs in the same year
INACT_1	0.135	0.343	1 if firm renewal occurs in the year before
EXP	0.023	0.148	1 if firm growth occurs in the same year
EXP_1	0.027	0.163	1 if firm growth occurs in the year before
Firm type			
VEGET	0.33	0.47	1 if firm type is vegetable growing
FLOWER	0.36	0.48	1 if firm type is cut flower production
Socio-economic variables			
AGE	46.6	9.8	Age of the entrepreneur
SUC	0.22	0.416	1 if entrepreneur has a long time horizon
OND	1.62	0.797	Number of entrepreneurs
SIZE	807	535	Firm size (sbe)
SOLV	0.453	0.352	Solvency (equity capital / total capital)
MOD	1.34	0.486	Relative degree of modernity of durable goods (book value / replacement value)
LOC	0.45	0.499	1 if firm is located in Westland, the Dutch greenhouse District
Perceptions			
SSTRUC	0.23	0.422	1 if entrepreneur mentions firm structure, including firm size as a strength
SPROD	0.5	0.501	1 if entrepreneur mentions production means as a strength
SMANA	0.671	0.471	1 if entrepreneur mentions management as a strength
SKNOW	0.077	0.267	1 if entrepreneur mentions knowledge as a strength
SMARK	0.104	0.305	1 if entrepreneur mentions market management as a strength
SFINA	0.126	0.333	1 if entrepreneur mentions financial situation as a strength
OPOLI	0.18	0.385	1 if entrepreneur mentions policy developments as an opportunity
OPROD	0.086	0.28	1 if entrepreneur mentions developments in production means as an opportunity
OMARK	0.315	0.466	1 if entrepreneur mentions market developments as an opportunity
OTECH	0.257	0.438	1 if entrepreneur mentions technical developments as an opportunity

Variable	Mean	St. dev.	Description
OCOMM	0.185	0.389	1 if entrepreneur mentions developments in communication and image building in sector and society as an opportunity
OSPAT	0.054	0.227	1 if entrepreneur mentions spatial developments as an opportunity
Year dummies			
DUM91	0.131	0.338	1 if observation is made in 1991
DUM92	0.131	0.338	1 if observation is made in 1992
DUM93	0.153	0.361	1 if observation is made in 1993
DUM94	0.158	0.365	1 if observation is made in 1994
DUM95	0.162	0.369	1 if observation is made in 1995
DUM96	0.171	0.378	1 if observation is made in 1996
DUM97	0.041	0.198	1 if observation is made in 1997

quested to participate in an additional survey. After skipping observations with missing values, a sample of 39 firms remains, covering 222 observations in the FADN-data[5]. A comparison of the descriptive statistics of the complete sample used in the first stage and the selection of firms in the second stage is presented in Table 3. Application of the independent samples t-test indicates that significant differences exist. Particularly, the quantities of inputs used by the firms in the sub-sample have higher values. It is not clear, a priori, whether these differences affect the parameter estimates of the second stage regression.

In the survey, producers were asked to mention the most important strategic changes and innovations in the period 1991-1998. The answers of the participants have been checked and compared with the investment level reported in the FADN data. Firm growth is measured as a dummy variable, which takes the value 1 if the area and firm size measured in standardized firm units both increased by at least 5%.

The variables representing perceptions (i.e. the SWOT-analysis) have also been obtained from the survey[6]. Respondents have been asked to mention strengths, weaknesses, opportunities and threats in open-ended questions, with at most three items per category, according to procedures as described in management handbooks (e.g. Davids (2001) and Lynch (2000)). The answers have been categorized as shown in table 4. [7]Comparison of perceptions with socio-economic variables is not useful. First, comparison is only possible for internal characteristics which are objectively measurable like firm size. Second, the interpretation of the objectively measurable characteristics is subjective, e.g. the interpretation of firm size is dependent on objectives of the entrepreneur.

The classification for the two external and the two internal categories of the SWOT analysis has been kept equal[8]. After classification, the variables have been transformed for analysis. A dummy variable was created for each category, taking the value one if the entrepreneur mentioned at least one item in the category and zero otherwise.

Results

First stage: determination of efficiency by DEA

The program ONFRONT (Fare and Grosskopf, 2000) has been used to measure productivity growth and overall technical efficiency and scale efficiency, assuming strong disposability of all inputs. Table 5 present the average technical and scale efficiency for the complete sample of FADN firms used in the first stage. Results of the subset of firms that participated in the survey are presented in Table 6. This table has been extended with the descriptive statistics of productivity change, and its decomposition into efficiency change and technical change. Productivity change and efficiencies have been determined for specialized vegetables, cut flowers and potted plants firms separately for each year in the period 1991 – 1998. It is important to note that the mean technical efficiency is influenced by the size of these samples. In small samples, relatively more firms are producing on the production frontier.

Table 5. Descriptive statistics of technical efficiencies and scale efficiencies 1991 – 1998, whole dataset.

	Mean	St. dev.	Minimum	Maximum	sample size
Technical efficiency					
Vegetables	0.89	0.12	0.49	1.00	691
Cut flowers	0.92	0.10	0.56	1.00	706
Potted plants	0.93	0.10	0.54	1.00	412
Scale efficiency					
Vegetables	0.96	0.06	0.46	1.00	691
Cut flowers	0.96	0.06	0.54	1.00	706
Potted plants	0.95	0.07	0.47	1.00	412

Tables 5 and 6 show that technical efficiency of vegetable firms is smaller than technical efficiency of specialized cut flowers and potted plants firms. The standard deviation of technical efficiency is higher in vegetable production than in the production of cut flowers and potted plants, implying a larger variation in technical efficiency within the group of vegetable producers. Furthermore, Table 6 shows that the standard deviation of the productivity change is also higher in vegetable production than in cut flower and potted plant production. These findings are in line with the conclusion in section 3 that vegetable production is more risky than cut flower and potted plant production. Moreover, the larger differences in efficiency between vegetable producers contribute to the explanation of the high decrease in the number of firms and consequently the increase in firm growth (Table 5).

Comparison of Table 5 and 6 indicates that with the exception of potted plant growers, firms in the subset have a significantly lower technical efficiency than the firms who did not participate in the survey. This result seems to be consistent with finding of Verstegen et al. (2003) who found that participants in a survey are more altruistic than persons who do not participate. It is plausible that a negative relationship exists between the attitude to serve the interest of others and technical efficiency, which serves the entrepreneurial interest. A further comparison has been made between key variables of the

Table 6. Descriptive statistics of technical efficiencies and scale efficiencies 1991 – 1998 of sample used for further analysis.

	Mean	St. dev.	Minimum	Maximum	Sample size
Technical efficiency					
Vegetables	0.84*	0.13	0.58	1.00	74
Cut flowers	0.89*	0.11	0.62	1.00	80
Potted plants	0.91	0.09	0.71	1.00	68
Total sample	0.88*	0.12	0.58	1.00	242
Scale efficiency					
Vegetables	0.96	0.05	0.80	1.00	74
Cut flowers	0.97	0.04	0.85	1.00	80
Potted plants	0.96	0.06	0.75	1.00	68
Total sample	0.96	0.05	0.75	1.00	222
Productivity change					
Vegetables	1,06	0,31	0,61	2,96	63
Cut flowers	1,03	0,19	0,64	1,92	68
Potted plants	1,03	0,14	0,81	1,46	58
Total sample	1,04	0,23	0,61	2,96	189
Efficiency change					
Vegetables	1,00	0,21	0,65	2,04	63
Cut flowers	1,01	0,13	0,74	1,47	68
Potted plants	0,99	0,10	0,78	1,23	58
Total sample	1,00	0,15	0,65	2,04	189
Technical change					
Vegetables	1,06	0,12	0,71	1,46	63
Cut flowers	1,01	0,10	0,82	1,45	68
Potted plants	1,04	0,08	0,82	1,25	58
Total sample	1,04	0,10	0,71	1,46	189

total data set and the subsample using an independent samples t-test. The average firm size of the subsample (807 sbe, i.e.standardised firm units) is significantly higher than the average firm size of the whole dataset (724 sbe). In the whole data set, the share of the firm types vegetable production, cut flower production and potted plant production are 38%, 39% and 23% respectively; for the subsample the shares are 33%, 36% and 31%. The average age of the entrepreneur does not significantly differ between the whole dataset (44.8) and the subsample (46.6). *A priori,* it is not clear whether the parameter estimates of the second stage regression are affected by the selection of the subsample.

In order to assess the impact of measurement errors on performance measures, a sensitivity analysis has been performed. This analysis is based on the super-efficiency ap-

Table 7. Results of Technical Efficiency and Scale Efficiency regression, for explanation of the variables, see Table 4.

Variable	Technical Efficiency		Scale efficiency	
	Marginal effect	p-value	Marginal effect	p-value
Constant	0.87	0.00	0.63	0.00
Firm type				
GROENTEN	-0.04	0.08		
BLOEMEN	0.01	0.58		
Socio-economic variables				
AGE	-0.22	0.03	0.03	0.53
SUC	0.00	0.88	0.01	0.11
OND	0.02	0.13	-0.01	0.14
SIZE	0.01	0.54	0.00	0.77
SOLV	0.12	0.00	-0.01	0.40
MOD	-0.03	0.12	0.01	0.14
LOC	-0.06	0.00	0.02	0.00
Perceptions				
SSTRUC	-0.00	0.91	0.02	0.00
SPROD	0.05	0.02	-0.03	0.00
SMANA	-0.01	0.49	-0.01	0.10
SKNOW	0.05	0.35	-0.04	0.00
SMARK	-0.06	0.03	0.01	0.15
SFINA	-0.07	0.01	0.02	0.06
OPOLI	-0.10	0.00	0.03	0.01
OPROD	0.03	0.37	0.01	0.30
OMARK	-0.05	0.00	0.01	0.35
OTECH	0.04	0.05	-0.02	0.00
OCOMM	0.12	0.00	0.01	0.88
OSPAT	-0.01	0.80	-0.03	0.03
Year effects				
DUM91			0.01	0.47
DUM92			0.02	0.18
DUM93			0.01	0.30
DUM94			0.02	0.17
DUM95			0.02	0.07
DUM96			0.01	0.37
DUM97			-0.02	0.08

Second stage: explaining technical and scale efficiency proach (Zhu, 2003) and shows large differences between years within each firm type (appendix 1). For vegetables the maximum score of the efficient firms during the years 1995 – 1998 was much higher than during 1991 – 1994. Cut flowers and potted plants show comparable differences. The maximum score in 1994 of firm type 'cut flower' (25.90) is much higher than the maximum score in 1991 (4.32). This indicates that the sample possibly contains outliers. Comparison of the raw data of the firms with the maximum sensitivity scores with the other firms in the samples showed that in each of the firm types one firm produced in fully depreciated greenhouses. The potential distortion of these firms on the production frontier has been investigated by determining the correlation coefficient between the maximum sensitivity scores and the average efficiency for each firm type and each year. Distortion would exist if the average efficiency in years with a high maximum sensitivity score would be significantly lower than in years with a low maximum sensitivity score. The correlation coefficient was not significant (at 5%) indicating the absence of distortions.

The results of the Tobit-regression are presented in Table 7. A correlation matrix has been calculated for the independent variables to assess the presence of multicollinearity. The results showed that there are no large correlations between independent variables; therefore, none of the variables have been skipped. The likelihood ratio test has been used to test the goodness of fit of the model (appendix 2). The results show that both the blocks of socio-economic variables and the perceptions significantly contribute to the explanation of technical and scale efficiency. The block 'innovation and firm growth' does not contribute significantly, and has therefore been excluded from the analysis. The LR values (degrees of freedom) of the models for technical and scale efficiency are 108.84 (21) and 73.22 (26), respectively. Therefore, both models are significant at the critical 5% level.

The block firm type has a significant impact on technical efficiency. Specialised vegetables firms (VEGET) have a significantly lower technical efficiency than specialised potted plant firms. Technical efficiency does not differ between specialised potted plant firms and specialised flower firms (FLOWER).

Socio-economic variables have a number of significant effects on technical and scale efficiency. Contrary to results of Andreakos *et al*. (1997), Alvarez and Gonzalez (1999) and Amara *et al*. (1999), but in accordance with Wilson *et al*. (1998) age has a negative influence on technical efficiency. This suggests that structural developments in horticulture under glass require a flexible and sharp mind rather than experience. The developments concern different areas of entrepreneurship like marketing, assortment choices, production technology etc. Entrepreneurs cannot permit themselves to concentrate on one or two topics. A priori it is expected that these conditions provide a competitive advantage to young entrepreneurs. Although data on the education level are not available, the higher level of education of younger entrepreneurs may also play a role here.

The positive impact on technical efficiency of solvency (SOLV) suggests that firms that have been investing much (causing lower solvency) tend towards over investment. Firm size doesn't have a significant impact contrary to the results of Hallam and Machado (1996), Bravo-Ureta and Rieger (1991) and Wilson *et al*. (1998) but in line with the results of Amara *et al*. (1999) and Alvarez and Gonzalez (1999). Location in the glasshouse district (LOC) has a negative impact, implying that the presence of many colleagues in the vicinity increasing the scope for participation in study groups does not improve technical performance. This result may be caused by high land prices in the glasshouse district, causing high costs for structures.

The presence of a successor (SUC) has a positive impact on scale efficiency. This is explained by the fact that entrepreneurs with a long-term perspective more likely put incentives in reaching an optimal scale. Location in the glasshouse district (LOC) has a positive impact, implying that firms in the glasshouse district ceteris paribus have a more optimal scale than firms outside the glasshouse district. Solvency (SOLV) has a negative impact on scale efficiency suggesting that firms that an optimal scale is more likely reached by those firms that have made substantial investments (lowering the firm's solvency).

Several perception variables have a significant impact on technical and scale efficiency.[9] Perception categories can be categorised as variables that have a direct relation with technical efficiency and variables with an indirect relation. Perception variables with a direct impact are firm structure (SSTRUC), production means (SPROD), knowledge (SKNOW) as strengths and developments in production means (OPROD) and technology (OTECH) as opportunities. Mentioning production means (SPROD) as a strength and perceiving developments in technology (OTECH) as opportunities have a significant positive impact on technical efficiency. A firm with good production facilities has a balanced set of high quality input like labour, assortment, which directly affects technical efficiency. Developments in technology give the entrepreneur possibilities to improve production facilities. The impact of the perception of the quality of the firm's production facilities is not in line with the impact of the more objective measure, modernity (MOD). This may imply that firm operators tend to overestimate the actual quality of the production facilities. Knowledge (SKNOW) as strengths and developments in production means (OPROD) as opportunity have a positive, though insignificant impact on technical efficiency. The insignificant impact SMANA suggests that the perception of firm operators about their own managerial capabilities are not related with technical efficiency.

Most perception variables with an indirect relation with technical efficiency have a significant negative impact. Mentioning marketing (SMARK) as a strength and market developments (OMARK) as an opportunity have negative impacts on technical efficiency implying that allocating managerial resources away from production has a negative impact on technical efficiency. Observing the own financial situation (SFINA), covering solvency, liquidity and profitability as a strength also has a negative impact on technical efficiency. This suggests that entrepreneurs with a perceived strong financial position lack a trigger to perform optimal, and have no direct need to improve their technical performance. It is striking that the more objective measure of financial position, solvency, has a contrary impact. Apparently, the perception of the financial position is not solely based on the solvency of the firm, but may also be related to e.g. future perspectives. The perception of policy developments (OPOLI) as an opportunity is negatively correlated with technical efficiency. This result may imply that firms that have not invested yet in energy saving technological innovations still have sufficient opportunities to improve technical efficiency and comply with goals set for energy improvement in the energy covenant with the government. Mentioning communications and image building in the sector and society (OCOMM) as an opportunity is positively related with technical efficiency. This effect may imply that firm operators that see communication and image building as an opportunity may be more open minded and better educated than other firm operators. An overall conclusion is that positive perceptions of developments and qualities that are directly (indirectly) linked with production have a positive (negative) impact on technical efficiency.

The relationships between perception variables and scale efficiency follow a similar pattern as the relationships between perception variables and technical efficiency. The perception of a strong firm structure (SSTRUC), as well as the perception of a strong financial situation (SFINA) has a positive influence on scale efficiency. Firm size is an important feature of firm structure and directly linked with the scale of the firm operation. Mentioning production means (SPROD) and knowledge (SKNOW) as strengths and technology as an opportunity (OTECH) is negatively correlated with scale efficiency. The meaning of these results is that firms, which mention these aspects, have a more short-term focus on production and more likely ignore the long-term focus on the optimal scale of the firm operation. Technological developments affect technical efficiency directly and scale efficiency indirectly. The relationship with scale efficiency exists if technological changes affect the optimal scale of production. The perception that policy developments (OPOLI) provide opportunities has a positive impact on scale efficiency. This suggests that policy developments like the liberalization of the energy market and the covenant on energy efficiency provide better opportunities for firms with an optimal scale. The negative impact of OSPAT suggests that firms with a positive perception about the opportunities of spatial developments have an unused potential in terms of firm scale. Also, these firms may have plans to move away from their current location. Similar to our finding for technical efficiency, we find here that mentioning strengths and opportunities that have a direct relationship with the firm's scale have a positive impact on scale efficiency.

Results of the likelihood ratio test show that the block of year-dummies is significant in the scale efficiency model, but not in the technical efficiency model (Appendix 2). However, Table 7 also shows that none of the year-dummies is significant at the critical 5% level. This suggests that year-specific effects caused by e.g. the rotation scheme of the sample and other year-specific effects (weather, markets) do not have a significant impact on the level of technical and scale efficiency.

Second stage: Explaining productivity change

OLS has been used to analyse the impact of a limited set regressors on productivity change, and its two components: efficiency change and technical change. Perceptions and socio-economic variables have been skipped from the analysis because tentative results showed no significant effects and low marginal values of the perceptions. The R^2 decreased slightly by skipping these variables.

The results (Table 8) show that only structural changes have a positive impact on efficiency change. Firm growth (EXPANS) has the largest marginal impact on productivity change. Innovation (INACT) also has a significant effect on productivity change. Socio-economic variables don't have any significant impact on productivity change. A second important result is that innovation and firm growth have an immediate effect on efficiency, i.e. the effect has eroded away after one year. Subdivision of productivity change into efficiency change and technical change clarify that both innovation and firm growth affect efficiency change. They have no significant impact on technical change: This can be explained by the fact that most firms use techniques after innovation and growth, which are already in use by efficiently producing firms.

Comparison of Tables 7 and 8 supports the conclusion that regressors that are stable over time explain the level of firm efficiency and variables that vary across years provide a better explanation for efficiency change. The results of the OLS regression on technical and scale efficiency change are supplementary to the results of the TOBIT-analysis on the efficiency levels and lend support to entrepreneurs who want to improve their performance through innovation and firm growth. Innovation and firm growth affect the firm structure, which is covered by the socio-economic variables affecting technical and scale efficiency.

Table 8. Parameter estimates and goodness of fit of OLS-model for productivity change

Variable	Mi		EC		TC	
	Marg. effect	p-value	Marg. effect	p-value	Marg. effect	p-value
Constant	1.01	0.00	0.98	0.00	1.03	0.00
Structural changes						
INACT	0.12	0.01	0.06	0.03	0.04	0.08
INACT_1	0.01	0.82	0.00	0.91	0.00	0.85
EXPANS	0.49	0.00	0.32	0.00	0.08	0.11
EXPANS_1	0.06	0.55	0.02	0.82	0.05	0.24
Goodness of Fit						
R^2	0.16		0.14		0.04	
Residual statistics	Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Predicted Value	1.04	0.09	1.00	0.06	1.04	0.02
Residual	0.00	0.21	0.00	0.14	0.00	0.10

Conclusion and future outlook

The necessity to innovate and continuously change the firm strategy on the one hand and the risk associated with wrong decisions about innovation or strategic change on the other hand create the need for more empirical insight in the relationships between performance, perceptions, innovation and firm growth. This paper uses DEA to compute productivity growth and technical and scale efficiency as indicators for firm performance. Next, TOBIT is used to explain the level of technical and scale efficiency and OLS to explain productivity growth and its decomposition. The main explanatory categories are socio-economic variables, structural changes (innovation and firm growth), and perceptions of the firm operator obtained from a SWOT-analysis. Until now, most studies have been limited to socio-economic variables, which mostly reflect the outcome of managerial decisions. This study incorporates both the decisions (structural changes) and possible causes for change (perceptions), making the analysis more in-depth. The focus of the application is on FADN data on Dutch glasshouse firms over the period 1991-1998, extended with a survey among a selection of the FADN firms.

The results show that innovation has no impact on the level of technical and scale efficiency. Firm growth has a significant positive impact on technical efficiency and has no impact on scale efficiency. Both innovation and firm growth have an immediate significant positive influence on the change in technical efficiency and firm growth has a significant positive influence on the change in scale efficiency. The socio-economic variables have more significant impacts on both technical and scale efficiency. Young entrepreneurs are technically more efficient than old producers. A long-term perspective and investments, indicated by the low solvency improve scale efficiency. Perceptions have a significant impact on both technical and scale efficiency. Positive perceptions about firm characteristics and external developments, which have a direct link with the production process have a significant positive effect on technical efficiency. Furthermore, results show that allocating managerial resources away from the production process, e.g. market orientation, reduces the technical performance. Positive perceptions about firm characteristics and developments therein (having a direct link with the firm's scale) contribute significantly to scale efficiency. Results also show that perceptions of the firm's characteristics may have different impacts on technical and scale efficiency than variables that measure these characteristics more objectively. This may imply that perceptions may not always reflect the actual situation, rather they may reflect the firm operators' subjective assessments. Yet another implication may be that perceptions are based on a broader set of variables than the firm's characteristics. Innovation and firm growth have a significant positive impact on the productivity growth, and on technical efficiency change; these variables have no impact on technical change.

The general conclusion is that variables which are rather stable over time like the socio-economic structure of the firm and the perceptions of the entrepreneur contribute to the explanation of the level of technical and scale efficiency whereas incidental changes like innovation and firm growth significantly contribute to the explanation of technical change in technical and technical efficiency change.

This paper is the first to explain technical and scale efficiency from socio-economic variables, strategic changes and perceptions. Perceptions trigger or prohibit managerial decisions, strategic changes reflect managerial decisions, and socio-economic variables like solvency and firm size are indicators of the outcomes of decisions. The results in this paper show that data about the firm-operator's perceptions contribute to the explanation of technical and scale efficiency. The data used in this study are a combination of panel data about socio-economic variables and strategic changes are used and cross-section data on perceptions. The understanding of efficiency could become more in-depth if panel data of perceptions are available, as perceptions may change over time.

Notes

1 The economic performance is optimal if the firm is not only technically efficient, but also allocatively efficient. In the last case the firm uses the inputs also in the optimal proportions, given their respective prices and the production technology. It is assumed that innovation and firm growth have a larger impact on technical efficiency than on allocative efficiency. Therefore, allocative efficiency has been left out of considerations in this study.

2 The deflators for capital in structures and machinery and installations are calculated from the data supplied by the LEI accounting system. Comparison of the balance value in year t and the balance value in year t-1 gives the yearly price correction used by the LEI. This price correction is used to construct a price index for capital and a price index for machinery and installations. These price indices are used as deflators.

[3] Because of the degressive method of depreciation of durable goods, the expected average value for modernity is 0.33

[4] It was not allowed to make use of firms who still participated in the FADN, because of their participation in other research. An additional request implied a risk that they would terminate for that reason their participation in FADN.

[5] Because of the loss of the first year for each firm, 189 observations are used to explain productivity change. However, because of missing values in regressors, this is not exactly 39 observations (the number of firms) less than the number of observations used to explain technical and scale efficiency.

[6] Panel data about perceptions were not available and could not be reconstructed. Cross-sectional data after the participation in FADN was the best alternative.

[7] No other empirical studies have been found using the same procedure, so the reliability of this procedure could not be compared. However, the meaningful answers of the respondents showed that they were able to understand the questions.

[8] A two level classification has been applied, which can be requested at the first author.

[9] Threats and weaknesses have been excluded from the analysis. Adding 12 binary variables will cause multicollinearity. The consequence is that the interpretation of the relationships between efficiency and positive perceptions (strengths and opportunities) may falsely result in conclusions that mentioning development in opposite categories would show opposite relationships. This is not automatically the case, because the referred developments are not necessarily the same. E.g., a negative relationship between political developments as an opportunity and efficiency does not imply that the relationship between political developments as a threat and efficiency is positive. Environmental legislation can be a threat and expansion of the European Union can be an opportunity. Therefore, the TOBIT estimations have been repeated after replacement of strengths by weaknesses and opportunities by threats. The analysis of these results corresponds to the above-described results.

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Appendix

Table A. Sensitivity analysis of efficiency scores

Firm type	Year	Average efficiency	Maximum sensitivity score
Vegetables	1991	0.93	4.48
	1992	0.90	5.37
	1993	0.90	4.16
	1994	0.86	4.29
	1995	0.90	11.03
	1996	0.84	14.09
	1997	0.90	13.05
	1998	0.88	12.64
Cut flowers	1991	0.94	4.32
	1992	0.91	2.93
	1993	0.91	4.12
	1994	0.87	25.90
	1995	0.91	26.38
	1996	0.92	24.22
	1997	0.92	26.51
	1998	0.91	6.78
Potted plants	1991	0.96	26.23
	1992	0.91	24.66
	1993	0.93	19.28
	1994	0.95	33.54
	1995	0.95	2.29
	1996	0.92	4.50
	1997	0.92	2.31
	1998	0.92	4.49

Table B. Outcomes of LR-test for TOBIT regressions

		Degrees of freedom	Log likelihood ratio
Technical efficiency	Innovation and firm growth	4	5.3
	Firm type	2	7.5*
	Socio-economic structure	7	28.6*
	Perceptions	12	50.6*
	Year dummies	7	5.2
Scale efficiency	Innovation and firm growth	4	2.6
	Firm type	2	0.9
	Socio-economic structure	7	14.7*
	Perceptions	12	33.1*
	Year dummies	7	18.7*

*significant at 5% level