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Merkies, A.H.Q.M.; Steyn, I.J.

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Arnold H.Q.M. Merckies
Ivo J. Steyn

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MODELLING CHANGING LAG PATTERNS IN DUTCH CONSTRUCTION

Arnold H.Q.M. Merckies & Ivo J. Steyn

Free University,
Faculty of Economics & Econometrics,
Dept. of Econometrics,
De Boelelaan 1105,
1081 HV Amsterdam,
The Netherlands.

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MODELLING CHANGING LAG PATTERNS IN DUTCH CONSTRUCTION

Arnold H.Q.M. Merckies & Ivo J. Steyn¹

1. Introduction

This paper is concerned with an apparently modest problem : the time structure of the relation between housing starts in a given period, and actual production of dwellings. Depending on the size and nature of a building project, a project can take from 1 to 12 quarters to complete, so that production in a given quarter is a weighted average of construction starts in previous periods. That lag pattern between construction starts and housing production is the issue here.

As we will make clear, the problem is made complex by three factors. Firstly, the actual lag pattern - as observed in empirical study - is of a shape which is difficult to describe in terms of a model which is linear in the coefficients. To solve this problem we will propose the use of a new generalisation of Almon's polynomial lag pattern. Secondly, this lag pattern changes over time, contracting and expanding in time with the economy. Finally, the quality of the measurements deteriorates over time, necessitating time-varying variance parameters.

The structure of this paper is as follows : in section 2, we will review the origins and nature of the lag pattern. In section 3, the problems of modelling a changing lag pattern are reviewed. Section 4 deals with the estimation of such a model, and section 5 discusses the results. Finally, section 6 summarises the most important features of the method used and reviews some of the results.

2. Average lag patterns and the accordion effect

Any construction project with total value A will generally take a number of periods to complete. The successive values produced in each time period, expressed as a fraction of the total value together form the lag pattern of the construction project. The lag pattern in the aggregate data then results as a convolution of the lag patterns of individual projects, see Merckies & Bikker[1979].

This aggregate lag pattern is written as $\Phi(L)$ in the following relation:

$$(1) \quad p_t = \Phi(L)x_t + \Xi(L)\epsilon_t \quad \epsilon_t \approx \text{i.i.d. } N(0, \sigma^2)$$

p_t = value of construction in period t
 x_t = total value of projects started in period t

At least approximately, the lag polynomial $\Phi(L)$ has to satisfy

$$(2) \quad \Phi(1) = 1$$

The MA lag polynomial of the errors theoretically has to satisfy the restriction $\Xi(1) = 0$ if measurements are perfectly reliable. We will review

¹ This research project was made possible by the Dutch Institute for the Construction Industry (EIB), whose support is gratefully acknowledged.

this restriction later.

However, the coefficients in the lag polynomial $\Phi(L)$ are not constant through time. In van Alphen & Merckies[1976] the empirical lag structure was calculated and compared with a number of theoretical lag patterns. It was noted that the lag pattern had a tendency to contract during slow periods, and expand during boom periods, reflecting a given production capacity and a tendency to redistribute that capacity over projects at hand as business slows down or speeds up.

This effect was nicknamed the "accordeon" effect.

A regression estimating (1) with fixed coefficients yields an "average" lag pattern over the sample period, and will therefore turn out to be a poor predictor.

Two possible solutions can be considered. The first is the use of an additional exogenous variable to capture the accordeon effect. This option was examined in van Alphen & Merckies[1976] and in de Vos & van Alphen[1985]. The results were ambiguous. Both papers ended up with models which, on later reflection, had not discovered a proper exogenous variable and failed to show proper predictive properties as a result.

A further complication is the strong suspicion that the quality of measurements of the progress in construction had deteriorated. The parameter σ^2 did not remain constant, increasing sharply in more recent years. In the next paragraph we will present an alternative way to capture the changing lag patterns, which also allows us to deal with the change in variance parameters.

3. Modelling changing lag patterns

The lag pattern, as represented by the coefficients of Φ , should have the following properties:

1. Unimodality
2. Positive coefficients for all lags
3. Unit sum

Furthermore, the mode should be variable, as should the modal value, to reflect the accordeon effect. The length of the lag pattern can be quite extreme, as shown in the empirical survey conducted by van Alphen & Merckies.

In practice, the awkward restriction (2) and the restriction on the MA polynomial can be avoided by inclusion of a stock variable n_t , defined as

$$(3) \quad n_t = n_{t-1} + x_{t-1} - p_{t-1}$$

This variable thus represents the total amount of construction yet to be built at the start of period t . As shown by de Vos and van Alphen[1985], inclusion of this variable in (1) automatically ensures that restriction (1) is satisfied in the implied reduced form of such a model. For, any model of the form

$$(4) \quad A(L)p_t = B(L)x_t + C(L)n_t + D(L)e_t$$

has, after substitution of (3) and rearrangement of terms, the following reduced form :

$$(5) \quad p_t = \frac{(1-L)B(L) + LC(L)}{(1-L)A(L) + LC(L)} x_t + \frac{(1-L)D(L)}{(1-L)A(L) + LC(L)} \varepsilon_t$$

in which the restrictions $\Phi(1) = 1$ and $\Xi(1) = 0$ are always satisfied. We therefore estimate a model of the form

$$(6) \quad p_t = \alpha p_{t-1} + \beta x_t + \gamma x_{t-1} + \delta n_t + \varepsilon_t$$

and allow the coefficients of this model to vary over the sample period, arriving at a model we will call Model 1.

The disadvantage of Model 1 is that the lag pattern in the reduced form of (6) - as in (5) - is not immediately obvious from the estimated coefficients in (6). The second line of approach we will therefore examine has the lag coefficients as a linear transformation of the estimated coefficients. The usual way to capture a long lag pattern by a simple linear regression is the use of an Almon polynomial lag :

$$(7) \quad \varphi_1 = \gamma_0 + \gamma_1 i + \gamma_2 i^2 + \dots + \gamma_m i^m$$

As is well known, a lag pattern as in (7) can be estimated simply by linear regression.

The Almon polynomial lags are not suitable for our purposes for two reasons. The polynomial lag pattern is incapable of representing an infinite lag pattern, and the range of lag patterns available as Almon lags does not include the long-tailed, skewed lag pattern found in construction data (see Fig.1).

An alternative solution would be to approximate $\Phi(L)$ by a rational lag function as in Jorgenson[], which at least has sufficient flexibility to overcome these two objections, but apart from the fact that this does not allow easy reconstruction of the lag coefficients, the estimation of such a rational lag model is far from trivial.

We will introduce a third alternative which combines the advantages of both the above methods. The method can be seen as a generalisation of the Almon lag and we will refer to it as a generalised Almon lag.

Instead of using a polynomial function for φ_1 as in (7), we will use :

$$(8) \quad \varphi_1 = \gamma_0 + \gamma_1 f_1(i) + \gamma_2 f_2(i) + \dots + \gamma_m f_m(i)$$

where the functions f are known. A restricted subclass of (8) was considered in Speaker, Mitchell & Gelles[1989].

Obviously, this gives us a virtually unlimited range of lag patterns, which can be estimated simply by linear regression. Infinite lag patterns can also be incorporated, for instance by the following special case of (8) :

$$(9) \quad \varphi_1 = \frac{A(i)}{B(i)}$$

where $A(i)$ and $B(i)$ are polynomials. If $B(i)$ contains unknown coefficients, only numerical estimation is possible, but if B is known, (9) can be rewritten as

$$(10) \quad \varphi_1 = a_0 \frac{1}{B(i)} + a_1 \frac{i}{B(i)} + \dots + a_m \frac{i^m}{B(i)}$$

For our problem, we will specify the lag structure as follows :

$$(11) \quad \Phi(L) = \varphi_0 + \varphi_1 L + \varphi_2 L^2 + \dots + \varphi_k L^k$$

$$(12) \quad \varphi_1 = \frac{a + bi^2}{1 + i^4} \quad a, b \geq 0$$

The function (12) has several advantages. It produces an unimodal lag pattern, with positive coefficients, and changes in the lag pattern can be implemented by changing the two coefficients a and b , which jointly influence both modulus and modal value.

The restriction (2) leads to a restriction on the coefficients a and b , namely

$$(13) \quad \sum_{i=0}^k \varphi_i = 1 \quad \text{or} \quad a \sum \frac{1}{1 + i^4} + b \sum \frac{i^2}{1 + i^4} = 1$$

We will use a lag length $k=10$. In that case, the restriction is :

$$(14) \quad 1.5782a + 1.0334b = 1$$

The time-varying version of (11)-(12) will be referred to as Model 2.

Time-varying parameter versions of both Model 1 and Model 2 do suffer from an imperfection : condition (2) becomes almost impossible to impose a priori and can only be checked a posteriori. If the lag polynomial $\Phi(L)$ is time-varying, the equivalent of (13) is :

$$(15) \quad \sum_{i=0}^k \varphi_i^{t+1} = 1 \quad \forall t$$

For our Model 2 this becomes:

$$(16) \quad \sum_{i=0}^k \frac{a_{1+t} + b_{1+t} i^2}{1 + i^4} = 1 \quad \forall t$$

Although we will not impose this awkward condition exactly, an approximate version of it can be imposed by ensuring that condition (14) holds for $t=0$, and that the changes in a and b are negatively correlated, while (16) holds exactly if these changes have a correlation of -1 . In Model 1 an equivalent restriction is virtually impossible to formulate, let alone impose. Both models need to be augmented further by the inclusion of a seasonal dummy, and by a dummy to cope with the disastrous winter of 1979, which completely unbalanced the construction industry during 1979.1.

Finally, a few remarks about the way in which the parameters of the two models vary over time. Since we do not have an a priori reason to suppose the various coefficients have equilibrium levels to which they tend, we will assume a

nonstationary development of all coefficients :

$$(17) \quad \beta_t = \beta_{t-1} + \eta_t \quad \eta_t \text{ white noise}$$

4. Kalman Filter and Hyperfilter

Both models can be written as a State Space model, of the following form :

$$(18a) \quad \alpha_t = T\alpha_{t-1} + \varepsilon_t \quad \varepsilon_t \sim N(0, \sigma^2 Q)$$

$$(18b) \quad y_t = z_t' \alpha_t + u_t \quad u_t \sim N(0, \sigma^2)$$

with the following specifics:

	Model 1	Model 2
α_t	$(\alpha \ \beta \ \gamma \ \delta \ D \ S_t \ S_{t-1} \ S_{t-2})'_t$	$(a \ b \ D \ S_t \ S_{t-1} \ S_{t-2})'_t$
T	$\text{diag}(I_5, M)$	$\text{diag}(I_3, M)$
Q	$\text{diag}(q_1, q_2, q_3, q_4, 0, q_5, 0, 0)$	$\text{diag}(P, 0, p_3, 0, 0)$
z_t'	$(p_{t-1} \ x_t \ x_{t-1} \ n_t D_t \ 1 \ 0 \ 0)$	$(z_{1t} \ z_{2t} \ D_t \ 1 \ 0 \ 0)$

where the auxiliary variables z_1 and z_2 are defined as follows:

$$(19) \quad z_{1t} = \sum_{i=0}^k \frac{x_{t-1}}{1+i^4} \quad z_{2t} = \sum_{i=0}^k \frac{x_{t-1} i^2}{1+i^4}$$

and the matrices M and P are

$$(20) \quad M = \begin{bmatrix} -1 & -1 & -1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \quad P = \begin{bmatrix} p_1 & p_{12} \\ p_{12} & p_2 \end{bmatrix}$$

This choice leads to a seasonal term as in Harvey[1984], in which the sum of four consecutive seasonal terms is white noise. Finally, the dummy D_t is defined as 1 in the first quarter of 1979, and 0 otherwise.

For the estimation of a State Space model as in (18a)-(18b) the most widely used method is as follows : as soon as all variance parameters are known, the State vector (which in this case contains our time-varying coefficients and the various dummies) can be estimated with a Kalman Filter, during which the likelihood is also easily calculated. Estimates of the unknown variance parameters are thus obtained numerically, by running a Kalman Filter for succeeding approximative values until an optimum is reached.

However, this approach is not only time-consuming and vulnerable to numerical problems, it also assumes that the variance parameters are constant over the sample period. While we do not have enough information about these parameters

to model such changes explicitly, we do wish to make such changes visible during estimation.

We will therefore estimate our models with a Hyperfilter (see Merckies & Steyn[1988]). In an ordinary Kalman Filter, the variance parameters are kept constant while processing the observations. In a Hyperfilter, estimates of the variance parameters are also updated as new observations become available, leading to a wholly recursive algorithm. The Hyperfilter we will use here is the modified version of the RPE Hyperfilter used in Merckies & Steyn[1988].

As a final practical point, the program used was only able to cope with diagonal variance matrices. Therefore we modelled the two correlated disturbance terms in Model 2 as follows :

$$(21) \quad \varepsilon_{1t} = \xi_{1t} + \xi_{2t} \quad \varepsilon_{2t} = \xi_{3t} - \xi_{2t}$$

with ξ_1 , ξ_2 and ξ_3 independent white noise, so that

$$(22) \quad \begin{aligned} p_1 &= \text{var}(\xi_1) + \text{var}(\xi_2) \\ p_2 &= \text{var}(\xi_3) + \text{var}(\xi_2) \\ p_{12} &= -\text{var}(\xi_2) \end{aligned}$$

5. Some results

The data used were quarterly observations on the construction of dwellings from 1971.1 to 1986.2. Model 1 used up one lag which left 61 observations. For Model 2, a maximum lag length of 10 was used, giving 52 observations spanning the period 1973.3 to 1986.2. The data have been corrected for aborted projects, so that the relation (3) holds exactly.

For both Model 1 and Model 2, starting conditions for the Hyperfilter have been generated as in Steyn[1989]. For Model 2, the starting values of a and b have also been chosen so that relation (14) holds.

Table 1 summarises some of the salient results for the two models. In Model 1, the variances of the coefficients turned out to be insignificantly different from zero (LR test value of 3.01 at 4 degrees of freedom), and only the seasonal term showed significant variance. A plot of the variance of this seasonal is given in Fig.2. The measurement variance did show some variation, increasing sharply in 1982.4, see Fig.3.

With the constant coefficients, the implied lag pattern could be reconstructed and this is shown in Fig.4. As discussed, this Model only produces an "average" lag pattern over the sample period if the coefficients are constant.

In Model 2, the results are strikingly different. The two coefficients a and b can not be taken as constant (LR test value of 11.5 at 2 degrees of freedom), and the lag patterns thus change over time. Two sample lag patterns are shown in Fig.5, and the accordion effect is clearly visible.

The measurement variance σ^2 is shown in Fig.6 and two shocks in 1981.2 and 1982.4 are clearly visible. Similar shocks were found in an examination of the relation between issued construction permits and started construction projects in Merckies & Steyn[1988]. The explanation seems to lie in a general deterioration of the predictability of the construction sector, possibly

caused by changed legislation and/or deterioration of the quality of the measuring process. It is interesting that Model 2 showed both shocks, while in Model 1 only the latter shock was visible. The seasonal term in Model 2 behaved almost identically to that in Model 1, including the change in its variance. Estimates for the 1979.1 dummy were also virtually identical in the two models.

The covariance structure of Model 2, as parametrised in the matrix P (see [20]) turned out to be virtually singular, and the hypothesis that $\rho_i = 0$ could not be rejected. (LR test value of 0.65 at 1 degree of freedom) This would imply that changes in a_t and b_t are perfectly (negatively) correlated, ensuring that (16) holds exactly for all periods. To give an indication of the swift convergence of the variance estimates, the parameter p_1 is plotted in Fig.7. The "blip" in 1982.1 is clearly visible.

Summarising, both models appear to have their advantages and disadvantages. In Model 1, most coefficients can be taken as constant, leading to fairly simple estimation - although the changing seasonal pattern makes regression impractical! - but even in a regression context, the parameter σ^2 could not be taken as constant. The lag pattern can be reconstructed as a nonlinear function of the estimated coefficients, but it fails to capture the changes noted in the data.

In Model 2, on the other hand, the changing lag patterns noted in practice are captured perfectly, as are the two deteriorations in measurement quality. The accordion effect is also demonstrated.

Finally, post-sample predictions were carried out for the period 1986.3 - 1987.4. The MSE for Model 2 was almost 30% lower than that for Model 1, indicating that the versatility of Model 2 pays off in improved prediction quality.

6. Conclusions

Estimating the relationship between building starts and building production in a given period turns out to be a complex econometric problem. Not only does the relation have a long and clearly nonpolynomial lag structure, this lag structure also changes over time, responding to economic contractions and expansions. Finally, the measurability of these patterns also appears to change over time, deteriorating sharply in the early 1980's.

The first problem was solved by a generalisation of the Almon lag method, which allows virtually any shape for the lag pattern the researcher wishes to impose. The second problem was solved by allowing the coefficients to change over time, leading to a State Space model. To capture the third effect, this State Space model was then estimated with a Hyperfilter, giving successive estimates of the variance parameters and spotlighting the changes in these parameters.

The end result is a highly versatile model, which will follow changes in the data faithfully : changes in the lag pattern and changes in the volatility of the lag pattern. Despite all this, the model could still be estimated reasonably simply on an ordinary PC.

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Table 1 Some estimation results (final estimates)

Model 1

	α	β	γ	δ	D
estimate	0.121	0.183	-0.048	0.368	-1.010
variance	0	0	0	0	-
MSE	0.024				

Model 2

	a	b		D
estimate	0.156	0.744		-1.036
variance	0.004	0.004		-
MSE	0.014			

Table 1 **Some estimation results (final estimates)**

Model 1

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Model 2

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variance	0.004	0.004	-
MSE	0.014		

A skewed lag pattern

"Average" lag pattern

Some sample lag patterns

Variance of seasonal term

Model 1 (Model 2 is similar)

Measurement variance

Model 1

Measurement variance

Variance of epsilon(1)