ADJUSTMENT COST AND PARTIAL ADJUSTMENT MODELS FOR GERMAN AGRICULTURE

von

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1 Introduction

In this paper we will try to empirically explain the movements of aggregate outputs and inputs in West German agriculture based on microeconomic theory. The standard approach for supply side modelling relies on profit maximizing behaviour, typically represented by an aggregate profit function as in GRINGS 1985. The technical details of this approach are continuously scrutinized and improved (recently: SCHOKAI, MORO 1996), but fundamental criticism has been raised: Individual decision makers are acting in an environment that is more complicated than implicit in the profit function framework (e.g. WITZKE 1993):

- imperfect labor and capital markets imply farm–household interdependencies;
- risk aversion can affect production levels and input composition;
- adjustment costs render the static framework inadequate.

Because we are focussing on the latter point in this paper we maintain strong assumptions regarding the first complication:

- The elasticity of total household labour supply is considered zero, leaving only the allocation of labour to agriculture or to the off-farm labour market as endogenous.
- The nominal interest rate is exogenous to agricultural households, i.e. a divergence of borrowing and lending rates and liquidity constraints are assumed away.

Uncertainty may receive a kind of reduced form treatment in an adjustment cost framework. We assume that uncertainty about the future economic environment causes decision makers to behave according to DAY's (e.g. 1976) "principle of cautious optimizing", but with a fuzzy "zone of flexible response". This may be shown to reduce to psychic adjustment costs (WITZKE 1993). Apart from this behavioural rule, the only consequence of uncertainty considered here is a continous revision of expectations. In each year, decision makers form "static" expectations for future prices that are taken to prevail indefinitely. Because they are not yet known at the beginning of the year, expectations for output prices are based on last year's values. Given expected prices, decision makers determine the long-run income maximizing solution and a sequence towards this goal. However, only the first step of this sequence is carried out because plans are revised next year based on revised expectations. Adjustment costs are likely to cause sluggishness in responses to changing incentives. In essence, we are introducing dynamics into the standard profit maximizing model.

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From a more policy oriented perspective, this paper is motivated by the controversy on whether the traditional "farm problem" issue of average factor income disparities between agriculture and nonagriculture can be explained by permanent or transitory phenomena. GARDNER (1992) and others seem to favour the first type of explanations, i.e. permanent non–market benefits of agriculture or low opportunity costs for a large portion of agricultural family labour. Instead of forming a sequence of static equilibria, apparent factor income disparities that persist over many years may be viewed also as a sequence of dynamic equilibria where the static equilibrium condition of equalized marginal factor incomes is never attained due to adjustment costs (WITZKE 1994, pp. 121–2). This paper checks whether aggregate time series data on German agriculture are consistent with this second interpretation of the "farm problem". However, an affirmative answer is not an empirical rejection of the first type of explanations, because this might imply similar dynamics when viewed from an aggregate perspective. A more direct test would have to operate on individual data sets (e.g. as in TSIGAS, HERTEL 1989).

The paper proceeds as follows: Section 2 develops the models to be estimated and compared. Section 3 gives a short sketch of the data used. Section 4 shows the results obtained and section 5 concludes.

2   Adjustment cost and partial adjustment models: theory

Dynamic duality theory (EPSTEIN 1981) is the easiest way to develop a theoretically consistent framework for estimation in an adjustment-cost framework. In this setting, producers are assumed to maximize the discounted stream of future profits that result from net sales of quasi–fixed "netputs" K (positive quantities for outputs, negative for inputs) at rental prices P and from net sales of variable netputs L at prices W:

(1) $J(K, P, W, Z) = \max_{\dot{K}} \{ \int_{t=0}^{\infty} (e^{-rt} \pi(W, Z, K, \dot{K} + \delta K) + P' K) \, dt \}$

with a momentary normalized restricted profit function:

(2) $\pi(W, Z, K, \dot{K} + \delta K) = \max_L \{ L_0(L, Z, K, \dot{K} + \delta K) + W' L \}$

and the symbols

K   = nx1 vector of quasi–fixed netput quantities;
$\dot{K}$ = gradient vector of K with respect to time t;
P   = nx1 vector of normalized rental prices of quasi–fixed netputs;
δ   = nxn diagonal matrix of depreciation rates;
r   = nominal interest rate;
Z   = qx1 vector of fixed factors;
W   = mx1 vector of normalized prices of variable netputs;
L   = mx1 vector of variable netput quantities;
L_0 = numeraire netput.

In the empirical application below, the vector of quasi–fixed netputs K will have the elements machinery, buildings and family labour. In this case the problem of asymmetric adjustment costs (see HSU, CHANG 1990) does not seem relevant, because gross investment is strictly positive and family labour is decreasing monotonically over the period investigated (1965–1992). Variable netputs in vector L will be animal outputs and operating

126

inputs including hired labour. The variable numeraire L_0 is plant production, i.e. all prices are normalized using the index of plant output prices W_0. Elements of the vector of "fixed factors" Z will be a constant, a linear time trend, total land and land squared, i.e. changes in total land for agriculture are assumed to be exogenously determined by urban growth. The time trend reflects technological change that is not anticipated. In this case, the Bellman equation associated with problem (1) is (LARSON 1989, WITZKE 1993):

(3) $rJ = \max_{\dot{K}} \{\pi(W, Z, K, \dot{K} + \delta K) + J_K \dot{K}\}$

After choosing an approximating functional form for J(.), we will differentiate (2) with respect to prices P and W and use the envelope theorem to derive the behavioural functions to be estimated. The value function J(.) is approximated with the well known normalized quadratic functional form as in several applications for US agriculture (e.g. BALL, SOMVARU, VASAVADA 1989, TSIGAS, HERTEL 1989), i.e.

(4) $J(K,P,W,Z) = \dfrac{1}{2}\begin{pmatrix} K' & P' & W' & Z' \end{pmatrix} \begin{pmatrix} A_{KK} & A_{KP}^{-1} & A_{KW} & A_{KZ} \\ A_{PK}^{-1} & A_{PP} & A_{PW} & A_{PZ} \\ A_{WK} & A_{WP} & A_{WW} & A_{WZ} \\ A_{ZK} & A_{ZP} & A_{ZW} & A_{ZZ} \end{pmatrix} \begin{pmatrix} K \\ P \\ W \\ Z \end{pmatrix}$

Matrix A may be chosen symmetric without loss of generality. Matrix A_{ZZ} is assumed zero except for the first row and column. Squared time and interaction terms between time and land are thus neglected to conserve degrees of freedom. Matrix A_{KK} is assumed zero as well, again to conserve degrees of freedom, but also to render J(.) quasi–homothetic in quasi–fixed netputs. This is a necessary condition for perfect aggregation (compare EPSTEIN, DENNY 1983; LUH, STEFANOU 1991). Due to the squared land terms, aggregation errors are not completely assumed away, but this "naive" specification proved nonetheless useful in other applications (see WITZKE 1996b). Differentiation of (3) with respect to P yields (using the envelope theorem):

(5) $r J_P' = K + J_{PK} \dot{K}^* \Leftrightarrow \dot{K}^* = J_{PK}^{-1} (r J_P' - K)$

and with (4), the discrete approximation $\dot{K}^* \approx K_t - K_{t-1}$ is given by

(6) $K_t - K_{t-1} = A_{PK} [r (A_{PK}^{-1} K_{t-1} + A_{PP} P_t + A_{PW} W_t + A_{PZ} Z_t) - K_{t-1}] \Leftrightarrow$
        $K_t = r A_{PK} A_{PP} P_t + r A_{PK} A_{PW} W_t + r A_{PK} A_{PZ} Z_t + ((1 + r) I - A_{PK}) K_{t-1}$

with I denoting the identity matrix of appropriate dimension. Differentiation of (3) with respect to W yields, proceeding in a similar way:

(7) $L_t = r (A_{WP} - A_{WK} A_{PK} A_{PP}) P_t + r (A_{WW} - A_{WK} A_{PK} A_{PW}) W_t$
        $+ r (A_{WZ} - A_{WK} A_{PK} A_{PZ}) Z_t + A_{WK} A_{PK} K_{t-1}$

Some final, rather tedious manipulations result in the numeraire equation that is also estimated (comp. EPSTEIN 1981, eq. (13)):

(8) $L_{0t} = r J - P_t' K_t - J_K \dot{K}_t - W_t' L_t =$
        $0.5 r Z_t' A_{ZZ} Z_t - 0.5 r P_t' A_{PP} P_t - r P_t' A_{PW} W_t - 0.5 r W_t' A_{WW} W_t$
        $- Z_t' A_{ZK} [r A_{PK} A_{PP} P_t + r A_{PK} A_{PW} W_t + r A_{PK} A_{PZ} Z_t - A_{PK} K_{t-1}]$

The system of netput supplies (6) to (8) may be rewritten in the "flexible accelerator" or "partial adjustment" form, expressing the present adjustment of netput supplies $X_t - X_{t-1}$ as a fraction of the deviation of last years quantities from the long run equilibrium $\bar{X}_t$:

$$\left(X_t - X_{t-1} \right) = \qquad D \qquad \left(\overline{X}_t - X_{t-1} \right) \qquad \text{or:}$$

(9)

$$\begin{pmatrix} L_{0t} - L_{0t-1} \\ L_t - L_{t-1} \\ K_t - K_{t-1} \end{pmatrix} = \begin{pmatrix} 1 & 0 & -Z_t{}'A_{ZK}A_{PK} \\ 0 & I & -A_{WK}A_{PK} \\ 0 & 0 & A_{PK} - rI \end{pmatrix} \begin{pmatrix} \overline{L}_{0t} - L_{0t-1} \\ \overline{L}_t - L_{t-1} \\ \overline{K}_t - K_{t-1} \end{pmatrix}$$

with long run equilibrium values found by setting $K_t - K_{t-1} = 0$:

(10) $\quad K_t = r (A_{PK} - r I)^{-1} A_{PK} (A_{PP} P_t + A_{PW} W_t + A_{PZ} Z_t)$

(11) $\quad L_t = A_{WK} A_{PK} K_t + r (A_{WP} - A_{WK} A_{PK} A_{PP}) P_t + r (A_{WW} - A_{WK} A_{PK} A_{PW}) W_t$
$\qquad\quad + r (A_{WZ} - A_{WK} A_{PK} A_{PZ}) Z_t$

(12)[1] $\quad L_{0t} = 0.5\, r\, Z_t{}' A_{ZZ} Z_t - 0.5\, r\, P_t{}' A_{PP} P_t - r\, P_t{}' A_{PW} W_t - 0.5\, r\, W_t{}' A_{WW} W_t$
$\qquad\quad + r\, Z_t{}' A_{ZK} K_t$

The flexible accelerator form (9) does not follow from the general model (1) of dynamic behaviour under adjustment costs. Instead it reflects insufficient flexibility of a second-order approximation of J(.), see EPSTEIN 1981. Richer specifications would have matrix D from (9) depending on prices as well, but this would imply a third order approximation of J(.) that is impractical under most circumstances and has not been attempted so far. In spite of this limitation, even the "workable" adjustment cost model is a considerable generalization of the static profit function model. Regularity conditions for theoretically consistent specifications include convexity of J(.) in prices (P, W), symmetry of its Hessian (matrix A in our case) and stability of matrix $(A_{PK} - r I)$. However, there is nothing in the model that requires the matrix of derivatives of short run netput supplies (6) to (8) or long-run netput supplies (10) to (12) with respect to prices to be symmetric or positive semidefinite. Consider the matrix of derivatives of short run quasi–fixed netput supplies with respect to prices P which is $(r\, A_{PK} A_{PP})$ from (6). A little rearranging shows that symmetry of $A_{PK} A_{PP}$ is also sufficient for the symmetry of long run netput supplies (10). Symmetry and positive semidefiniteness of this matrix does not follow from symmetry and positive semidefiniteness of matrix A_{PP}. Instead it is an additional restriction (rejected e.g. in BALL, SOMVARU, VASAVADA 1989) that would force the dynamic netput supplies (6) to conform to restrictions derived from the well-known *static* profit maximization model.

Consider further the adjustment matrix D. Stability requires its eigenvalues to be smaller than one in absolute value but nothing prevents them from being complex. Consequently, the adjustment path might be cyclical (GREENE, pp. 622–5) and short-run responses might overshoot the long-run response or go in the opposite direction than that suggested by long run equilibrium analysis of $\overline{X}_t$. This cannot occur if $A_{PK} A_{PP}$ is symmetric and positive definite (EPSTEIN, DENNY 1983, p. 655, MORTENSEN 1973, p. 662), i.e. if the restriction mentioned above holds.

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[1] Having derived the complete system of netput supplies, we may explain why squared land has been entered as a distinct element of vector Z. Contrary to the standard formulation of the normalized quadratic this will introduce squared land terms in every netput equation, not only in the numeraire, thus diminishing the pecularity of the latter. Because A_{ZZ} is zero except for the first row and column, the numeraire $\overline{L}_{0t}$ is linear in Z as are the other netput equations.

Nonetheless the dual adjustment model (4) has some drawbacks, which may motivate an alternative description of the dynamics in an adjusting agriculture:

- It is evident that the model (6) to (8) is *very* nonlinear in parameters. This may cause practical problems in achieving convergence, checking for local optima, calculating elasticities and standard errors or conducting certain tests.
- The assumption of static expectations is questionable, but difficult to generalize in the dual framework (for an attempt see EPSTEIN, DENNY 1983).
- The geometric decay assumption, i.e. a constant depreciation rate matrix δ, in inconsistent with the loss of technical efficiency of an asset being smallest in the first years of its service live, contrary to what is usually expected (see WITZKE 1996a).
- The interest rate r has to be assumed constant for dynamic duality to work properly.
- A simple theory is useful as a guidance for intuition and plausibility and as a protection against new "findings" emerging from undetected technical errors. The implications of dynamic optimization might be too complex to replace the static profit maximization framework for these purposes.

The alternative specification suggests itself upon looking at the flexible accelerator format (9). Long run supplies X_t might be derived from a static profit function model and the multivariate partial adjustment mechanism might be appended to this ad hoc (see e.g. TSIGAS, HERTEL 1989). To facilitate comparisons and to stay as close as possible to the adjustment cost model (4) it is useful to choose the normalized quadratic for the profit function, i.e.

$$(13) \qquad \pi(W_t, P_t, Z_t) = \frac{1}{2} \begin{pmatrix} W_t & P_t & Z_t \end{pmatrix} \begin{pmatrix} B_{WW} & B_{WP} & B_{WZ} \\ B_{PW} & B_{PP} & B_{PZ} \\ B_{ZW} & B_{ZP} & B_{ZZ} \end{pmatrix} \begin{pmatrix} W_t \\ P_t \\ Z_t \end{pmatrix}$$

As above, matrix B is taken to be symmetric and B_{ZZ} is zero except for the first row and column. Hotellings lemma gives the following system of long run netput supplies:

$$(14) \qquad \begin{pmatrix} \overline{L}_t \\ \overline{K}_t \end{pmatrix} = \begin{pmatrix} B_{WZ} \\ B_{PZ} \end{pmatrix} Z_t + \begin{pmatrix} B_{WW} & B_{WP} \\ B_{PW} & B_{PP} \end{pmatrix} \begin{pmatrix} W_t \\ P_t \end{pmatrix}$$

The numeraire equation for variable netput L_0 becomes[2]:

$$(15) \qquad \overline{L}_{0t} = Z_t' B_{ZZ} Z_t - \frac{1}{2} \begin{pmatrix} W_t & P_t \end{pmatrix} \begin{pmatrix} B_{WW} & B_{WP} \\ B_{PW} & B_{PP} \end{pmatrix} \begin{pmatrix} W_t \\ P_t \end{pmatrix}$$

To the system of long run equilibrium netput supplies we append a partial adjustment mechanism corresponding to (9) with a free parameter matrix D:

$$(16) \qquad \begin{pmatrix} L_{0t} - L_{0t-1} \\ L_t - L_{t-1} \\ K_t - K_{t-1} \end{pmatrix} = \begin{pmatrix} 1 & 0 & D_{L0K} \\ 0 & I & D_{LK} \\ 0 & 0 & D_{KK} \end{pmatrix} \begin{pmatrix} \overline{L}_{0t} - L_{0t-1} \\ \overline{L}_t - L_{t-1} \\ \overline{K}_t - K_{t-1} \end{pmatrix}$$

Substituting and rearranging shows the short run netput supplies to be:

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[2] Note again that this is effectively linear in Z_t because B_{ZZ} is zero except for the first row and column.

(17) $K_t = D_{KK} B_{PP} P_t + D_{KK} B_{PW} W_t + D_{KK} B_{PZ} Z_t + (I - D_{KK}) K_{t-1}$

(18) $L_t = (B_{WP} + D_{LK} B_{PP}) P_t + (B_{WW} + D_{LK} B_{PW}) W_t + (B_{WZ} + D_{LK} B_{PZ})$
$Z_t - D_{LK} K_{t-1}$

(19) $L_{0t} = 0,5 Z_t' B_{ZZ} Z_t - 0,5 P_t' B_{PP} P_t - P_t' B_{PW} W_t - 0,5 W_t' B_{WW} W_t$
$+ D_{L0K} [B_{PP} P_t + B_{PW} W_t + B_{PZ} Z_t - K_{t-1}]$

Considering the dimensions of Z_t, W_t and P_t and the symmetry restrictions leaves 57 parameters to be estimated for the multivariate partial adjustment model. The adjustment cost model (6) to (8) would have 66 parameters in the present form, but the 4x3 matrix A_{ZK} with 12 parameters only appears in the numeraire equation (8) and would not be estimable with the observations available. Therefore we set all elements of A_{ZK} to zero except for the first row that is associated with the constant term. This renders the last term in (8) linear in $(P_t W_t Z_t K_{t-1})$, as is (19), and reduces the number of parameters to 57 as well.

The partial adjustment model is easier to estimate because the cross equation restrictions are less complex. Because it is not so tightly rooted in dynamic optimization theory it would be easy in principle to introduce alternative specifications for expectations or to incorporate more realistic forms of decay for capital stocks. However, the fact that the number of parameters is (made) the same suggests that it is not less restrictive than the adjustment cost model. The restrictions are simply *different*: Whereas the partial adjustment model imposes consistency of long run supplies with conventional static theory, the adjustment cost model imposes consistency of the value function with regularity conditions from dynamic optimization theory. Because the two are not equivalent it will be interesting to see what a difference this makes in terms of the empirical results.

3   Data

The data span the years from 1965 to 1992, the last year for which agricultural accounts were available for West Germany separate from East Germany. From 1973 onwards, Törnquist indices for *plant output, animal output and operating inputs* have been formed using the disaggregated agricultural accounts based on EUROSTAT data as available in the "base system" of the SPEL-model (WOLF 1995)[3]. Hired labor has been aggregated with the other, more conventional operating inputs. The capital stocks for *machinery* and *buildings* are being calculated as an accumulation of past investments corrected with depreciation rates of 4% and 17%. These rates were chosen to obtain capital stock series that fall more or less in the middle of a whole set of capital stock series from an independent sensitivity analysis for capital stock calculations based on more realistic assumptions than geometric decay (WITZKE 1996a). The corresponding user costs, i.e. the rental prices of machinery and buildings P_t, are calculated as asset prices P_{Kt} (taken from the agricultural accounts) times the sum of the assumed depreciation rates and interest rates (taken from German farm accountancy network data, BML, AB), i.e. $P_t = (r_t + D) P_{Kt}$. The average rate over the period investigated ($\approx 4,2$ %) was used as the constant interest rate "r" appearing in equations (1) to (12) above. *Family labor* input was measured using the "annual labor units" (or "AK") available in the SPEL data base but also in official

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3   More detailed information on the construction of the data or the complete data set is available upon request, see also WITZKE 1996b.

publications like the German report on agriculture (BML, AB). The "official wages" ("Vergleichslöhne") from BML, AB were used to obtain an estimate of the opportunity cost of family labour. Because they are expressed on a before tax basis, they have been corrected for sector specific income tax and social security deductions in or outside of agriculture. Finally *"land"* is simply the total area in agricultural uses ("LF"), regardless of land quality. Evidently this is again a very crude proxy for the land input.

Limited space does not permit the detailed discussion of the data in this paper. However, one interesting property shall be mentioned: The emergence of negative "profits" for the agricultural sector as a whole beginning from the end of the seventies, which is of course inconsistent with profit maximization. One might suspect this being due to measurement errors in the family labour variables. However, according to these data, family labour left agriculture sufficiently fast to offset the strong increase in wages and to keep labour cost roughly constant after 1977. Capital costs, one the other hand, continued to rise after 1977 because machinery and particularly buildings hardly adjusted to the rise in the user cost. All variants of the sensitivity analysis mentioned above show this continous rise, i.e. it does not seem to be the result of the geometric decay assumption. This might indicate already that machinery and buildings are affected by adjustment costs at least as severe as family labour but for a more thorough explanation, econometrics might help intuition.

4   Estimation and results

Both the adjustment cost and the partial adjustment cost model have been estimated using nonlinear SUR as implemented in GaussX. Because both models contain lagged dependent variables, autocorrelation in the residuals would not only bias the standard errors but also the estimated parameters. However first estimations of both models showed clear signs of autocorrelation in the family labour equation and to a much lesser extent also in the plant and machinery equations. Consequently, univariate AR(1) errors have been assumed for the family labour equation. This left some autocorrelation in the plant output equation and, to be on the safe side, AR(1) errors have been included here as well. Upon this correction, the Q–statistics at lag 1 (corresponding to inapplicable DW–statistics) were insignificant of remaining autocorrelation at error probabilities of 0.2 or higher. Higher order autocorrelation was absent at significance levels of at least 0.1 in general. The final specification of both models was thus more or less consistent with white noise errrors.

An implication of the need to correct for autocorrelation (also in TSIGAS, HERTEL 1989, EPSTEIN, DENNY 1983) is, however, that neither the adjustment cost nor the partial adjustment model is able to fully account for the dynamics of adjustment of German agriculture. Complications that were removed from consideration in the introduction, i.e. aggregation problems, farm household interdependencies, simple treatment of uncertainty might be responsible for this as well as a wrong functional form. In defense of the adjustment cost model, however, it may be mentioned that autocorrelation was considerably worse in the pure normalized quadratic profit function model, i.e. a large part of the dynamics *is* explained. It may also be mentioned that the R^2 in the equation with the worst fit (machinery), improved from below 0.7 in the normalized quadratic to over 0.9 in the dynamic models. The estimated dynamics of the adjustment process hinge upon the parameters of the adjustment matrix D which are reproduced in table 1. Note that they are nonlinear functions of the structural parameters in (9).

Table 1: Adjustment parameters for the adjustment cost and partial adjustment models

	adjustment cost model		partial adjustment model	
	Value	Std. Err.	Value	Std. Err.
D_{L0K1}	0.029	(0.135)	-0.061	(0.135)
D_{L1K1}	**0.415**	**(0.114)**	**0.447**	**(0.112)**
D_{L2K1}	-0.253	(0.149)	**-0.366**	**(0.150)**
D_{K1K1}	*0.431*	*(0.111)*	*0.546*	*(0.114)*
D_{K2K1}	-0.015	(0.027)	0.013	(0.028)
D_{K3K1}	**-0.003**	**(0.001)**	-0.003	(0.002)
D_{L0K2}	0.117	(0.123)	0.149	(0.111)
D_{L1K2}	**0.754**	**(0.299)**	-0.010	(0.112)
D_{L2K2}	**-0.550**	**(0.315)**	0.130	(0.163)
D_{K1K2}	**0.389**	**(0.114)**	**0.318**	**(0.110)**
D_{K2K2}	*0.295*	*(0.024)*	*0.274*	*(0.026)*
D_{K3K2}	**0.014**	**(0.001)**	**0.013**	**(0.001)**
D_{L0K3}	**-10.897**	**(5.729)**	-8.458	(5.804)
D_{L1K3}	-11.968	(11.997)	-3.307	(5.164)
D_{L2K3}	7.622	(11.698)	2.855	(7.698)
D_{K1K3}	-7.227	(5.101)	**-9.063**	**(5.287)**
D_{K2K3}	**-8.419**	**(1.104)**	**-8.218**	**(1.216)**
D_{K3K3}	*0.191*	*(0.057)*	*0.217*	*(0.066)*

Bold values are significant at the 10% level

The own adjustment coefficients D_{KiKi} (in italics) are particularly easy to interpret. They show that, according to the adjustment cost model, of a given disequilibrium in machinery, buildings or family labour, only 43%, 29% or 19% is eliminated in the first year ($K_{it} - K_{it-1}$ = $D_{KiKi} [\bar{K}_{it} - K_{it-1}]$), if the other quasi–fixed netputs were in equilibrium or cross equation relationships played no role. The corresponding values for the partial adjustment model do not differ significantly (e.g. using standard t–tests at the 10% level) which is also the case for most off–diagonal elements of D. A close resemblance of both models in the adjustment cost matrices may be observed also in TSIGAS, HERTEL 1989, p.25. Therefore, the following comments pertain both to the adjustment cost and to the partial adjustment model.

Cross equation effects are clearly significant in some cases, i.e. the models do not support a simplification to diagonal adjustment (comp. BALL, SOMVARU, VASAVADA 1989, contrary to LUH, STEFANOU 1991; see also WITZKE 1993, p. 214). A coefficient of $D_{K2K3} = -8.4$ indicates, for example, that an excess demand for family labour, i.e. $\bar{K}_{3t} - K_{3t-1} < 0$[4], would cause *lower* investment in buildings ($K_{2t} - K_{2t-1} = D_{K2K3} [\bar{K}_{3t} - K_{3t-1}] + ...$). This is a kind of "substitutability in adjustment needs", because an expansive tendency in one netput reduces expansion of the other. For family labour, however, we had excess supply ($\bar{K}_{3t} - K_{3t-1} > 0$) which was particularly high in the 60s and first years of the 70s. According to $D_{K2K3} < 0$, this operated towards an *increase* of the buildings stock ($K_{2t} - K_{2t-1} < 0$) which is what we observed in these years. On the contrary $D_{K3K2} = +0,01$ indicates that excess supply in buildings, present in every year of the period investigated, should have reinforced the *reduction* of the family labour force. Positive off–diagonal elements of matrix D indicate, therefore, a kind of "complementarity in adjustment needs".

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[4]   Remember the netput notation of $K_{it} < 0$ for inputs.

The adjustment matrix D_{KK} needs not be symmetric. Some asymmetry in orders of magnitude is simply due to differing units of measurement. However, the examples of D_{K2K3} and D_{K3K2} illustrate that even differences in sign may occur, to some extent certainly contrary to intuition. Although these differences are difficult to explain, it should be stressed that dynamic optimization implies in no way a (sign-) symmetric adjustment matrix. Occasional tests of this condition (e.g. in STEFANOU et al. 1992, p. 289) are therefore completely arbitrary. An asymmetric matrix D_{KK} may have complex eigenvalues which imply that adjustment is cyclical towards the equilibrium, if they are all smaller one in absolute value. A cyclical path of adjustment is indeed what is implied by table 1. The complete adjustment matrix D is also asymmetric because disequilibria in quasi-fixed netputs may influence the supply of variable netputs, whereas disequilibria in variable netputs are ruled out by definition. Some of the elements of D_{LK} are highly significant. For example $D_{L1K1} = 0,4$ implies that excess demand for machinery $(K_{1t} - K_{1t-1} < 0)$ would *reduce* supply of animal products, presumably because investment in machinery tends to be associated with substitution away from animal production. Additional interpretation of the results of table 1 may be left to the reader.

The presentation of price elasticities shall be introduced with a look at the eigenvalues of the submatrices of A and B accociated with the prices, because they indicate whether the value or profit functions are convex, as required by dynamic or static profit maximization. As it turned out, they are not for the adjustment cost model, but the violation is almost certainly insignificant, given the eigenvalues $(-0.16, 72.2, 165, 461, 2454)$ for the relevant submatrix from A. The eigenvalues for the partial adjustment profit function, on the other hand, do satisfy convexity $(0.002, 2.97, 7.0, 29.7, 150)$. Because the convexity requirements are thus met (essentially), all price elasticities elasticities should be consistent with the relevant theory.

These price elasticities are usually quite complicated functions of the underlying parameters, which are difficult to interpret by themselves. Table 2 presents price elasticities, evaluated at the sample means, together with their approximate standard errors[5]. Although standard errors are usually not given (e.g. by BALL, SOMWARU, VASAVADA 1989), they are indispensible to direct attention to those elasticities that may be taken seriously from a statistical viewpoint. We may note first that the price elasticities are remarkably similar for the adjustment cost and the partial adjustment model. This similarity is much closer than in TSIGAS, HERTEL 1989 (p. 25, without standard errors) and is probably due to our explicit care of not introducing other sources of deviations apart from the differences in the parametrization following from the different theories. Significant differences only arise in the elasticities with respect to the rental price of buildings, but these elasticities are close to zero. Therefore, even the significant differences may be said to be irrelevant. The fact that the two models agree should increase confidence in their results.

The long-run, i.e. fully adjusted, elasticities are usually smaller than 0,5, i.e. they do not support an elastic reaction of agriculture to price incentives in the long run. On the other hand they are not negligible, for example as puplished in Ball, Somvaru, Vasavada 1989. This may be due to the data satisfying convexity "voluntarily", without imposition. Overall they may be called plausible and only few of the significant results will surprise and thus require further comment, for example certain regressive relationships. The latter may be

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[5] According to the "delta method" (Greene 1993, p. 297), as implemented in GaussX.

perfectly reasonable for certain technologies. For example, we find the elasticity of buildings with respect to the plant output price to be negative as is the elasticity of machinery with respect to the animal output price. The first of these results can be due to rising plant output prices causing substitution away from animal outputs which will be closely related to the use of buildings. The second may be explained in part by a reverse substitution away from machinery intensive plant production. In the case of buildings, however, substitution effects cannot explain why there is a (weaker) regressive relationship to animal outputs as well. Because the elasticities expressing these regressive relationships are small (and partly insignificant) we may take them to be "approximately zero", not worth further inquiry.

The short-run, i.e. next year, elasticities confirm the Le Chatelier principle of lower short-run own price effects for the quasi-fixed netputs (lower right colunms of table 2) which are only about half the long run elasticities. For elasticities with respect to the operating inputs price there is hardly any difference between the short run and the long run what might be expected. The short-run own price elasticity of animal outputs, however, is *higher* than the long run elasticity. In a dynamic world this may happen, for example, if farmers can vary the fattening period in response of temporary price variation as is observed on BSE affected beef markets in the present situation. Correspondingly we find the elasticities of animal output with respect to other prices *increasing* in the short run as well. While somewhat surprising, similar examples of short-run responses exceeding long-runs have been obtained elsewhere (EPSTEIN, DENNY 1983, p. 661; BALL, SOMVARU, VASAVADA 1989, p. 286). They should help to beware of a simplistic intuition which would frequently suggest some scaling factor < 1 to be applied to long run elasticities, probably obtained from a static model, if knowledge of short run responses is required.

Regressive relationships are weakened or turned into normal relationships in most short run elasticities. The positive elasticity of animal outputs with respect to the machinery price, however is *considerably higher* in the short run than in the long run. While this may be an accompanying effect of other price elasticities of animal output becoming higher as well and while regressive relationships are easier to rationalize in the short than in the long run (see HERTEL 1987), we admit that this elasticity is suspicious.

Let us finally point to a small, but significant asymmetry in the elasticities of family labour with respect to the rental price of buildings and vice versa. Because the signs of these differ and because they are significantly different from 0, this is an evident violation of the symmetry condition on netput supplies. Note that in the short run, this occurs even in the partial adjustment model which imposes symmetry on the *long run* netput supplies.

5   Conclusions

The adjustment cost model has proven capable of explaining the dynamics of aggregate plant and animal outputs, operating inputs, machinery, buildings and family labour in the adjusting agriculture of West Germany. Within the limitations mentioned in the introduction, this explanation has the advantages of full theoretical consistency and of a coherent distinction of short and long run responses that is impossible to achieve in a static framework. In general, the empirical results are intuitive.

Table 2: Price elasticities for the adjustment cost and partial adjustment models

	long-run elasticities				short-run elasticities			
	adjustment cost		partial adjustment		adjustment cost		partial adjustment	
	Value	Std. Err.	Value	Std. Err.	Value	Std. Err.	Value	Std. Err.
Elasticity w.r.t. plant price of								
plant output	*0.44*	*(0.12)*	*0.42*	*(0.11)*	*0.43*	*(0.13)*	*0.47*	*(0.13)*
animal output	-0.11	(0.05)	-0.10	(0.05)	-0.21	(0.06)	-0.21	(0.05)
operating inputs	0.15	(0.08)	0.12	(0.07)	0.06	(0.08)	-0.01	(0.07)
machinery	0.20	(0.10)	0.22	(0.08)	0.04	(0.05)	0.09	(0.05)
buildings	-0.11	(0.03)	-0.11	(0.03)	-0.03	(0.01)	-0.02	(0.01)
family labour	-0.05	(0.04)	-0.05	(0.04)	-0.11	(0.02)	-0.10	(0.03)
Elasticity w.r.t. animal price of								
plant output	-0.26	(0.11)	-0.21	(0.10)	-0.17	(0.15)	-0.16	(0.15)
animal output	*0.21*	*(0.11)*	*0.19*	*(0.10)*	*0.35*	*(0.09)*	*0.29*	*(0.09)*
operating inputs	0.14	(0.12)	0.14	(0.11)	0.24	(0.13)	0.22	(0.13)
machinery	-0.26	(0.14)	-0.21	(0.11)	-0.15	(0.09)	-0.17	(0.08)
buildings	-0.04	(0.04)	-0.10	(0.05)	-0.02	(0.01)	-0.04	(0.01)
family labour	0.09	(0.05)	0.07	(0.05)	0.02	(0.04)	-0.03	(0.04)
Elasticity w.r.t. oper. inp. price of								
plant output	-0.22	(0.12)	-0.19	(0.12)	-0.23	(0.13)	-0.20	(0.14)
animal output	-0.12	(0.10)	-0.11	(0.09)	-0.14	(0.07)	-0.15	(0.07)
operating inputs	*-0.34*	*(0.15)*	*-0.34*	*(0.15)*	*-0.35*	*(0.13)*	*-0.36*	*(0.13)*
machinery	0.05	(0.14)	0.11	(0.11)	0.05	(0.07)	0.10	(0.07)
buildings	0.07	(0.04)	0.12	(0.05)	0.02	(0.01)	0.03	(0.01)
family labour	0.03	(0.07)	0.05	(0.07)	0.05	(0.04)	0.08	(0.04)
Elasticity w.r.t. machinery price of								
plant output	-0.06	(0.05)	-0.10	(0.04)	0.01	(0.16)	-0.20	(0.21)
animal output	0.02	(0.03)	0.04	(0.02)	0.31	(0.07)	0.36	(0.09)
operating inputs	-0.01	(0.04)	0.03	(0.03)	0.23	(0.12)	0.39	(0.15)
machinery	*-0.54*	*(0.12)*	*-0.63*	*(0.10)*	*-0.18*	*(0.07)*	*-0.28*	*(0.08)*
buildings	0.16	(0.04)	0.25	(0.04)	0.03	(0.02)	0.03	(0.02)
family labour	0.16	(0.04)	0.16	(0.03)	0.20	(0.04)	0.26	(0.05)
Elasticity w.r.t. buildings price of								
plant output	0.02	(0.01)	0.02	(0.01)	0.03	(0.03)	0.07	(0.04)
animal output	0.01	(0.01)	0.01	(0.00)	-0.03	(0.01)	-0.05	(0.02)
operating inputs	0.01	(0.01)	0.02	(0.01)	-0.02	(0.02)	-0.06	(0.03)
machinery	0.08	(0.02)	0.12	(0.02)	0.01	(0.01)	-0.02	(0.01)
buildings	*-0.04*	*(0.02)*	*-0.09*	*(0.02)*	*-0.01*	*(0.01)*	*0.03*	*(0.02)*
family labour	0.00	(0.01)	-0.01	(0.01)	-0.04	(0.01)	-0.07	(0.02)
Elasticity w.r.t. fam. lab. price of								
plant output	0.08	(0.05)	0.05	(0.04)	-0.07	(0.15)	0.03	(0.15)
animal output	-0.02	(0.03)	-0.04	(0.03)	-0.27	(0.06)	-0.25	(0.06)
operating inputs	0.04	(0.05)	0.04	(0.04)	-0.16	(0.10)	-0.18	(0.09)
machinery	0.48	(0.10)	0.40	(0.08)	0.23	(0.06)	0.24	(0.06)
buildings	-0.03	(0.04)	-0.07	(0.04)	0.02	(0.01)	0.02	(0.01)
family labour	*-0.22*	*(0.05)*	*-0.23*	*(0.04)*	*-0.12*	*(0.02)*	*-0.13*	*(0.03)*

Source: Own computations

In several instances however, they appear somewhat odd when judged by conventional intuition. In our view, this kind of intuition is frequently rooted in well-known properties of static models and ad-hoc presumptions on how these properties translate into a dynamic framework. Therefore, the paper has elaborated on the complexities of dynamic responses to changing incentives for agriculture based on theory and empirical examples. This should contribute to a more cautious reliance on intuition when judging surprising empirical

results. Nonetheless, this model is not yet ready for practical policy analysis. There are some elasticities that are indeed difficult to believe. Moreover, the analysis would require considerable disaggregation in order to analyse actual policies. We have ignored the milk and sugar quota, for example, hoping that this misspecification can be absorbed by the error terms in the respective equations. For a politically relevant analysis, it might be a very interesting finding that the simpler and more flexible multivariate partial adjustment model yielded results that were indistinguishable from those of the adjustment cost model for all practical purposes. This is particularly interesting because the adjustment cost framework implies a certain lack of flexibility due to its theoretical rigour. Several generalizations might be worth future attempts and easier to implement within the partial adjustment approach. This would cause a certain loss of theoretical rigour, but perhaps at small practical cost.

Coming back to the policy related question in the introduction, the study has shown that factor use in agriculture, being apparently too high particularly in the case of family labour, might be explained indeed with adjustment costs. Insofar the evidence supported the static disequilibrium – dynamic equilibrium view of the "farm problem". Nonetheless, we cannot exclude that other explanations are equally consistent with the aggregate data investigated in this study.

6   Zusammenfassung

In diesem Papier wurden ein Anpassungskostenmodell und ein Modell partieller Anpassung erläutert, die zur empirischen Erklärung der Dynamik des aggregierten Angebots an pflanzlichen und tierischen Erzeugnissen sowie der Faktornachfrage nach Vorleistungen, Maschinen, Gebäuden und Familienarbeit in der westdeutschen Landwirtschaft 1965-92 in der Lage waren. Wo die Ergebnisse der Intuition widersprachen, dürfte dies sowohl eine Folge von Modellvereinfachungen sein wie an der Komplexität der hier vorgestellten dynamischen Unternehmenstheorie liegen. Ein für die zukünftige Forschungsarbeit interessantes Teilergebnis war, daß sich das Anpassungskostenmodel in den empirischen Ergebnissen kaum von dem Modell partieller Anpassung unterschied, welches wegen seines ad hoc Charakters zwar theoretisch weniger geschlossen, dafür aber deutlich flexibler für Modifikationen ist.

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