EXPLAINING GROWTH IN DUTCH AGRICULTURE: PRICES, PUBLIC R&D, AND TECHNOLOGICAL CHANGE

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Abstract

This paper analyzes the sources of growth of Dutch agriculture (arable, meat, and dairy sectors). Because the time series data (1950-1997) are non-stationary and not cointegrated, it is argued that a model estimated in first differences should be used. Estimated price elasticities turn out to be very inelastic, both in the short-run and the long-run. The direct distortionary effect of price support has therefore been rather limited. However, price support has an important indirect effect by improving the sectors investment possibilities and therewith the capital stock. Public R&D expenditure mainly affected agriculture by contributing to yield improvement therewith favoring intensification of production.

Keywords: growth, technology, cointegration, non-stationarity, agricultural policy
JEL classification: Q18 Agricultural Policy; O13 Agricultural development

Introduction

From evidence over the period 1967-1992 including 130 countries, it appeared that 50 percent of the world food production was produced in countries whose growth rates exceeded 2.25 percent, whereas the remaining half was produced by countries with lower, but usually still positive growth rates (Mundlak, 2000, 3). Countries with large agricultural production belong to the category of economies with the relatively high growth rates. Agricultural output growth is often connected with distortive agricultural policies, in particular with price support. Whereas nominal prices usually increased over time, however, more than 70 percent of world production was produced in countries where the real product prices fell (Mundlak, 2000, 3).

Growth in agricultural trade exceeds output growth. Periods of slowdown in the growth of agricultural trade, like happened in 1980s and again in the late 1990s intensify the debate about the degree of distortion of the agricultural policies of the WTO member states. High producer prices and the general absence of production controls in Europe have been of particular concern to the United States as the EU, at the cost of substantial export subsidies, emerged to a net cereals exporter (Bouchet *et al* 1989). With the Uruguay Round agreement on agriculture, the trade conflicts between the main world exporters seems to have been balanced, but with the new Doha Round now going on, still there remain two fundamentally different views on the sources of growth in EU agriculture. According to the European view, output growth resulted mainly from 'autonomous' factors like technological change and structural policies. In this perspective price support has not been very distortive, and reducing price support can only have a limited impact on output. According to the alternative view, held by the US and the CAIRNS group, growth has been created by artificially high prices. As a consequence, EU agriculture is seen as cost-noncompetitive. Reducing the price support is expected to have large effects on the EU's agricultural output, investment and input use. With the MacSharry reform (1992) and the acceptance of de-coupling in the Midterm Review (2004) the EU gives in and reduces its distortive price support.

Bouchet *et al* (1989) tried to address this issue of conflicting views on the EU's growth of agricultural output by evaluating the long run changes (1960-84) in French agriculture. Their results suggest that technological change is the dominant factor explaining output growth. Moreover, they find that output is price responsive, but more so in the long run than in the short run, but that price responses are inelastic, even when capital and (family) labor optimally adjust. A similar result was found by Lopez (1985), who analyzed the short, intermediate and long-run supply responses of the Canadian food processing industry. The weakness of the Bouchet et al (and Lopez) paper is not their methodological approach, but rather their ignorance of non-stationarity in the data, which since the mid 1980s has been regarded as one of the main issues in empirical modelling (Charemza and Deadman, 1997). As is well known now, the statistical properties of regression analysis using non-stationary time series are dubious: if series are non-stationary one is likely to finish up with a model showing promising diagnostic test statistics even when there is no sense in the regression analysis.

This paper provides an analysis similar to that of Bouchet *et al* (1989), focusing on the Netherlands, which takes into account the non-stationarity issue and tries to use an adjusted estimation procedure. Our results indicate that in general data series like those used by Bouchet *et al* are non-stationary. However, it appears that even when accounting for non-stationarity, the final results obtained by Bouchet *et al* for France remain valid, at least when seen from a Dutch perspective.

The aim of this paper is to analyze the long-term evolution of Dutch agriculture. The basic question to be answered is what caused the output growth. Is it coming from a combination of high price support and high price sensitivity of agricultural supply? Or are Bouchet *et al* right when they argue that price support has hardly influenced output growth and is therefore hardly 'distortionary'? If price support is not distortionary in a direct way, is it then not still 'distortionary' in an indirect way? And how significant is this indirect impact on agricultural output? Finally, what conclusions can be drawn from analyzing the long-term evolution of Dutch agriculture for the current policy debate, in particular with respect to the issue of decoupling of support?

The remainder of the paper is organized as follows: Section 2 provides a brief description of the main developments in Dutch agriculture since the 1950s. The model specification is presented in Section 3. Section 4 gives a revised model, corrected for the non-stationarity found in the data and the cointegration problems occurring when estimating the model in levels. Section 5 provides a detailed discussion of the estimation results. Section 6 closes with the main conclusions and suggestions for further research.

Long term development of Dutch agriculture

The Dutch agricultural sector (including horticulture) has been experiencing a tremendous development since the World War II. As Table 1 shows, since the 1950s gross output has increased with a factor 4.4, whereas the input of labor and land declined with 36 and 16 percent respectively. In general output growth was strongest in those sectors where production was not or only loosely tied to land (pigs, poultry). The input of capital and purchased inputs (e.g. energy, fertilizer, animal feed produced elsewhere, services) increased with a factor of 2.4 and 5.0 respectively. Since the mid-1980s the amount of purchased inputs more or less stabilizes (decoupling).

Over the period 1950-2000 the number of farms has decreased with 218 thousand, or about 70%. At the same time gross output per farm increased with a factor 14.4, whereas the volume of capital input (excluding the value of land) and land used per farm increased with a factor of 8.0 and 2.6 respectively. As is reflected by output per hectare and the use of purchased inputs per hectare, agricultural production greatly intensified. Because the output growth exceeded domestic demand growth, the reliance on exports of Dutch agriculture increased over time. At his moment about 75% of the value added of the sector depends on exports, whereas 30 years ago this was less than 60% (Van Bruchem, 2001).

In the following the focus is on arable and animal (meat and dairy) production (excluding horticulture). The growth of livestock production has been much higher than arable production. Whereas land-based outputs (arable crops and dairy production) roughly tripled in the period 1950-96, production of the livestock sector in 1996 was nearly six times as large as in 1950. Since the late 1980s all outputs are stabilizing. In the dairy sector, where a quota system was introduced in 1984 output has actually declined during the last considered decade. Although the livestock sector (meat) is subject to a relatively light CAP support regime, it has shown a tremendous growth. The shares of arable, meat and milk in the total gross agricultural output value in 1995 are respectively 14, 63 and 23 percent, which underscores that Dutch agriculture is particularly strong in animal production (total output value share 86 percent).

Table 1. Structural development of Dutch agriculture 1950-2000

	Unit	1950	1960	1970	1980	1990	2000
Number of farms	x1000	315	284	185	145	125	97
Labor	1000 AJE	550	437	290	235	215	198
Land	x 1000ha	2328	2317	2143	2020	2006	1956
Capital	index	100	103	129	178	196	237
Purchased inputs	index	100	189	302	453	491	496
Gross production	index	100	141	206	317	408	442
Labor/farm	AJE/farm	1.75	1.54	1.57	1.62	1.72	2.04
Land/farm	ha/farm	7.4	8.2	11.6	13.9	16.0	20.2
Output/farm	index	100	156	350	688	1031	1438
Capital/farm	index	100	119	226	404	512	798
Output/ha	index	100	141	223	363	472	524
Purchased inputs/ha	index	100	189	328	521	568	591

Source: Van Bruchem (2001).

With respect to the input side, labor input has been substantially reduced. For hired labor the decline took largely place in the period 1950-1973, after which it stabilized and since the mid-1980s even slightly starts to increase again. In contrast, family labor shows a continuous decline, which since the late 1980s outpaces the hired labor decline. The amount of aggregated output per unit of aggregated labor showed a strong and steady increase since the early 1960s, with the 'labor productivity' in 1996 being nearly 12 times as large as in 1950. The decline of labor input (aggregate labor input declines by 62%) was compensated for by an increase in the input of capital. The capital stock increased with 110% in the period 1950-1985, after which it started to slowly decline.

Fertilizer input showed a strong increase in the period 1950-1985 (+115%), but a strong decline thereafter. The level of (total) fertilizer input in 1996 was only 1.4 times as large as in 1950. Fertilizer use per unit of output was more or less stable over the period 1950-1967, but started to decline thereafter. In 1996 the amount of fertilizer used per unit of output was 63% below the 1950-level. The use of fertilizer per unit of land (arable and pasture) increased in the period 1950-1983 (+176%), after which it started to decline (1983-1996: -40%). The strong increase in the intensive livestock production and its heavy reliance on purchased compound feeds, is reflected in the feed use, which in 1985 and 1986 was more than ten times as large as in 1950.

The quasi-fixed land input is rather stable and slowly declining over time. In 1996 it has declined by 17 percent as compared to 1950. Land productivity substantially increased: over the period 1950-1996 the arable output per unit of arable land and the dairy output/unit of grassland increased by 260 and 300 percent respectively.

All output prices (normalized by price of fertilizers) are highly fluctuating over time. The price for arable output fluctuated, but did not show a particular trend[1]. Partly this will be due to the fact that the arable output price and the feed price by which it is normalized contain a lot of common elements (in particular shared coarse grain prices). The (normalized) milk price showed a downward trend until the early 1980s, after which it started to strongly increase until 1989. After 1989 the milk price increase stagnated. The introduction of the milk quota in 1984 and the policy reforms in the arable sector (price declines for coarse grains) have improved the milk/feed price-ratio. The meat/feed price-ratio showed strong fluctuations, and reached its highest values in the early 1970s. It seems that there has been a level shift in 1958, after which the price-ratio fluctuated about 1.2 times its 1950-value. The strongest input price increase has been the price increase of hired labor. It showed a strong increasing trend until 1980, followed by stagnation in the early 1980s and a downswing in the second half of the 1980s.

Figure 1 gives the public expenditures for research and development on agriculture by the Dutch government. The Netherlands is famous for its so-called *OVO-drieluik*, the integrated schooling, extension services and research framework. This coordinated network is said to have contributed a lot to the increase in the human capital of the farmers, to provide farmers with good information about innovations and the potential benefits when applying them to their specific farm situation (Roseboom and Rutten, 1998; *cf.* Alston, Norton and Pardy (2002) for a similar result for the US). Moreover it stimulates the development of new innovations, which may partly come from spin-offs of breakthroughs elsewhere in the Dutch economy or in the international agricultural sphere. As a consequence the public expenditure on R&D could be well treated as an investment-variable, leading to the build up of a ‘capital stock’ of innovations and farmer skills. For this reason Figure 1 not only shows the annual investments in agricultural R&D, but also the accumulated value or the ‘capital stock’ it creates. It is assumed that new expenditures increase the stock and may have effects lasting longer than one year. At the same time new investments may create new knowledge and improved practices, which make part of the old knowledge obsolete. Therefore also a 4% depreciation factor is applied to the public R&D ‘capital stock’.

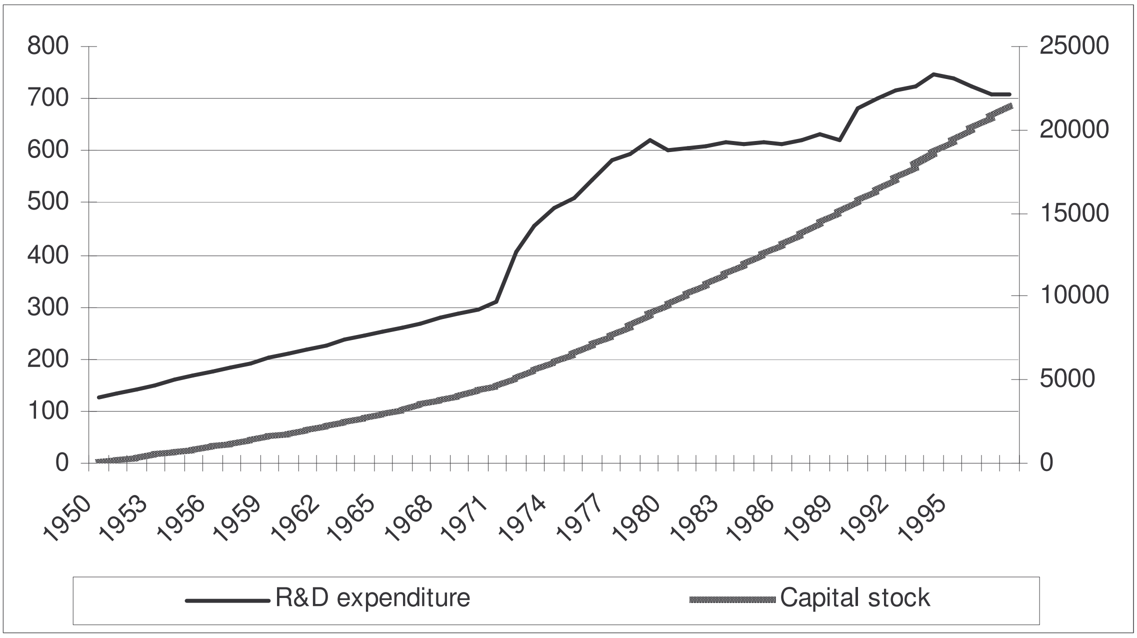

Figure 4 Public R&D expenditures and ‘capital’-formation in Dutch agriculture
Source: Based on Roseboom and Rutten, 1998 and own estimates

Model and specification

Output and input price responsiveness in agriculture has been widely analyzed using a dual (restricted) profit function approach (Chambers, 1988). The impact of public research expenditures on agricultural output has been analyzed within the context of a primal production function approach (see for example Fulginiti and Perrin, 1993). In this study a profit function framework which accounts for R&D expenditures is chosen.

Following Bouchet *et al* (1989) let the short-run restricted profit function be $\prod = \prod(P, Z, W)$, where P is a vector of the expected output and variable input prices (P_i: i=1,…,m), Z is a vector of the quasi-fixed inputs (Z_j: j=1,…,n), and W is a vector of the fixed inputs and exogenous factors. (W_k: k=1,…,s). Let R be a vector of market prices of the quasi-fixed inputs (R_j: j=1,…n). At a long-run optimum, the partial derivatives of the restricted profit function with respect to the quantities of the quasi-fixed inputs (shadow prices) are equal to their long-run equilibrium market prices:

$$R_j = \frac{\partial \prod}{\partial Z_j} = Z_j(P, Z, W) \qquad (1)$$

By solving equations (1) for the optimal Z_j’s, the long-run, profit maximizing levels of the quasi-fixed inputs, Z*=Z*(P,R,W) can be derived.

Using relationships among the derivatives and Hessian matrices of the restricted and unrestricted profit functions (discussed by Lau and others), long-run output and variable input demand function and the associated elasticities can also be obtained. Using these elasticities, the long-run effects of research as well as pricing and other government policies can be assessed. Empirical derivation of the long-run results from an estimated short-run variable profit function is facilitated when specifying it to be a normalized quadratic function. The advantage of this functional form is that closed-form expressions can be derived for the optimal levels for the quasi-fixed factors. The quadratic specification of the short-run profit function is:

$$\begin{aligned}\Pi = \beta_0 + \sum_i \alpha_i P_i + \sum_j \mu_j Z_j + \sum \delta_k W_k \\ + \frac{1}{2}\sum_i \sum_{i'} \lambda_{ii'} P_i P_{i'} + \frac{1}{2}\sum_j \sum_{j'} \gamma_{jj'} Z_j Z_{j'} + \frac{1}{2}\sum_k \sum_{k'} \chi_{kk'} W_k W_{k'} \\ + \sum_i \sum_j \eta_{ij} P_i Z_j + \sum_i \sum_k \phi_{ik} P_i W_k + \sum_j \sum_k \theta_{jk} Z_j W_k\end{aligned} \tag{2}$$

Taking the partial derivative with respect to output/ variable input prices (Hotelling's Lemma) of this profit function, the short-run output supply and variable input demand functions are then:

$$\pm Q_i = \frac{\partial \Pi}{\partial P_i} = \alpha_i + \sum_{i'} \lambda_{ii'} P_{i'} + \sum_j \eta_{ij} Z_j + \sum_k \phi_{ik} W_k \qquad i = 1, \ldots, m, \tag{3}$$

Where the sign modifier of Q_i is positive for an output supply equation and negative for a variable input demand equation. Equations (1) are linear and can be solved readily for the Z^*_j. When capital (j=K) and family labor (j=L) are assumed to be quasi-fixed, their optimal levels are:

$$\begin{bmatrix} K^* \\ L^* \end{bmatrix} = \frac{1}{\Delta}\begin{bmatrix} \gamma_{LL} & -\gamma_{KL} \\ -\gamma_{LK} & \gamma_{KK} \end{bmatrix}\begin{bmatrix} R_K - \mu_K - \sum_i \eta_{iK} P_i - \sum_k \theta_{Kk} W_k \\ R_L - \mu_L - \sum_i \eta_{iL} P_i - \sum_k \theta_{Lk} W_k \end{bmatrix} \tag{4}$$

where $\Delta = \gamma_{KK}\gamma_{LL} - (\gamma_{KL})^2$. Defining the partial derivatives of the optimal capital and labor equations as:

$$\delta_{KP_I} \equiv \frac{\partial K^*}{\partial P_i} = -\frac{1}{\Delta}(\gamma_{LL}\eta_{iK} - \gamma_{KL}\eta_{iL}) \qquad i=1,\ldots, m$$

$$\delta_{KW_k} \equiv \frac{\partial K^*}{\partial W_K} = -\frac{1}{\Delta}(\gamma_{LL}\theta_{Kk} - \gamma_{KL}\theta_{Lk}) \qquad k=1,\ldots, S$$

$$\delta_{LP_i} = \frac{\partial L^*}{\partial P_i} = -\frac{1}{\Delta}(\gamma_{KK}\eta_{iL} - \gamma_{LK}\eta_{iK}) \qquad i=1,\ldots, m$$

$$\delta_{LW_k} = \frac{\partial L^*}{\partial W^*} = -\frac{1}{\Delta}(\gamma_{KK}\theta_{Lk} - \gamma_{LK}\theta_{Kk}), \qquad k=1,\ldots, S.$$

The long-run output supply and variable input demand functions can be expressed as:

$$\begin{aligned}\pm Q_i^* = \alpha_i + \sum_{i'} (\lambda_{ii'} + \eta_{i'k}\delta_{kp_i} + \eta_{i'l}\delta_{lp_i}) P_{i'} + (\mu_k \delta_{kp_i} + \mu_l \delta_{lp_i}) - \delta_{kp_i} R_k - \delta_{lp_i} R_l \\ \sum_k (\phi_{ik} + \theta_{kk}\delta_{kw_k} + \vartheta_{lk}\delta_{lk_k}) W_k\end{aligned} \tag{5}$$

Note that equation (5) accounts for the additional impacts of prices on output and variable inputs (price slopes are adjusted as compared to (3)) through capital and family labor adjustment. Moreover,

Q_i has now become a function of the prices of the quasi-fixed inputs capital and (family) labor, whereas also the intercept term (see the second right hand side term between brackets) and the coefficients for the exogenous factors (see the term associated with W_k) have been changed in comparison with the short-run equations (3).

A complication in the model discussed above is how to handle the introduction of the milk quota in 1984. Within the theoretical framework the rationing of milk output implies that that instead of the price of milk the quota restriction becomes an explanatory variable. Moreover, microeconomic theory indicates that imposing a constraint on one output in a multiple output technology will lower the supply elasticities of the unregulated outputs (Le Chatelier/Samuelson effect). Bouchet *et al* (1989) simply ignore the introduction of the milk quota, whereas Oskam (1992) based his empirical estimates on the pre-quota period only. Jongeneel (2000, 167-188) took the after 1984-period as a starting point and assumed a cost minimization approach with milk quantity as a quasi-fixed output variable, whereas the endogeneity of milk output in the pre-quota period is accounted for by relying on an instrumental variable estimator. The ideal approach would be to combine a profit maximization and cost minimization model, taking into account the relationships between the two models (*cf*. Fulginiti and Perrin, 1993). Although in theory possible, following this procedure one ends up with a highly non-linear model which is difficult to estimate. In this study we choose a relatively simple 'solution' by respecifying the milk output supply equation (3) in an ad hoc way as

$$Q_i \approx \alpha_i + \sum_{i' \neq milk} \lambda_{ii'} P_{i'} + DUM^{quota} \lambda_{i,milk} P_{milk} + \sum_j \eta_{ij} Z_j + (1 - DUM^{quota}) \vartheta \bar{Q}_{milk} + \sum_k \phi_{ik} W_k \qquad i = \text{milk} \qquad (3')$$

where DUM^{quota} represents a dummy variable which has the value of 1 in the pre-quota period and the value 0 from 1984 and onward. $\bar{Q}_{milk}$ is the quota level, and ϑ the parameter associated with the quota variable.

Estimation

Data series and stationarity

In our analysis, outputs are real value of gross arable production and real value of milk and meat production. Hired labor, fertilizer, and feed are variable inputs, the quantity of which is represented by its real value. Family labor is seen as quasi-fixed inputs, as well as capital investments (buildings and equipment). "Quasi-fixed" means they are fixed inputs in the short-run but variable and chosen optimally in the long run. Investment in land consolidation and total expenditure on agricultural R&D are defined as fixed inputs as they are exogenously given. To take into account of the accumulation and depreciation effect of the R&D expenditure, we use the lagged sum of annual expenditure and the discounted total expenditure from year 1949 until the previous year as a proxy. The variables used in the estimation are listed in Annex A, which also provides some descriptive properties. To impose homogeneity, prices are normalized with fertilizer price, and consequently the equation for fertilizer was dropped out. A big event that is likely to have had an impact on agricultural production was the introduction of (binding) milk quota in 1984.

In order to investigate the time series properties of the data, the Augmented Dickey Fuller test was performed to identify the order of integration of the (individual) variables involved in the postulated long run relationships. As is shown in Table 2 all series appear to be non-stationary and integrated of order 1. As such this emphasizes that it is highly relevant to take the time series properties into account in long term growth of agricultural output analysis[2].

Table 2. Augmented Dickey-Fuller Test for the variables in the model (1949-1997)

Variable	Level						First Difference		Order of integration
		Test statistic[a]	Critical Value			Test statistic[a]	Critical Value		
			1%	5%			1%	5%	
GPAR	CTL[a]	-3.096	-4.163	-3.507		-11.325	-2.611	-1.948	I(1)
MEATR		1.337	-2.611	-1.948		-2.830	-2.611	-1.948	I(1)
MILKR	C	-1.462	-3.571	-2.923	C	-5.470	-3.575	-2.924	I(1)
FERTR	C	-2.123	-3.571	-2.923		-6.000	-2.611	-1.948	I(1)
LAB3	CL	-2.687	-3.575	-2.924	C	-3.435	-3.575	-2.924	I(1)
NGPAP	L	-0.130	-2.612	-1.948	L	-10.140	-2.613	-1.948	I(1)
NMEATP		0.230	-2.611	-1.948	L	-8.138	-2.613	-1.948	I(1)
NMIKLP	CT	-2.183	-4.158	-3.505		-6.673	-2.611	-1.948	I(1)
NLAB3P		-0.134	-2.611	-1.948		-9.694	-2.611	-1.948	I(1)
NFERTP	C	-2.721	-3.571	-2.923		-7.022	-2.611	-1.948	I(1)
DCRDEXP	CTL	-2.333	-4.163	-3.507		-3.454	-2.611	-1.948	I(1)
ARABL	L	-0.938	-2.612	-1.948		-4.753	-2.611	-1.948	I(1)
GRASS	C	1.864	-3.571	-2.923	C	-5.093	-3.575	-2.924	I(1)

[a] The letter(s) C or CT indicate whether that test contained a constant or a constant plus a linear time trend. The letter L indicates that lagged value was included to exclude serial correlation

Estimation procedure

The model was estimated using a two-step estimation procedure. Firstly, the short-run system of output supply and variable input demand equations (3) was estimated. Secondly, the remaining undetermined parameters of the profit function were estimated, by regressing a 'corrected profit variable' on the remaining variables, or (cf. Bouchet et al, 1989).

$$\bar{\Pi} = \beta_0 + \sum_j \mu_j Z_j + \sum \delta_k W_k + \frac{1}{2}\sum_j \sum_{j'} \gamma_{jj'} Z_j Z_{j'}$$
$$+ \frac{1}{2}\sum_k \sum_{k'} \chi_{kk'} W_k W_{k'} + \sum_j \sum_k \theta_{jk} Z_j W_k \qquad (6)$$

The estimation of (6) provides estimates for the $\gamma_{jj'}$ and θ_{jk} parameters, that are necessary to determine the long run price responses (see equation (4)).

As stated before, non-stationary series leads to spurious correlation characterized by over excitingly high R-squares, low Durbin Watson-statistics and non-stationary residuals. This was confirmed by the results found when estimating the model with the variables in levels following the procedure described above. Even with cross equation restrictions for symmetry imposed, the R^2's are all above 0.96. Some own price reactions were in conflict with economic theory. When we calculated the elasticities the order of magnitude was rather similar to Bouchet et al. (1989). The price sensitivity of agricultural output and input was found to be low. The Augmented Dickey Fuller (ADF) test statistic was calculated to check for stationarity of the residuals[3]. For arable and meat the null hypothesis is rejected at a 5% of significance level, implying no presence of cointegration. For the other variables a unit root could not be rejected. Instead of estimating the model in levels, therefore the model is re-specified in differences. Since all variables appeared to be integrated of order 1, they follow a difference stationary process and first differencing of the variables will generate stationary series.

Firstly, the system of supply and demand equations (3) was redefined in first-difference form. As can be seen from (3) the original intercept α_i will cancel out

$$\pm\Delta Q_i = \alpha_i^* + \sum_{i'} \lambda_{ii'} \Delta P_{i'} + \sum_j \eta_{ij} \Delta Z_j + \sum_k \phi_{ik} \Delta W_k \qquad i = 1, \ldots, \text{m}^3, \tag{7}$$

A constant was added to account for a technology-shifter (replacing the linear trend variable in the levels-model). (Estimation results are available upon request from the authors). As compared to the levels version of the model, goodness of fit has been substantially lowered (in particular for the arable supply function). The goodness of fit for the arable, meat, milk, hired labour, and fertilizer equations are respectively 0.11, 0.64, 0.41, 0.32 and 0.45, which are still satisfactory given that the model is now in first differences[4]. All parameters associated with own price responses have the appropriate sign, and 4 out of 5 were significant. Evaluating the t-values, 22 out of 42 two parameters are significant. The significance levels of the price (and other) parameters have declined in comparison with estimating the same model in level-terms. This confirms the problems with non-stationarity (but no cointegration) in the levels model, which is known to lead to overstated R-square and t-values.

In order to determine the long-run elasticities, the remaining part of the profit function was estimated. Firstly, however, (see equation 6) the equation had to be respecified in terms of first differences as

$$\Delta\overline{\Pi} = \sum_i \alpha_i \Delta P_i + \sum_j \mu_j \Delta Z_j + \sum \delta_k \Delta W_k$$
$$+ \frac{1}{2}\sum_j \sum_{j'} \gamma_{jj'} \Delta(Z_j Z_{j'}) + \frac{1}{2}\sum_k \sum_{k'} \chi_{kk'} \Delta(W_k W_{k'}) + \sum_j \sum_k \theta_{jk} \Delta(Z_j W_k) \tag{8}$$

and where $\overline{\Pi}$ differs from $\overline{\prod}$ because it includes as an additional term $\sum_i \alpha_i P_i$. The estimation yields a high goodness of fit, which is exceptional for a model estimated in first differences. Also the Durbin Watson statistic is reasonable, indicating that autocorrelation is not a serious problem. Crucial parameters with respect to generating the long-run elasticities are γ_{KK}, γ_{LL} and γ_{KL}. Although all three parameters have a plausible sign (γ_{KK} and γ_{LL} should be non-positive), only γ_{LL} is significantly different from zero.

Discussion

The associated short-run price and fixed factor elasticities are given in Table 3. In comparison with the levels version of the model, as well as in comparison with the elasticities found for France in the Bouchet *et al* study, the own-price responses are very low. With exception of the own price responses for meat and fodder, all absolute own price elasticities are smaller than 0.1 and in 3 out of 6 cases even below 0.05. As such our results confirm the results found for the period 1949-1983 by Oskam (1991, 68). With respect to arable and dairy farming the connectedness to land (ARABL and GRASSL) is clear. This is not only reflected in the significant (positive) production elasticities, but might also explain the low own price responses and non-significant cross price elasticities between both sectors. Arable land and pasture land have both a rather permanent character in the Netherlands and operate as stable quasi-fixed factors. Meat production, which is less connected to land, has the highest relative own price response (0.133), although it is still highly inelastic. Non-surprisingly, meat output shows the most pronounced sensitivity with respect to feed price. Depending on the type of meat production, feed costs can have a share up till 70% of total production costs.

Table 3 Price and factor elasticities short-run model (standard errors between brackets)

dependent			**quantities**			
explanatory	**GPAR**	**MEATR**	**MILKR**	**LAB3**	**FERTR**	**FODR**
GPAP	0.007	0.083	-0.044	-0.008	0.015	0.087
	(0.953)	(0.082)	(0.350)	(0.849)	(0.849)	NA
MEATP	0.261	0.133	0.090	0.029	-0.117	0.376
	(0.082)	(0.311)	(0.262)	(0.506)	(0.356)	NA
MILKP	-0.096	0.062	0.063	0.132	-0.108	0.103
	(0.350)	(0.262)	(0.613)	(0.087)	(0.356)	NA
LAB3P	0.001	-0.026	-0.004	-0.007	0.009	-0.004
	(0.849)	(0.624)	(0.087)	(0.670)	(0.473)	NA
FERTP	0.004	0.011	0.015	0.038	-0.047	0.028
	(0.849)	(0.356)	(0.489)	(0.473)	(0.728)	NA
FODP	-0.211	-0.287	-0.114	-0.135	0.232	-0.602
	NA	NA	NA	NA	NA	NA
FAMILYLAB	-0.451	0.226	-0.839	1.657	-1.070	-0.662
	(0.724)	(0.813)	(0.155)	(0.000)	(0.215)	(0.243)
CAPR	0.792	1.970	0.007	0.134	0.670	1.113
	(0.296)	(0.001)	(0.069)	(0.576)	(0.189)	(0.003)
ARABL	0.764			-0.022	-0.549	
	(0.382)			(0.937)	(0.350)	
GRASS		-0.995	0.782			-0.189
		(0.387)	(0.255)			(0.267)
CDRDEXP	-0.194	-0.247	0.499	0.070	0.749	0.439
	(0.765)	(0.616)	(0.093)	(0.728)	(0.090)	(0.267)
QQUOTA			-0.007			
			(0.836)			

Feed input has a relatively high own price demand elasticity (-0.602), although it is still inelastic. The availability of relatively low priced compound feedstuffs in comparison with other EU countries because of the nearly zero import tariffs on cereal substitutes and the good seaport access (the so-called “gate of Rotterdam”) heavily contributed to the growth of the Dutch meat production sector. The positive cross price elasticities between milk and meat output reflect the complementarity between both outputs. This confirms the importance of the dairy cow stock in beef and veal production, and the significant share of beef and veal in total Dutch meat output. Although the cross price elasticities between milk and arable output are not significantly different from zero, their signs suggest that they are competing sectors. Fertilizer prices appear to have no significant impact on any of the outputs. The price range in which fertilizer prices are varying is not influencing its optimal allocation. Fertilizer application is most likely to be determined by what is optimal from an agronomic point of view (see literature about Von Liebig hypothesis, for example Paris, 1992).

Some interesting results are found with respect to expenditure on research and development and the capital input in agriculture. Jointly they play an important role in explaining the evolution of agricultural outputs and fertilizer input (cf. Ahearn, Yee and Huffman (2002: 17) for a similar finding for the US). With respect to arable output capital plays a significant role, but research and development expenditure is not significant. This suggests that technical progress in the arable sector has mainly come from capital goods, and their improved quality over time. The impact of improved crop varieties on increased yields (genetic progress), which was expected to show up in the coefficient for the R&D variable could not be detected. However, this effect is indirectly captured by the positive impact of R&D expenditure on fertilizer usage. The genetic progress favored higher yielding crops, which for the realization of their genetic potential relied on increasing fertilizer input. A similar effect of R&D expenditure was found with respect to feed usage. An increase in R&D expenditure increases the use of feed. This again suggests that the progress generated by R&D expenditure has been mainly affecting genetic progress in milk yields and meat growth efficiency (feed conversion rates). This lead to an improved output price-feed cost ratio, which in turn improved the competitive position of Dutch agriculture. It explains why an improved feed efficiency ultimately leads to an increased feed use (although the feed input per unit of output significantly declined). Likewise in the arable sector, also with respect to meat output the role of the capital stock is dominating, whereas the contribution of R&D expenditure is non-significant. Non-family labor has no significant response to any of the price variables or quasi-fixed variables.

Table 4 Long-run elasticities (standard errors between brackets)

dependent	Quantities					
explanatory	GPAR	MEATR	MILKR	LAB3	FERTR	FODR
GPAP	0.0108	0.0848	-0.0447	-0.0006	0.0310	0.0904
	(0.0550)	(0.0159)	(0.0308)	(1.3742)	(0.2452)	(0.0228)
MEATP	0.2730	0.0959	0.1159	-0.1088	-0.1222	0.3365
	(0.8740)	(0.2526)	(0.4899)	(21.8368)	(3.8970)	(0.3618)
MILKP	-0.0972	0.0780	0.0178	0.1149	-0.0956	0.0917
	(0.1485)	(0.0429)	(0.0833)	(3.7112)	(0.6623)	(0.0615)
LAB3P	0.0003	-0.0158	-0.0036	-0.0084	0.0117	-0.0031
	(0.0002)	(0.0001)	(0.0001)	(0.0055)	(0.0010)	(0.0001)
FERTP	-0.0089	0.0093	0.0130	0.0504	-0.0273	0.0209
	(-0.2200)	(-0.2595)	(-0.1028)	(-0.0589)	(0.1802)	(-0.5496)
FODP	-0.2202	-0.2595	-0.1028	-0.0548	0.1810	-0.5496
	(0.3921)	(0.1133)	(0.2198)	(9.7971)	(1.7484)	(0.1623)
OCCAP*	0.0990	-0.1177	0.0390	0.4267	-0.3679	-0.1441
	(38.1071)	(47.1736)	(29.9993)	(43.0062)	(35.7406)	(45.2475)
OCLAB*	-0.0001	-0.0001	0.0000	0.0000	0.0000	0.0001
	(0.0069)	(0.0082)	(0.0064)	(0.0092)	(0.0076)	(0.0084)
ARABL	0.5908			1.5759	0.3635	
	(0.0416)			(1.0405)	(0.1857)	
GRASS		-1.3002	0.2281	-0.4349	1.6333	-0.3777
		(0.0163)	(0.0316)	(1.4095)	(0.2515)	(0.0234)
CDRDEXP	-0.1408	-0.6052	0.2464	-0.1122	0.3586	-0.1207
	(0.0038)	(0.0011)	(0.0022)	(0.0959)	(0.0171)	(0.0016)
QQUOTA			-0.0053			
			(0.0005)			

*) Price elasticities for other capital (OCCAP) and non-family labor (OCLAB); for fixed land inputs, R&D expenditure and milk quota still quantity-elasticities are presented.

As was indicated in equation 7 also when the model was re-formulated in first-differences a shift-variable (see constant α_i^*). This parameter is likely to pick up the trend in the first difference of the dependent output and input variables (rate of change in output and input levels) not explained by (the differences in) the other explanatory variables. As such this parameter may also pick up changes in the quality of the explanatory variables. This seems in particular relevant with respect to the capital and R&D variables. However, the constants are in no case significantly different from zero.

Table 4 presents the long-run elasticities. With respect to the price responsiveness not much has changed as compared with the short-run. As is expected from the Le Chatelier-Samuelson theorem, the long-run price responsiveness is not lower than in the short-run (Chambers, 1988, 145-149). The increase in price sensitiveness of agricultural output and input is however very limited: the deviation between the derived long-run and short-run own price elasticities is in all cases less than 2 percent. This is further emphasized by the significance levels. Because the elasticities are highly non-linear in the estimated parameters (see for example equation 4), standard errors were simulated using Monte Carlo-analysis[5]. All own price elasticities, except for the own price response of feed input, appear to be not significantly different from zero. Except for the labor input equation, the average deviation of all short-run own-price and cross-price elasticities as compared to the long-run ones is less than 5 percent. The simulated standard deviations for OCCAP have rather extreme values and require futher analysis.

Some analysis was done with respect to the relative contribution of the explanatory variables in the evolution of agricultural outputs. The normalized arable price increased by 13 percent over the 44-year period 1950-53 till 1994-1996, but contributed only to a 0.14 percent increase in arable output. As compared to the other explanatory variables, the (normalized) own price increase for arable products explained about 0.2 percent. The remaining 99.8 percent of explained arable output growth was accounted for by the other variables. Similar percentages were found for meat and dairy output. Looking to the average own price contribution to output growth its relative contribution is less than 3%, with thus 97 percent of the explained output growth accounted for by the other explanatory variables. It are the quasi-fixed variables rather than (relative) prices which are explaining output growth. Strange enough the contribution of research and development expenditure is negative for arable and meat. However, when combining research and development and the capital stock, into an effective or quality-corrected capital contribution (embodied technical change) the impact on output growth in the arable, meat and dairy sectors is 27%, 23% and 124% respectively.

Conclusions

In this paper a restricted dual profit function approach is used to get insight into which are the factors (prices, quasi-fixed factors, public R&D expenditure) which explain the growth in agricultural output for the arable, intensive livestock and dairy sector in the Netherlands. The analysis is based on aggregated time series covering the period 1950-1996. Because these series, even after normalization appeared to be non-stationary, the standard approach of estimating the profit system in levels, as was for example applied by Bouchet *et al* (1989) and Oskam (1992), is no longer valid. In this paper estimation was in first differences, which solved the time series non-stationarity problems. It is found that the supply of arable, intensive livestock (meat) and dairy products are price responsive, but the response of output to price changes appears to be highly inelastic. As such our results support the conclusion drawn by Bouchet *et al* (1989: 292) that the persistence of high support prices due to the EU's common agricultural policy (CAP) has only slightly increased agricultural output as compared to a no-price support policy. As a consequence no big downward adjustments in output have to be expected from policy reforms which decrease price support (*viz.* MacSharry reform, 1992 and Agenda 2000, 1999) or aim for de-coupling (Midterm Review).

However, with price support having only a small direct effect, it is argued that there is likely to be a significant indirect effect. This indirect effect goes via the relatively increased revenues due to price support, which lead to increased savings and subsequently to increased investments. These investments have a significant impact on productive capacity and the growth of this capacity. In general there seems no reason to believe that when price support is replaced by direct income payments, this mechanism of using 'surplus' profits for investments in the capital stock will change. The origin of these 'surplus profits', *viz.* whether they come from coupled or decoupled payments is not likely to have much impact.

Although the capital stock is subject to depreciation, this 'capacity' impact of price support seems to have a kind of a 'rachet-effect'. Once done, investments keep their impact on agricultural output, even under adverse market conditions. The over time increase of the capital stock helped to meet the resource endowments of the Netherlands, where labor costs are relatively high and land is relatively scarce. Investment in the capital helps to ease the labor and land scarcity, and by contributing to high labor and land productivity growth rates, it sustained the competitive position of Dutch agriculture. The relatively high and increasing labor productivity outside agriculture creates a continuous pressure on agriculture to also cope with this non-agricultural productivity increase. Therewith agriculture can secure some kind of income parity, or at least avoid falling behind the general income evolution in the Dutch economy.

Public research and development (R&D) expenditures appear to affect agricultural output mainly by influencing biological or genetic progress. This leads to a (price-independent) increase in crop yields and milk output per cow. To realize the improved biological potential increased amount of variable inputs (fertilizer, feed) are required. As a result production has become more intensive in these inputs as would have been the case when the government would not have supported research and development in agriculture. The reduction in public R&D money spent on agriculture during the recent years and its reallocation to non-traditional agricultural outputs is likely to have a negative effect on future output growth.

Finally some qualifications should be made with respect to our findings. A number of the estimated coefficients should be interpreted with caution because they were not significant. This study only takes public R&D expenditures into account and as such not accounts for R&D expenditures done by the private commercial sector (e.g. Huffman and Evenson (1993) for evidence to include both). Moreover, no convergence-term, accounting for the R&D impact generated by public and private R&D expenditures outside the Netherlands was included in the analysis (spill-in effects). Finally, the switch to quantity rationing in 1984 (introduction of milk quota) was 'solved' in an ad hoc way. These qualifications not only denote the limits of our research, but also imply suggestions for future research.

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Annex A. Variables abbreviation of the Model

ARABL = area of arable land
CAPLSN = capital in livestock
CAPLSP = capital in livestock price index
CAPLSR= capital in livestock
CAPN = nominal value of total capital invested
CAPP = price index of total capital invested
CAPR = real value of total capital invested
FERTN = fertiliser expenditure
FERTP = fertiliser price
FERTR= real fertiliser demand
FODN = feed input expenditure
FODP = feed input price index
FODR= feed input
GAS=1 after 1959, =0 before 1959.
GPAN = gross arable production value
GPAP = price index gross arable production
GPAR=
GPLIN = gross livestock production (incl. milk and eggs)
GPLIP = price index gross livestock production
GPLIR= real livestock production value.
GRASS = permanent grazing land area
INVBD = investment deduction for buildings (percentages)
INVBN = gross investment in buildings
INVBP = price index of investment in buildings
INVED = investment deduction for equipment (percentages)
INVEN = gross investment in equipment
INVER= real investment in equipment
INVEP = price index investment in equipment
INVRN = nominal investment in land consolidation
INVRP = investment price index land consolidation
INVRR= real investment in land consolidation
LAB1 = labour volume of farmers
LAB2 = labour volume of other family labour
LAB3 = volume of hired labour
LAB3P = wage cost per unit of hired labour
LAND = land area
MEATN= nominal output value of meat.
MEATP= price index for meat
MEATR= real output value of meat
MILKN= nominal output value of milk
MILKP= price index of milk
MILKR= real output value of milk
QUOTA = 0 before 1985, since 1985=1
RDEXP = total expenditure on agricultural R&D (million constant 1995 Dutch guilders).
CRDEXP= cumulated expenditure on agricultural R&D research
TR = trend variable (1949=1, 1950=2, etc.)
WEATH=weather index

End notes:

1. If we would have deflated the agricultural prices with a general CPI deflator, the real agricultural output prices would have shown all a downward trend, like in Bouchet et all (1989: 282).
2. Since the ADF test has low power against relevant trend stationary alternatives not necessarily all series have to be of the difference stationary-type (Maddala, 1992, 586). Moreover, the unit root might not have been rejected because of structural breaks in the data (Maddala, 1992, 587).
3. The test statistics for arable, meat, milk, labour and fertilizer were respectively -6.56, -5.03, -0.44, -3.03 and -3.65. Critical value at 5% significance level is -4.42 (Davidson and Mackinnon (1993).
4. For milk equation 3' was re-specified in first-differences.
5. The standard errors are based on 5000 drawings from the multinomial parameter distribution (done with @Risk5.4 software).