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September 1993

THE DYNAMICS OF INVESTMENT AND LABOUR DEMAND: THEORETICAL ISSUES AND AN APPLICATION TO THE DUTCH MANUFACTURING INDUSTRY

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RM 93-020

J.E.Lit.code: D92

The Dynamics of Investment and Labour Demand :

Theoretical Issues and an Application to the Dutch Manufacturing Industry

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April 1993

ABSTRACT

Lucas' (1967) adjustment costs model and Kydland and Prescott's (1982) time-to-build model induce mutually exclusive time-series properties that can be recovered from data. This paper investigates three variants of a theoretical model which give insight into the parameter restrictions implied by each of the two sources of dynamics separately. The variants, which simultaneously determine the interrelated demand for capital structures, equipment and labour, are analyzed using quarterly Dutch manufacturing data for the period 1971-1990. In a model with gestation lags, the additional dynamics induced by adjustment costs are not significant. This is not surprising since the economic interpretation of adjustment costs in addition to time-to-build is not obvious. Non-nested hyptheses tests, however, show that the two specifications imply mutually exclusive time series properties which are statistically significant.

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We gratefully acknowledge the financial support from the Netherlands Organisation for the Advancement of Pure Research (N.W.O.), the Centre de Recherche en Economie et Statistique (CREST), Paris, and the Royal Netherlands Academy of Arts and Sciences (K.N.A.W.).

1. Introduction

Large investment projects are usually not carried out within short time periods. Investment plans are made, decisions are taken and the necessary financial and/or legal permissions have to be obtained before plans can be realized. During this gestation process of an investment project (initial) plans are often revised, improved and sometimes cancelled. As emphasized by Kydland and Prescott (1982), gestation lags in the creation of physical capital can cause specific time-dependent investment fluctuations. Firms face (irreversible) investment expenditures during the gestation period, that often will only become productive when the project has been completed. The irreversibility and non-productiveness of investment expenses entail that uncertainty grows with the expected length of time-to-build. As an alternative, the (quasi-)fixedness of some production factors has been explained in terms of adjustment costs which imply that changes in production factors are costly, but become productive immediately.

The purpose of this paper is to investigate the importance of adjustment costs in a model with a multiperiod time-to-build for plants (later referred to as structures) using quarterly data for the Dutch manufacturing industry. A factor demand model is specified that encompasses Lucas' (1967) adjustment cost model and Kydland and Prescott's (1982) time-to-build model. Three variants of the model with time-to-build for structures are presented, estimated and compared : a model without adjustment costs, a model with adjustment costs for changes in the net stock of plants, and a model with adjustment costs for gross plants investments.

The paper is organized as follows. In section 2, some statistical information is presented which describes the evolution of the creation of the stock of plants in the Dutch manufacturing industry in the period 1975-1990. Measures of the average construction time of Dutch manufacturing plants are reported. The results resemble the lead times of plants that were found for other industrialized countries, like the U.S.. Section 3 describes a factor demand model for capital structures, capital equipment and labour. The dynamic specification for capital structures includes both adjustment costs and a multiperiod time-to-build. The dynamics of capital equipment and labour follow from adjustment costs. The economic interpretation of adjustment costs for structures beside time-to-build is discussed in section 4. A closed form solution of the theoretical model is derived that encompasses both dynamic specifications for capital structures. This solution is a vector ARMAX process that uncovers parameter restrictions implied by each source of investment dynamics separately. The vector ARMAX model is estimated using quarterly data series for the Dutch manufacturing industry (1971.I - 1990.IV). The estimation results are presented in section 5. Section 6 concludes.

2. Stylized Facts about the Gestation of Plants

The creation of plants starts in the pre-construction period in which designers' plans are drawn and building permits are obtained. This period is followed by the construction period in which the construction actually takes place. Statistical information about the gestation of plants in the Dutch industry is only available for the industry as a whole. The stylized facts presented in this section are concerned with reconstruction, expansions and new plants. The restorations of plants are not considered.
For new projects, reconstructions and expansions of the size of 20.000 Dutch guilders (DFL) and larger, annual data for the period 1979-1986 indicate that the orders received by architects lead the total value of building permits issued by about one year. Disaggregate data would probably show a shorter lead time. The starting date of the construction on the building site that is also determined by the available production capacity in the building industry, lags the received orders by approximately one year but follows a much smoother path than received orders and the issue of building permits.

The time-to-build becomes apparent from table 2.1.[1] The figures are expressed in DFL (in thousands) and concern reconstructions, expansions and new plant projects from 50,000 DFL onwards.
Table 2.1 shows the value-put-in-place on the building site per vintage for the period 1988.I - 1990.IV. For instance, the first column indicates that

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[1] These non-published data were obtained from the Central Bureau of Statistics (CBS, "Afdeling Bouwnijverheid").

interpretation of adjustment costs for structures beside time-to-build is discussed in section 4. A closed form solution of the theoretical model is derived that encompasses both dynamic specifications for capital structures. This solution is a vector ARMAX process that uncovers parameter restrictions implied by each source of investment dynamics separately. The vector ARMAX model is estimated using quarterly data series for the Dutch manufacturing industry (1971.I - 1990.IV). The estimation results are presented in section 5. Section 6 concludes.

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in the first quarter of 1988 in total 449,484,000 DFL were spent on the building of plants of which 2,320,000 DFL on projects that were started before 1986, 3,165,000 DFL on projects started in the first quarter of 1986, and so on. The zeros in 1986.IV and 1988.I indicate that in these periods no large projects were started.
The last row in the table gives the calculated construction time for this category of plant projects. This construction time ranges from 10 to 17 quarters.
Similar figures (not given here) for the restoration and rebuilding of plant projects for the same period and also for projects from 50,000 DFL onwards, indicate that this category has a construction time ranging from 4 to 9 quarters.
Figure 2.1 is based on the data of table 2.1. It visualizes that the distribution of investments during construction (as well as the construction time) changes over the sample period.[2]

These statistics do not reveal the variation among the projects under construction. For instance, the projects that were started before 1986 and still had to be finished in 1988.I, 1988.II, 1989.II-1989.IV concern just a few plants, whereas many other projects were finished within a short time. As a consequence, an average time-to-build can still not be determined for any of these time periods.

The classification of plants according to their individual building sum (total expenditures during construction) for 1979-1989 given in table 2.2 shows that between 1/4 and 1/5 of all (reconstructions, expansions and new plant) projects for which a building permit was issued, consisted of small projects of 20,000 - 50,000 DFL.

A weighting of the ratios of values and production per building sum class by the amount of projects per class in 1985 gives an average "time-to-build" of 13.8 months. For 1986, 1988 and 1989, these statistics are 12.6, 12.4 and 13.2 months respectively.

[2] See also Van Alphen and Merkies (1976) for the estimation of distributed lags in the construction of houses and Merkies and Steyn (1991) for the changing of lag patterns and construction periods over the business cycle (referred to as the "accordeon" effect) concerning house constructions.

Table 2.1 Time-to-build of reconstructions, expansions and new plants in the Dutch industry 1988-1990
(in thousand Dfl, projects from 50,000 Dfl onwards)

before '86	2,320	1,200	0	0	0	678	531	284	0	0	0	0
86.I	3,165	1,570	458	692	543	586	447	522	0	0	0	0
86.II	3,321	2,862	2,242	3,511	1,800	0	0	0	0	0	0	0
86.III	12,393	10,453	7,610	10,602	7,140	2,295	0	0	0	0	0	0
86.IV	4,863	0	0	0	0	0	0	0	522*	575*	415*	554*
87.I	20,872	15,358	9,965	7,717	5,136	1,926	1,188	0	0	0	0	0
87.II	60,371	29,172	13,809	10,499	1,803	1,426	748	0	0	0	0	0
87.III	112,914	44,612	15,184	13,590	10,680	5,700	1,510	0	0	0	0	0
87.IV	149,078	91,279	28,101	13,560	8,262	6,920	3,237	2,193	1,972	2,233	1,624	2,146
88.I	80,187	148,394	73,194	38,915	16,696	10,117	4,673	1,787	0	0	0	0
88.II	0	12,1988	171,493	136,780	59,398	29,848	17,426	13,696	7,609	5,110	2,615	2,590
88.III	0	0	82,667	177,399	110,659	44,844	15,617	10,957	9,061	7,144	4,800	6,300
88.IV	0	0	0	116,572	201,053	141,527	44,993	19,660	5,408	4,344	3,139	3,449
89.I	0	0	0	0	95,965	183,876	92,957	51,241	20,817	12,238	6,216	5,938
89.II	0	0	0	0	0	127,755	185,175	147,622	66,427	41,644	18,056	14,936
89.III	0	0	0	0	0	0	91,475	188,797	115,604	76,218	30,230	24,037
89.IV	0	0	0	0	0	0	0	109,606	157,075	134,962	55,654	43,054
90.I	0	0	0	0	0	0	0	0	152,175	216,133	101,379	64,716
90.II	0	0	0	0	0	0	0	0	0	149,556	196,778	166,201
90.III	0	0	0	0	0	0	0	0	0	0	88,915	212,297
90.IV	0	0	0	0	0	0	0	0	0	0	0	113,066
Total	449,454	466,888	404,723	529,837	519,135	557,498	459,977	546,365	536,670	650,157	510,021	681,288
Construction time in quarters	≥10	≥11	11	12	13	≥15	≥16	≥17	≥14	≥15	≥16	≥17

* Value before 1987

Table 2.2 Reconstructions, expansions and new plants in the industry 1979-1989

Building sum Dutch guilders x1000	Number of projects of which building permits are issued									
	1979	1980	1982	1983	1984	1985	1986	1987	1988	1989
									*	*
20-50	725	876	663	601	670	688	768	809	.	.
50-100	737	815	544	488	503	594	694	713	686	708
100-200	791	760	460	387	460	563	696	759	755	833
200-500	1092	1067	515	447	510	666	826	902	896	985
500-1,000	486	492	217	211	209	283	367	390	445	486
1,000-2,000	243	276	106	79	113	153	182	197	244	251
2,000-5,000	120	141	76	60	77	105	117	127	156	178
5,000-10,000	25	39	20	18	16	20	28	31	42	41
10,000-20,000	10	10	7	11	14	12	12	9	11	16
20,000-	3	4	2	7	3	3	5	6	0	7
Total	4232	4480	2610	2309	2575	3087	3695	3943	3235	3505

The year 1981 is missing.
* Figures missing

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Total	449,454	466,888	404,723	529,837	519,135	557,498	459,977	546,365	536,670	650,157	510,021	681,288
Construction time in quarters	≥10	≥11	11	12	13	≥15	≥16	≥17	≥14	≥15	≥16	≥17

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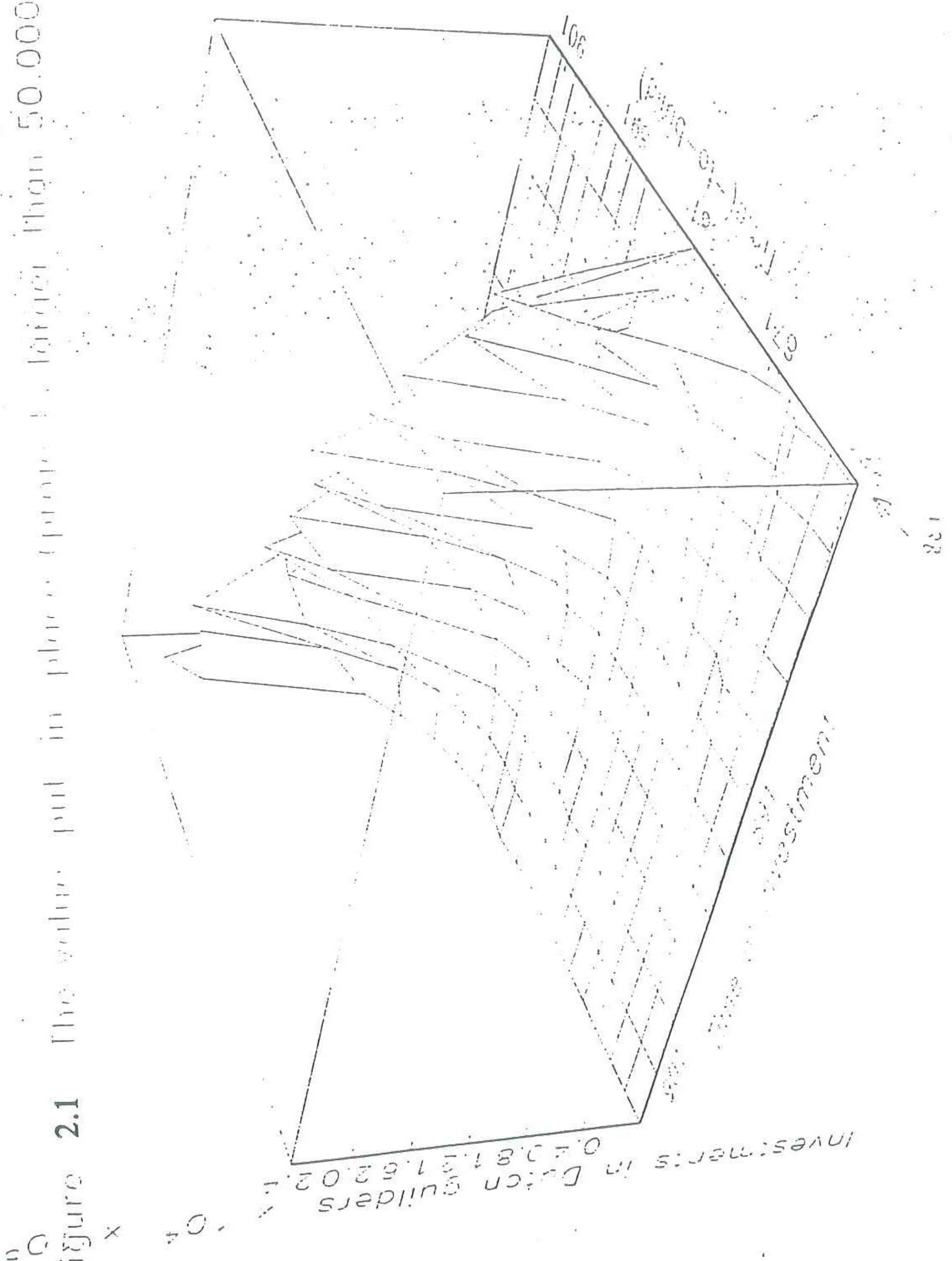
2,000-5,000	120	141	76	60	77	105	117	127	156
5,000-10,000	25	39	20	18	16	20	28	31	42
10,000-20,000	10	10	7	11	14	12	12	9	11
20,000-	3	4	2	7	3	3	5	6	0
Total	4232	4480	2610	2309	2575	3087	3695	3943	3235

Building sum Dutch guilders x1000	1989
	*
20-50	708
50-100	833
100-200	985
200-500	486
500-1,000	251
1,000-2,000	178
2,000-5,000	41
5,000-10,000	16
10,000-20,000	7
20,000-	
Total	3505

The year 1981 is missing.
* Figures missing



Reconstruction, expansions and new plants in the industry 1988.I–1990
Figure 2.1 The value put in place (projects larger than 50.000 Dfl)

To summarize, from these stylized facts it can be concluded that the construction time in the industry is about 10 to 17 quarters for new plant projects (reconstructions, expansions and new plants) and 4 to 9 quarters for the restoration and rebuilding of plants. As projects of less than 50,000 DFL were not included, the average time-to-build of construction will be less. When averaging data of building permits that were issued and taking into account the variations among projects, a time-to-build of 12 to 14 months during 1985-1989 is found.

Data on the plants' gestation also give some information about the cancellations of projects during the gestation time. During 1979-1986, 22% of all orders received by architects and 4.5% of all projects for which building permits were issued in the Dutch industrial sector were withdrawn. Information about changes in investment plans during the construction time is not available. As alterations in the construction period are not taken into account, the construction time calculated from the information in tables 2.1 and 2.2 will be biased. However, one could reason that changes in investment plans may become less likely as the gestation process proceeds. Therefore changes in investment plans during the construction period are likely to be negligibly small compared with the withdrawal rates mentioned.

The above findings are confirmed by analyses with U.S. quarterly data (1947-1960) by Jorgenson and Stephenson (1967), who estimated the average number of lags between the determinants of investment behaviour and actual investments. In a survey of individual firms, Mayer (1960) found a construction time of eleven months on average for both new plants and large additions to existing plants. Although the findings for the U.S. date back to the fifties and sixties, they closely resemble the calculated plants' construction durations for the Dutch industry.[3]

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3 In analyses for the U.S. that appeared after Kydland and Prescott's (1982) seminal paper a time-to-build of about 3 or 4 quarters is generally assumed (see e.g. Park (1984), Altug (1989)).

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3. The Theoretical Factor Demand Model

The construction process of structures has been formalized by Kydland and Prescott's (1982). Their specification for gestation lags is used in a partial adjustment cost model. To obtain linear decision rules, the production and adjustment cost functions are assumed to be linear-quadratic. The parameters of the decision rules can then be written as nonlinear functions of the underlying technology, gestation lags and adjustment cost parameters.

In order to formalize the construction process of capital stock, Kydland and Prescott (1982) specify the law of motion for capital as

$$K_t = (1 - \kappa)K_{t-1} + S_{1,t} \qquad \text{with} \qquad 0 \le \kappa \le 1 \tag{3.1a}$$

$$I_t = \Sigma_{j=1}^{J} \delta_j S_{j,t} \tag{3.1b}$$

$$\Sigma_{j=1}^{J} \delta_j = 1 \qquad \text{with} \qquad 0 \le \delta_j \le 1 \tag{3.1c}$$

and

$$S_{j,t} = S_{j+1,t-1} \qquad \text{for} \qquad j = 1,2, \ldots J-1, \tag{3.1d}$$

where K_t is the physical capital stock at the end of period t, κ is a constant depreciation (or retirement) rate and I_t is the flow of gross investments during period t.

The expenditures of the capital project that is j periods from completion during period t is represented by $S_{j,t}$. The total construction time or time-to-build equals J. If J = 1, then $I_t = S_{1,t}$. According to (3.1), at each moment (at most) J current capital projects $S_{j,t}$ (j = 1,2, ... J) exist that can be characterized by their production stage j. The capital project that is completed at the end of time period t, $S_{1,t}$, is added to the productive capital stock K_t (equation (3.1a)). Gross investments consist of the sum of the values-put-in-place $\delta_j S_{j,t}$ (j = 1,2, ... J) of the current projects at time t. Both the time-to-build and the distribution of the investments during the time-to-build (see (3.1c)) are assumed to be fixed. The last equality in the specification states that the size of a project measured by total expenditures is not changed during the period of installation. This assumption implies that once investment plans are made, they can not be revised.[4]

Equation (3.1d) can be rewritten as

$$S_{j,t} = S_{1,t+j-1} \qquad \text{for} \qquad j = 2,3, \ldots J.$$

By substituting (3.1d) in (3.1b) and using (3.1a), gross investments can be expressed as a weighted sum of current and future capital stock, that is

$$I_t = \Sigma_{j=0}^{J} \phi_j K_{t+j-1} \qquad \text{where} \qquad \phi_0 = (\kappa - 1)\delta_1$$

$$\phi_j = \delta_j + (\kappa - 1)\delta_{j+1} \quad \text{for} \quad j = 1,2, \ldots J\text{-}1$$

$$\phi_J = \delta_J. \tag{3.2}$$

A one period time-to-build ($J=1$, so $\delta_J=1$) reduces the gross investments to the sum of retirement (κK_{t-1}) and the change in net capital stock (K_t-K_{t-1}). The multi-period time-to-build ($J > 1$) sums retirement and net changes weighted by the time-to-build parameters, that is $\delta_j \kappa K_{t+j-2}$ and $\delta_j(K_{t+j-1} - K_{t+j-2})$ (for $j = 1,2, \ldots J$). The sum of the weights in (3.2) still equals the retirement rate, that is

$$\Sigma_{j=0}^{J}\phi_j = \kappa. \tag{3.3}$$

The representative firm is assumed to make a contingency plan for structures, K_t^s, equipment, K_t^e, and labour input, N_t, that maximizes the real present value of expected profits. The planning problem is formalized as

$$\underset{\{X_h^d\}_{h=0}^{\infty}}{\text{Max}} \quad E_t \, \Sigma_{h=0}^{\infty} \beta^h[(\alpha + \lambda_{t+h})'X_{t+h} - \tfrac{1}{2}X_{t+h}'AX_{t+h} - P_{t+h}'Y_{t+h} - \tfrac{1}{2}Z_{t+h}'\Gamma Z_{t+h}] \tag{3.4}$$

subject to

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[4] Park (1984) generalizes this fixed investment plans specification by allowing for revisions of the plans during the gestation period.

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[4] Park (1984) generalizes this fixed investment plans specification by allowing for revisions of the plans during the gestation period.

$$I_t^e = \Delta K_t^e + \kappa^e K_{t-1}^e \tag{3.4a}$$

$$I_t^s = \Sigma_{j=0}^{J} \phi_j^s K_{t+j-1}^s \quad , \tag{3.4b}$$

where the ϕ_j^s's are given in (3.2) with κ being replaced by the depreciation rate of structures denoted by κ^s.
The 3x1 vectors of technology shocks λ_t and real prices P_t are assumed to be generated by the following VAR(1) and VAR(p) process respectively

$$\lambda_t = R\lambda_{t-1} + \epsilon_t^{\lambda}, \qquad \epsilon_t^{\lambda} := [\epsilon_{1t}^{\lambda}\ \epsilon_{2t}^{\lambda}\ \epsilon_{3t}^{\lambda}]' \sim IIN_3(0,\Sigma^{\lambda}), \tag{3.4c}$$

where R is a matrix with elements ρ_{ij} ($i,j = 1,2,3$) and

$$P_t = \Sigma_{k=1}^{p} M_k P_{t-k} + \epsilon_t^p, \qquad \epsilon_t^p := [\epsilon_{1t}^p\ \epsilon_{2t}^p\ \epsilon_{3t}^p]' \sim IIN_3(0,\Sigma^p), \tag{3.4d}$$

where M_k is a matrix with elements μ_{ij} ($i,j = 1,2,3$).
Further are defined

$$\lambda_t := [\lambda_{1t}\ \lambda_{2t}\ \lambda_{3t}]', \quad X_t := [K_t^s\ K_t^e\ N_t]', \quad X_t^d := [K_{t+J-1}^s\ K_t^e\ N_t]',$$

$$P_t := [C_t^s\ C_t^e\ W_t]', \quad Y_t := [I_t^s\ I_t^e\ N_t]'.$$

When adjustment costs depend on net investments in structures and equipment,

$$Z_t := \Delta X_t,$$

and when they depend on gross investments,

$$Z_t := [I_t^s\ I_t^e\ \Delta N_t]'.$$

Parameters are
$\beta \in (0,1)$ being a constant discount rate,
$\alpha := [\alpha_1\ \alpha_2\ \alpha_3]'$ and $A := \text{diag}(a_1,a_2,a_3)$, where $a_i > 0$, $i = 1,2,3$, being the production function parameters and $\Gamma := \text{diag}(\gamma_1,\gamma_2,\gamma_3)$, where $\gamma_i > 0$, $i = 1,2,3$, the adjustment cost parameters,

$\kappa^i \in [0,1]$ for $i = s,e$ and

$$\delta_j \in [0,1] \text{ for } j = 1,2, \ldots J, \text{ with } J > 1. \tag{3.4e}$$

The key feature of this model is the time-to-build specification (3.4b) that forces the firm to make decisions about new structures projects, $S_{J,t}$ or K^s_{t+J-1}. As started projects can not be changed during construction, the end of the period structures stocks from t until t+J-1, K^s_t ... K^s_{t+J-1}, (instead of only K^s_t) are already determined at the beginning of time period t.

The last component of the criterium function (3.4) represents the (convex) adjustment costs. It will be assumed that net changes in labour demand incur additional costs (hiring and firing costs) at an increasing rate, so the last term Z_t equals ΔN_t. The literature on capital input dynamics is on two minds when adjustment costs are concerned. One avenue of research has focussed on costs arising from net changes in the capital stock (e.g. Treadway (1969) and Lucas (1967a)). The second avenue of research concentrated on costs induced by gross investments (Gould (1968) and Lucas (1967b)). They all assume a one period construction time, like the specification for equipment in (3.4a), in which case the difference between these two alternatives is only the depreciation because

$$\tfrac{1}{2}\gamma_2(I^e_t)^2 = \tfrac{1}{2}\gamma_2(\Delta K^e_t + \kappa^e K^e_{t-1})^2.$$

If replacement investments ($\kappa^e K^e_{t-1}$) incur costs, the specification of gross investment adjustment costs is advisable. However, the variable costs of total investment imply that revenues are obtained when there are disinvestments ($I^e_t < 0$) or, in other words, when capital is sold off. Nickell (1975) eliminates the possibility of the existence of second-hand capital stock markets, in which case the decision to invest is irreversible ($I^e_t \geq 0$) and as a consequence the gross investment adjustment cost specification is only defined for positive arguments. Especially in macroeconomic research this assumption is plausible because disinvestments

$\kappa^i \in [0,1]$ for $i = s,e$ and

$\delta_j \in [0,1]$ for $j = 1,2, \ldots J$, with $J > 1$. (3.4e)

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($I^e_t < 0$) are not observed at the aggregate level.[5]

Moreover, a multi-period construction time, like the specification for structures in (3.4b) changes the dynamic specification of adjustment costs. The adjustment costs (of plants) specifications, ACP_{1t} and ACP_{2t}, defined as

$$ACP_{1t} := \tfrac{1}{2}\gamma_1(\Delta K^s_t)^2 \text{ and } ACP_{2t} := \tfrac{1}{2}\gamma_1(I^s_t)^2 = \tfrac{1}{2}\gamma_1(\Sigma^J_{j=0}\, \phi^s_j K^s_{t+j-1})^2, \tag{3.5}$$

are not equal, even if there is no depreciation ($\kappa^s = 0$).

ACP_{1t} implies that adjustment costs occur if $S_{1,t} \neq \kappa^s K^s_{t-1}$. If the value of retirement exceeds the value of currently completed plants ($\kappa^s K^s_{t-1} > S_{1,t}$), ACP_{1t} can be interpreted as scrappage costs. The interpretation of the costs when more plants are completed than retired ($\kappa^s K^s_{t-1} < S_{1,t}$) is however far less clear. At the moment of a plants' completion, costs to install equipment and other costs to make plants usable for production are needed. But these costs can also be interpreted as adjustment costs of equipment.

The main principle of the adjustment costs theory is to penalize quick adjustments. In most factor demand models, the assumption of instantaneous and costless adjustment of changes in the labour and the physical capital stock is represented by the specification of a convex adjustment cost function (like $Z_t{}'\Delta Z_t$ in (3.4)). The convexity assumption thereby implies that one unit adjustment is more costly than twice half this same unit. Most importantly however, is the difference in economic interpretation between costs of adjustment and time-to-build. For instance, the adjustment costs of building a new plant imply that, being halfway through construction, the plant already contributes for fifty percent to the firm's production capacity, whereas time-to-build means that investments become only productive after the completion of the plant. While the two sources of dynamics are identifiable, it appears that in a model with time-to-build the additional dynamics induced by adjustment costs is economically

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5 On macro levels negative net capital stock changes ($\Delta K^s_t < 0$), let alone disinvestments, do not occur. The treatment of economic (depreciation) and technical obsolescence (retirement) of capital stock is important here. Nickell (1975), among others, pays attention to this issue.

difficult to interpret. Finally, adjustment costs and time-to-build have different implications for the dynamics of factor demand. Therefore, their relevance for explaining fluctuations in investment and labour demand can be tested using statistical information.

4. Adjustment Costs and Time-to-build : Linear Decision Rules for Capital Structures

Assuming a VAR(1) process for prices P_t in (3.4d), the model (3.4) has a closed form solution that resembles the form given in Palm, Peeters and Pfann (1992) :

$$X_t^d = C_0 + \Sigma_{j=1}^{J+1} R_j X_{t-j}^d - M^* P_t + (RM^*) P_{t-1} + \epsilon_t, \tag{4.1}$$

where $X_t^d := [K_{t+J-1}^s, K_t^e, N_t]'$

C_0 is a 3x1 vector with constants

$R_1 = R + F_1$

$R_j = F_j - RF_{j-1}$ for $j = 2,3, \ldots J$

$R_{J+1} = -RF_J$

$F_1 = \mathrm{diag}(f_{1,1}, f_{1,2}, f_{1,3})$

F_j is a 3x3-zero-matrix with only (1,1)-element $f_{j,1}$ for $j = 2,3,\ldots J$

M^* are 3x3-matrices (depend on M)

$\epsilon_t \sim IIN_3(0,\Sigma)$,

$Cov(\epsilon_{it}, \epsilon_{js}^p) = 0, \quad \forall t,s \quad i,j = 1,2,3.$

The closed form solution that results consists of a structures, an equipment, and a labour input equation that are only related by contemporaneous disturbances. In (4.1) no interrelation exists if technology shocks are assumed not to be interrelated (that is R = $\mathrm{diag}(\rho_1, \rho_2, \rho_3)$ in (3.4c)).[6] If only the contemporaneous correlations hold,

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[6] This is the case because no interrelation is assumed in the production and the adjustment costs function. If A or Γ were non-diagonal the first order conditions for structures would contain future values of both labour and equipment. As a consequence the derivation of the closed form solution is more difficult.

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each separate equation can be estimated consistently (at the loss of efficiency).

In the following paragraph, the structures equation is singled out from (3.4). This offers the opportunity to pay attention to the differences in closed form solutions when adjustment cost functions in either net capital stock or gross investments are considered. In order to emphasize the implications of adjustment costs, the model without adjustment costs is given as a benchmark model. The empirical contents of the derived equations (model 1, 2 and 3) will be discussed in section 5, together with the decision rules for labour and capital equipment.

4A. Time-to-Build and No Adjustment Costs : Model 1

The equation for K_{t+J-1}^s associated with (4.1) can be expressed in terms of gross investments[7] (e.g. Palm et al. (1992) for the derivation) where gross investments are a weighted sum of past, current and future capital stock (unlike I_t^e, see (3.4a)) and depend on many lagged technology shocks and lagged prices. Elimination of the unobserved technology shocks is done by Koyck transformation. When $\Gamma = 0$, equation (4.1) becomes

$$I_t^s = C_1 + \rho_1 I_{t-1}^s - \Sigma_{j=0}^{J+1} m_j P_{t-j} + \Sigma_{j=0}^{J} \varphi_{J-j}^s \epsilon_{1t-j}, \tag{4.2}$$

with $m_0 = \phi_J^s m^*$

$m_j = (\phi_{J-j}^s - \rho_1 \phi_{J-j+1}^s) m^*$ for $j = 1,2, \ldots, J$

$m_{J+1} = -\rho_1 \phi_0^s m^*$,

where C_1 is the constant term and ϵ_{1t} is ϵ_{1t}^λ multiplied by ρ_1^{J-1}/a_1. Equation (4.2) is the reduced form equation for gross investments with no adjustment

[7] In the empirical analyses gross investments series are used. The estimation with physical capital stock series would be preferable, but is not possible because the physical capital stock series that exist in the Netherlands is a constructed series; using a benchmark for capital stock, gross investments are added assuming that there is a one period time-to-build, which is not in harmony with the theoretical model under consideration.

costs and J gestation lags (referred to as Model 1), being an ARMAX(1,J,J+1) process; the X-part refers to the factor prices $P_{t-J-1}, \dots, P_t$. If no persistence in technology shocks is assumed ($\rho_1 = 0$), a MAX(J,J) process results.

4B. Time-to-Build and Adjustment Costs of Net Capital Stock : Model 2

If adjustment costs are induced by net changes in the capital stock ($Z_t := \Delta X_t$, $\Gamma \neq 0$), the Euler equations for capital structures can be transformed in a similar way to become

$$I^s_t = C_1 + (f_1+\rho_1)I^s_{t-1} - f_1\rho_1 I^s_{t-2} - \Sigma^{J+1}_{j=0}\, m_j P_{t-j} + \Sigma^{J}_{j=0}\, \varphi^s_{J-j}\epsilon_{1t-j}, \tag{4.3}$$

where C_1 is the constant term, ϵ_{1t} is ϵ^{λ}_{1t} multiplied by a constant, m_j is defined as in (4.2) and f_1 is the solution of $f^2 - bf + \beta^{-1} = 0$ such that $|f_1| < 1$.[8] It should be noted that in this model m^* contains many more future price predictions than m^* in model 1 (see (4.2)).

Equation (4.3) is the reduced form equation for gross investment in structures if adjustment costs are assumed for changes in the net stock of structures that have J gestation lags, and can be expressed as an ARMAX (2,J,J+1)-process. From the definition of f_1 we find that persistence in gross investments becomes higher (f_1 in (4.3) increases) when adjustment costs (γ_1) or the discount factor (β) increases, or marginal productivity decreases (by a decrease in a_1). Large increases in adjustment costs, for example, will force producers to maintain the same amount of or slowly change the productive capital stock unless productivity increases or the discount factor decreases.

Instead of assuming adjustment costs of net capital stock at period t, $\gamma_1(\Delta K^s_t)^2$, one could pose adjustment costs at period t+J-1, $\gamma_1(\Delta K^s_{t+J-1})^2$. Then the costs of the project that is initiated at period t, $S_{J,t}$ are already paid at period t, that is before the construction starts. The reduced form of this specification resembles the reduced form given in (4.3). The only

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[8] b equals $\dfrac{a_1}{\beta\gamma_1} + \dfrac{1}{\beta} + 1.$

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8 $$b \text{ equals } \frac{a_1}{\beta\gamma_1} + \frac{1}{\beta} + 1.$$

difference in structural form is the division by β^{J-1} instead of β in (4.3).

4C. Time-to-Build and Adjustment Costs of Gross Investments : Model 3

If adjustment costs are induced by gross investments ($\Gamma \neq 0$, $Z_t := [I^s_t, I^e_t, \Delta N_t]'$) the Euler equation for structures can be transformed to become

$$I^s_t = C_1 + \Sigma^{J+1}_{j=1}\, r_j I^s_{t-j} - \Sigma^{J+1}_{j=0}\, m_j P_{t-j} + \Sigma^{J}_{j=0}\, \varphi^s_{J-j}\epsilon_{1t-j} \tag{4.4}$$

with $r_1 = f_1 + \rho_1$

$r_j = f_j - \rho_1 f_{j-1}$ for $j = 2,3, \ldots, J$

$r_{J+1} = -\rho_1 f_J$

and f_j ($j = 1,2 \ldots J$) represents the roots of the characteristic equation associated with the Euler equation for K^s_{t+J-1}, and where C_0 is a constant, ϵ_{1t} is ϵ^{λ}_{1t} multiplied by a constant and m_j is defined as in (4.3) with m^* in this model representing a term that contains (much) information of future prices.

Equation (4.4) is the reduced form equation for gross structures investments if adjustment costs are assumed for gross investments and structures require J periods to be built; (4.4) is an ARMAX (J+1,J,J+1)-process. The assumption of adjustment costs of gross investments together with the fixed investment plan assumption imply an autoregressive part of Jth order. The investment projects that are started at the beginning of time period t need investments during the construction time and incur (adjustment) costs during the construction period. The fixedness of the investment plan entails that at a certain point in time adjustment costs are already determined for the part $(\Sigma^{J-1}_{j=1}\, \phi^s_j K^s_{t+j-1})^2/(I^s_t)^2$. So even if no new projects are initiated ($S_{J,t} = 0$), present investments are influenced by lagged investments. According to the convex adjustment cost assumption, $S_{J,t}$ is more costly than investing half of $S_{J,t}$ twice.
In this case the characteristic roots of the difference equation, the f_j's ($j = 1,2, \ldots, J$) in the autoregressive part, are also functions of the time-to-build parameters. The time-to-build parameters imply that $\phi_0 \leq 0$

and $\phi_J \geq 0$ (because $\kappa^s \in [0,1)$ and $\delta_j \in [0,1]$ for $j = 1,2, \ldots, J$), whereas the sign of ϕ_j ($j = 1,2, \ldots, J-1$) is unknown. Thereby, in contrast with the values of f_1 (4.3), the eigenvalues f_j ($j = 1,2, \ldots, J$) can contain imaginary parts.

The case of complex eigenvalues where $|f_j| < 1$ (and $|f_{J+j}| > 1$) ($j = 1,2, \ldots, J$) is referred to as "endogenous cycling" by Cassing and Kollintzas (1991). The cycling occurs in their general factor demand model as a result of a specified relation between the stock of production factors in the production function and the net changes in factors in the adjustment cost function. They are interested in the possibility of cycling in factor stocks (because of recursive interrelations) even in the absence of any stochastic disturbance, such as technology shocks. The model 3 is the special case of their general model where no interrelation between adjustment costs and production function is assumed, that is adjustment costs are here assumed to be "external" or the model is "strongly separable". However, model 3 takes into account gestation lags whereas their model does not.[9] In model 3 endogenous cycling is possible because of the combination of adjustment costs of gross investments and a multi-period time-to-build.

Table 4.1 summarizes the order of the three derived ARMAX-processes in this section, where r and p in this section were assumed to be both equal to one. While by selecting specific combinations of r and p one could obtain (approximately) observationally equivalent orders for the ARMAX-models, the restrictions on the parameters of these models are different and therefore the models are testable against each other.
Model 2 and model 3 are equivalent if structures require only one period to be built and are even equivalent in their structural form if above this there is no depreciation ($\kappa^s = 0$).

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Table 4.1 Plants investments models with time-to-build.

Model 1	Model 2	Model 3
Time-to-build and no adjustment costs	Time-to-build and adjustment costs of net capital stock	Time-to-build and adjustment costs of gross investments
ARMAX(r,J+r-1,J+p-1+r)	ARMAX(1+r,J+r-1,J+p-1+r)	ARMAX(J+r,J+r-1,J+p-1+r)
J = time-to-build or construction time p = autoregressive order of vector-process of prices r = autoregressive order of technology process		

The following section aims at answering two questions concerning the models summarized in table 4.1. First, given that structures need J ($\geq$ 2) periods to be built, can we analyze the relevance of investment fluctuations due to adjustment costs of either net changes of or gross investments in capital structures ? The second question to be answered is whether the adjustment costs are empirically important in addition to gestation lags. The no-adjustment cost model with a multi-period construction time (J $\geq$ 2) seems to have a richer specification than adjustment cost models without time-to-build (J = 1). Comparing the properties of both models is a non-nested testing problem because a model with only adjustment costs is compared with a multi-period time-to-build-model and the question is whether or not the two models are capable of capturing the same investment dynamics.

5. Empirical Results

5.1 Estimation

Quarterly data from the Dutch manufacturing industry (1971.I-1990.IV) are used for estimation. Investments in capital stock are disaggregated in structures (I_t^s) and equipment (I_t^e), where the structures data from the Netherlands only contain investments in plants. All time series are seasonally unadjusted. The base period is 1985.II. Quarterly dummies are included in all regressions to account for seasonal fluctuations. A description of the data is given in the appendix.

In order to estimate system (4.1), it was rewritten in gross investments. As convergence problems were encountered because of the high order moving average in each equation (see model (4.2)-(4.4) for the first equation), the time-to-build parameters were selected a priori and as a consequence the MA-part of the model was fixed prior to estimation.

For the six time series used here (I_t^s, I_t^e, N_t, C_t^s, C_t^e, W_t) unit roots and cointegration tests were carried out. With the exception of C_t^s, the series contain a unit root according to the augmented Dickey-Fuller tests (Fuller, 1976). Also four cointegration relationships in a model for the six variables were found using a Johansen-test (see Johansen and Juselius (1990)). The results indicate that factor demand is cointegrated with factor prices and that there exists one cointegration relationship between factor prices.

Table 5.1 presents the estimation results for the system of equations (see (4.1)) rewritten in gross investments. The different models 1, 2 and 3 are estimated (see (4.2)-(4.4)). Time-to-build is assumed to be 5 quarters (J = 5). The quarterly retirement rates of structures and equipment (κ^s and κ^e) are determined at 0.007 and 0.014 respectively according to retirement rates in "Statistics on stocks of capital goods" (Netherlands Central Bureau of Statistics).

The moving average part was determined prior to estimation to be linearly increasing $\delta_j = 2j/(J.(J+1))$ for $j = 1,2, \ldots, J$. This is in agreement with findings of Altug (1989) where also the investments expenditures decrease as the construction proceeds. This distribution followed from univariate analyses concerning the plant equation (see (4.2)-(4.4)).[10] Alternative specifications have been estimated. For J = 5, the above specification with $\delta_j = j/15$ yields the highest likelihood value of 600.14 (see also table 5.1). For the uniform distribution $\delta_j = 0.2$, the likelihood value is 521.69.

The hump-shape distribution $\delta_1 = \delta_5 = 1/9$, $\delta_2 = \delta_4 = 2/9$, $\delta_3 = 3/9$ yields a likelihood value of 448.67 and the model without time-to-build ($\delta_j = 0$, $j = 1,2,3,4$; $\delta_5 = 1$) has a likelihood value of 397.56. The estimates of the

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10 These results are not mentioned here because they are (statistically) inconsistent with the system (4.1); a high autocorrelation was found in the equipment and labour equation and suggest estimation of the system with interrelation (R non-diagonal).

In order to estimate system (4.1), it was rewritten in gross investments. As convergence problems were encountered because of the high order moving average in each equation (see model (4.2)-(4.4) for the first equation), the time-to-build parameters were selected a priori and as a consequence the MA-part of the model was fixed prior to estimation.

For the six time series used here (I^s_t, I^e_t, N_t, C^s_t, C^e_t, W_t) unit roots and cointegration tests were carried out. With the exception of C^s_t, the series contain a unit root according to the augmented Dickey-Fuller tests (Fuller, 1976). Also four cointegration relationships in a model for the six variables were found using a Johansen-test (see Johansen and Juselius (1990)). The results indicate that factor demand is cointegrated with factor prices and that there exists one cointegration relationship between factor prices.

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Table 5.1 Maximum likelihood estimates factor demand model with J = 5.

Dutch manufacturing industry 1974.I-1990.IV									
	Model 1			Model 2			Model 3		
R	0.88** -0.01** -0.00	0.59** 0.81** 0.06**	2.98 2.73** 0.13	0.89** -0.01 -0.00	0.63** 0.81** 0.06**	2.99 2.75** 0.13	0.80** -0.02 -0.00	0.62** 0.83** 0.07**	1.90 2.58** 0.09
M*	-5.12** -0.70** -0.04	3.33** 0.86** 0.02	2.63* 0.04 0.08**	-5.42** -0.69** -0.04	3.24** 0.86** 0.02	2.69* 0.04 0.08**	-5.44** -0.72** -0.04	3.37** 0.87** 0.03**	1.87** -0.01 0.08*
F_1	0 0 0	0 0.79** 0	0 0 0.70**	-0.05 0 0	0 0.79** 0	0 0 0.70**	0.00 0 0	0 0.80** 0	0 0 0.71**
$f_{2,1}$								0.04	
$f_{3,1}$								0.15	
$f_{4,1}$								0.11	
$f_{5,1}$								0.08	
$\Sigma \times 10^{-4}$	5.20 -1.21 -0.53	1.37 0.12	0.08	5.16 -1.15 -0.52	1.37 0.12	0.08	4.96 -1.07 -0.52	1.37 0.11	0.07
SKEW	-0.33	0.01	-0.10	-0.28	-0.46	-0.01	-0.39	-0.47	0.05
EXKURT	0.89	0.62	0.18	0.70	-0.25	0.68	1.15	-0.26	0.72
Q(2)	0.70	0.91	0.38	0.39	0.91	0.40	0.32	0.90	0.32
Q(10)	8.27	10.76	12.99	8.08	10.78	13.00	6.63	10.25	13.24
Q(20)	25.42	15.01	20.20	25.87	14.99	20.30	18.71	14.22	20.57
ARCH(4)	1.56	11.45*	3.00	1.74	11.33*	3.03	0.93	10.78*	3.04
LOGL	600.14			600.32			601.81		

* Significant at 5%-level
** Significant at 1%-level

The time-to-build parameters δ_j (j=1,2..J) are uniformly declining : $\delta_j=2j/(J.(J+1))$.
The retirement of plants and equipment (κ^s and κ^e) are 0.007 and 0.014 respectively.
Coefficients of quarterly dummies are not reported.

models with increasing investment distribution ($\delta_j = (6-j)/15$) and with investment outlays at the end of the construction time (the so-called delivery lags $\delta_1 = 1$, $\delta_j = 0$ for j = 2,3,4,5) did not give satisfactory results due to non-convergence of the estimation procedure.

Table 5.1 shows that interrelation (that is here the technology matrix R with non-zero elements) is highly significant, in particular for the interrelation with equipment. Moreover, the diagonal elements of R are less than one, indicating a stationary technology process.
The matrix of the first order process of prices, M^*, predominantly contains significant elements, but has wrong-signed element for the own-price effect of equipment (element (2,2) is positive).
Some residual autocorrelation is only found for the equipment series (and a 20-order autocorrelation for plant series in model 2). The ARCH-effect (Engle, 1982) that shows up for equipment is due to the first oil-crisis in the seventies.

The most important conclusion according to these results is that models 2 and 3 do not give rise to a significant increase in the likelihood function in comparison with model 1

Table 5.2 Maximum likelihood values factor demand model

Dutch manufacturing industry 1974.I-1990.IV			
J	Model 1 : No adjustment costs	Model 2 : Adjustment costs of net capital stock	Model 3 : Adjustment costs of gross investments
3	527.72 (32)	527.73 (33)	532.52 (35)
4	563.50 (32)	563.83 (33)	565.12 (36)
5	600.14 (32)	600.32 (33)	601.81 (37)

The numbers of the parameters (including quarterly dummies) are given in brackets.
The time-to-build parameters δ_j (j=1,2..J) are uniformly declining : $\delta_j=2j/(J.(J+1))$.
The retirement of plants and equipment (κ^s and κ^e) are 0.007 and 0.014 respectively.

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The numbers of the parameters (including quarterly dummies) are given in brackets.
The time-to-build parameters δ_j (j=1,2..J) are uniformly declining : $\delta_j=2j/(J.(J+1))$.
The retirement of plants and equipment (κ^s and κ^e) are 0.007 and 0.014 respectively.

In table 5.2 the likelihood-values are given for the same model when J = 3 and J = 4. These results also indicate that models 3 and 2 are not overwhelmingly preferable above model 1. Only when J = 3, model 3 seems to be preferred over models 2 and 1.

5.2 Comparison of the Time-to-build Model and Adjustment Costs Model

Until now based on the evidence given in section 2, a multi-period construction time of 5 quarters has been assumed for structures.

In the literature, factor demand models based on adjustment costs are predominant. The model here which incorporates both sources of dynamics can be used to test whether time-to-build, adjustment costs or both are needed to explain factor demand dynamics in manufacturing in the Netherlands.

If only time-to-build dynamics are modelled, an ARMAX(1,J,J+p) results (see table 4.1) for the structures equation. If only adjustment cost dynamics are modelled, an ARMAX(2,1,1+p) process is obtained. These two non-nested models are compared in table 5.3.

Table 5.3 Comparisons of the time-to-build model and the adjustment costs model

	The Netherlands - trivariate model	
	H0 : ARMAX(1,5,6)	H1 : ARMAX(2,1,2)
Likelihood-value	600.14 (32)	431.51 (33)
Likelihood-value*	706.40 (32)	333.66 (33)
N_0	-9.51	-16.91

The number in brackets is the number of parameters, J=5, p=1.
N_0 is the test-statistic that is N(0,1) distributed.
* These likelihood value are obtained with the predicted value(s) of the model under the other hypothesis.

This table gives the likelihood values of both models. The non-nested (Cox-) test is used here (see Pesaran and Deaton[11] (1978)) to test the H_0-hypothesis against the H_1-hypothesis and vice versa. To test H_1 against H_0, the Cox-statistic is obtained by estimating the assumed model under H_0 by fitting the predicted values of the assumed model under H_1. This likelihood-value is 706.4. The test-statistic N_0 is then obtained by comparisons of the determinants of the covariance matrices of the three models estimated and calculating an estimate of the variance. N_0, calculated to be -16.91 is standard normally distributed. This result indicates that the pure adjustment costs model is not accepted, so that it is not preferable to the time-to-build model.

On the other hand, reversion of the hypotheses gives the result (N_0 = -9.51), that is the time-to-build model is not accepted when it is compared with the adjustment cost model.

Although these test results may seem contradictory, it is a quite commor result of the test applied here. The conclusions that can be drawn fror these results are that adjustment costs can not capture dynamics modelle by a multi-period time-to-build. Above this, the time-to-build model seem also to neglect some features that are modelled by the adjustment cost model. This result differs from the findings in the previous section wher adjustment costs were found to be insignificant, if time-to-build wa implied. Both adjustment costs and gestation lags explain specifi features of the dynamics of investments in structures in the Dutc manufacturing industry. Our findings differ from those obtained by Ross (1988) using posterior odds who concludes that the time-to-buil specification is favoured approximately 2 : 1 over a first order cost-of adjustment model for U.S. manufacturing data.

5.3 Dynamic Properties of the Models

To interpret the estimation results presented in table 5.1 and t investigate the dynamics of the alternative specifications, the impuls responses (see for instance Lütkepohl (1990)) of I_t^s, I_t^e and N_t are comput for shocks in the prices, ϵ_t^p, and for technology shocks, ϵ_t^λ, using the M

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11 The tests are carried out as in Pesaran and Deaton estimating models with moving average parts, but calculating predict values without them.

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5.3 Dynamic Properties of the Models

To interpret the estimation results presented in table 5.1 and to investigate the dynamics of the alternative specifications, the impulse responses (see for instance Lütkepohl (1990)) of I^s_t, I^e_t and N_t are computed for shocks in the prices, ϵ^p_t, and for technology shocks, ϵ^λ_t, using the MA-

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representations of the decision variables and estimates from table 5.1. The graphs are given in figures 1 to 18, with the impulse order being I^s_t, I^e_t, N_t, C^s_t, C^e_t, W_t. The response of investments in plants and equipment is reversely related to labour for all price shocks. So there is a substitution effect of price shocks. The effect of a random price shock on equipment investment mimics that of structures investment. This suggests complementarity between the two types of investment. The effect of technology shocks is more complicated.

In general, the three decision variables respond in a similar way to technology shocks. Consequently, technology shocks affect the overall input of production factors simultaneously, whereas price shocks have a reallocation effect between structures and equipment on the one hand and labour on the other hand. Most importantly, as the estimates in table 5.1 already showed, the differences between the dynamics of three models are found to be small.

The Dutch manufacturing industry - model 1, 2 and 3 (see table 5.1)

Figure 1 Impulse from ϵ^{p}_{1t} to I^{s}

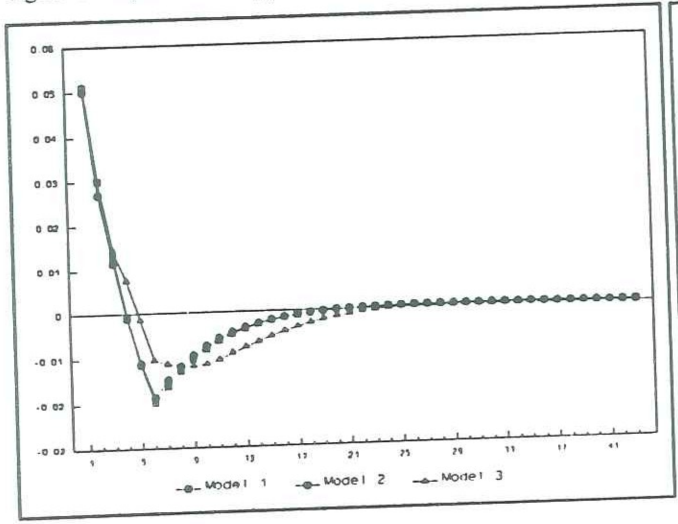


Figure 2 Impulse from ϵ^{p}_{1t} to I^{e}

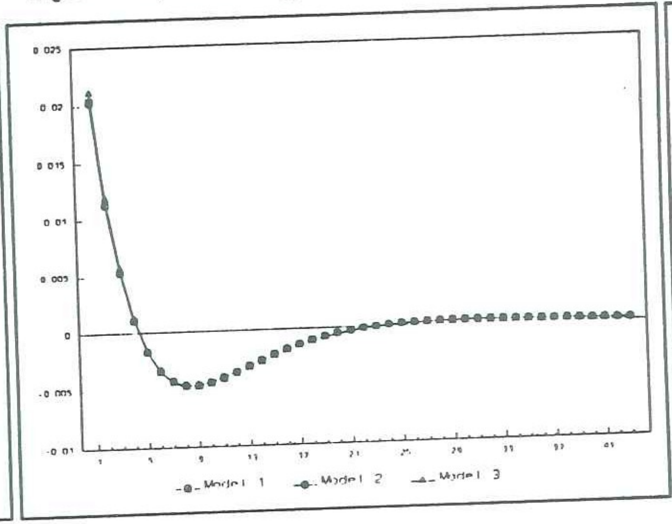


Figure 3 Impulse from ϵ^{p}_{1t} to N

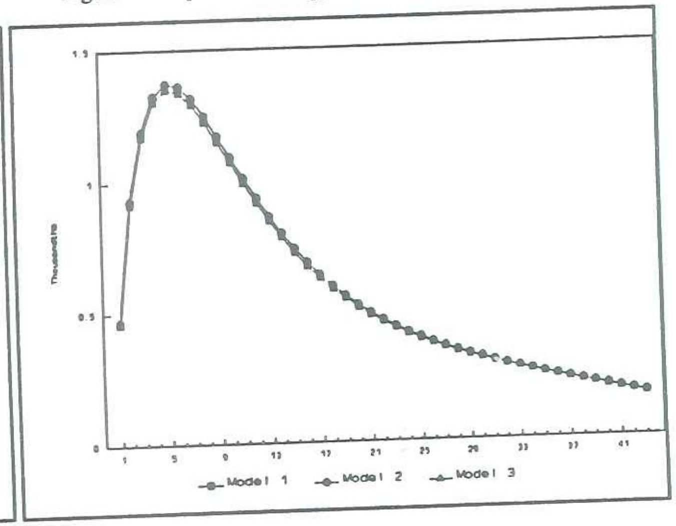


Figure 4 Impulse from ϵ^{p}_{2t} to I^{s}

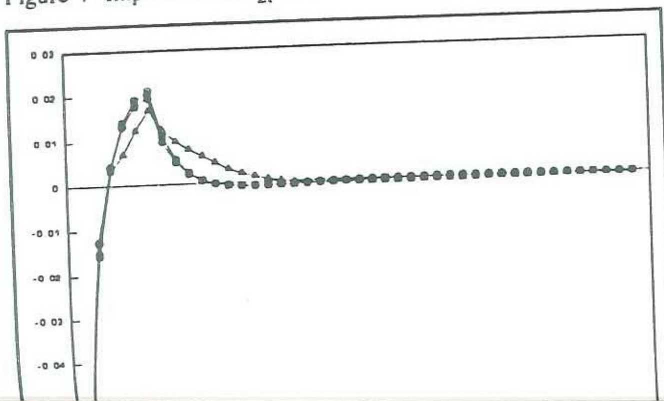


Figure 5 Impulse from ϵ^{p}_{2t} to I^{e}

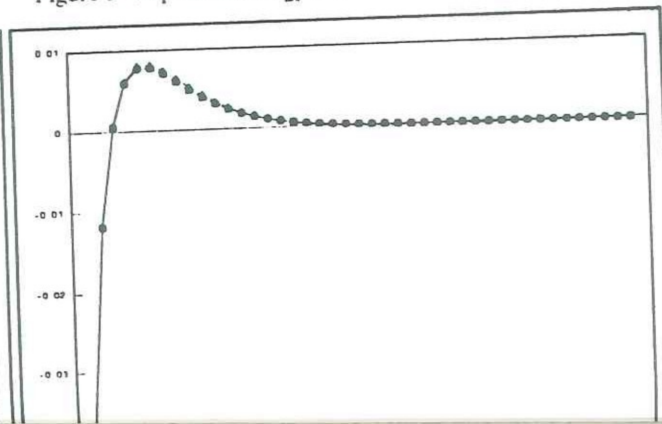
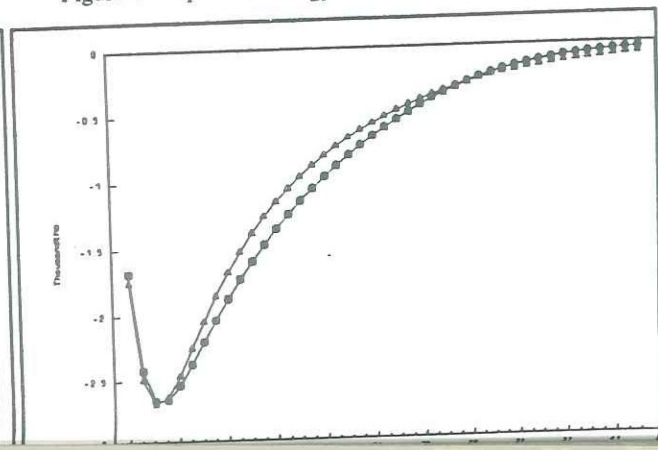


Figure 6 Impulse from ϵ^{p}_{2t} to N



The Dutch manufacturing industry - model 1, 2 and 3 (see table 5.1)

Figure 1 Impulse from ϵ^{p}_{1t} to I^{s}

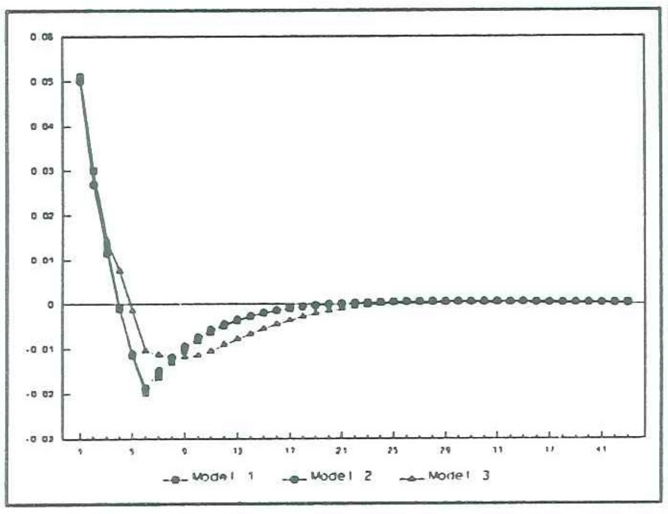


Figure 2 Impulse from ϵ^{p}_{1t} to I^{e}

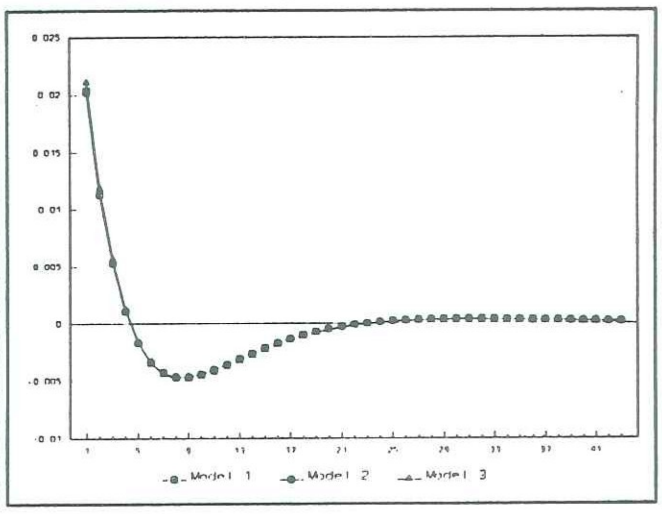


Figure 3 Impulse from ϵ^{p}_{1t} to N

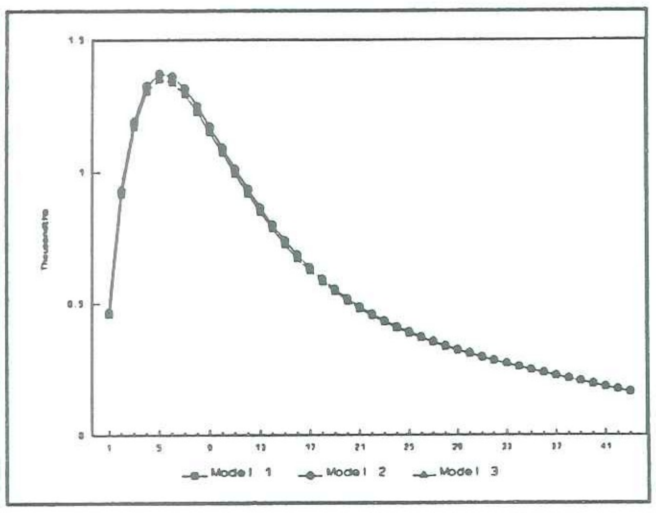


Figure 4 Impulse from ϵ^{p}_{2t} to I^{s}

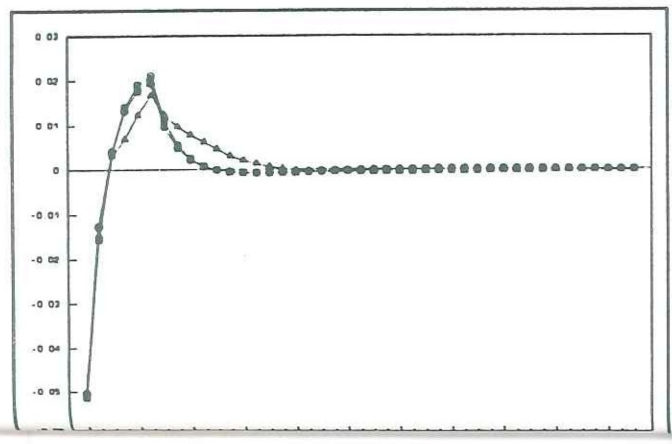


Figure 5 Impulse from ϵ^{p}_{2t} to I^{e}

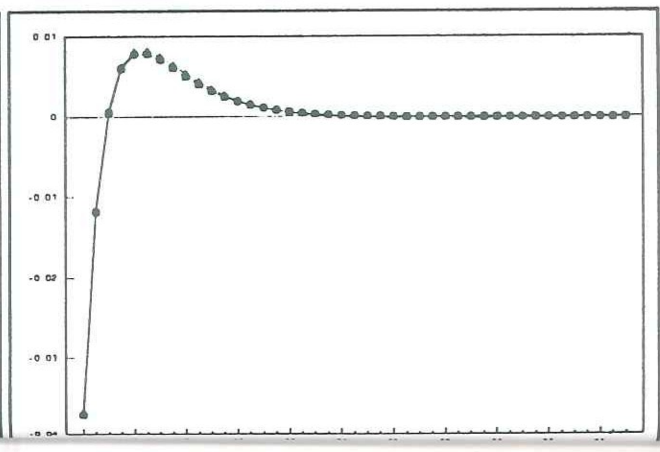


Figure 6 Impulse from ϵ^{p}_{2t} to N

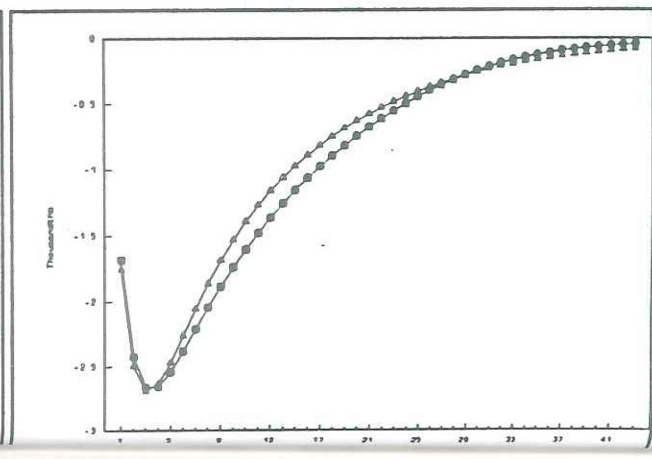


Figure 7 Impulse from ϵ^{p}_{3t} to I^{s}

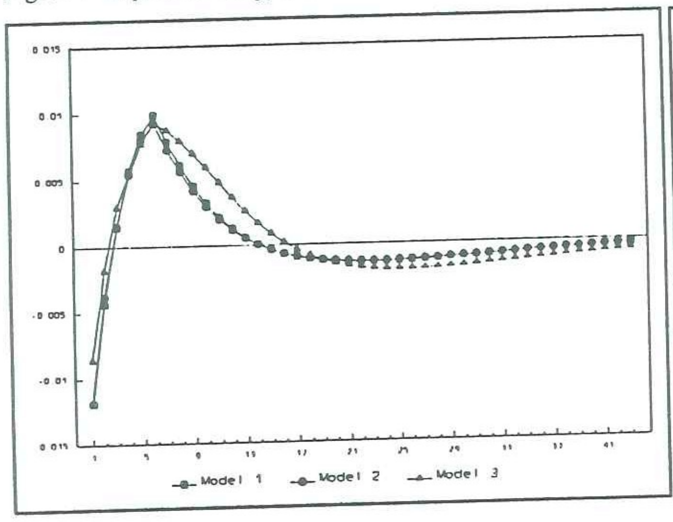


Figure 8 Impulse from ϵ^{p}_{3t} to I^{e}

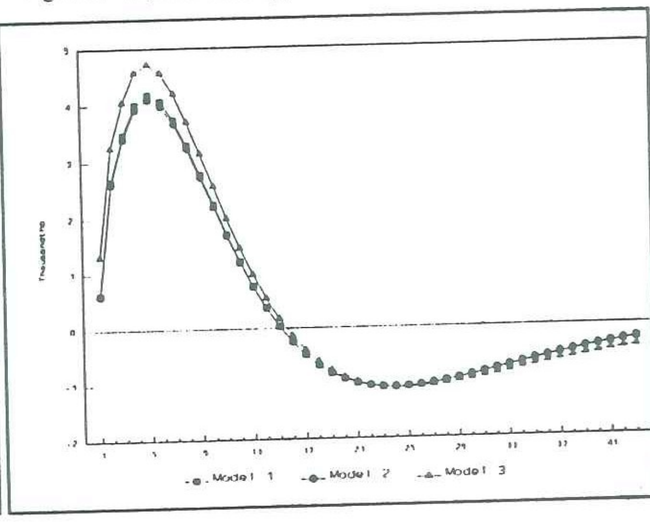


Figure 9 Impulse from ϵ^{p}_{3t} to N

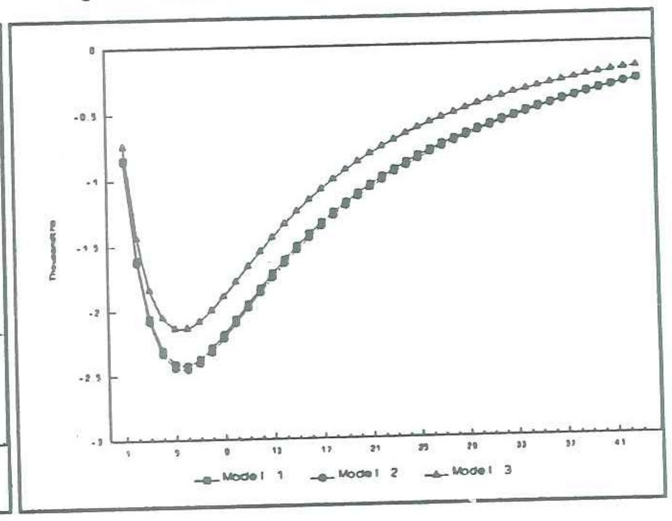


Figure 10 Impulse from ϵ^{λ}_{1t} to I^{s}

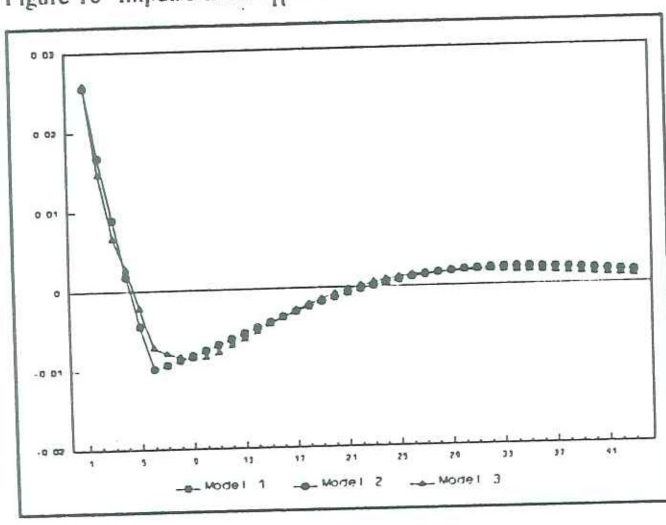


Figure 11 Impulse from ϵ^{λ}_{1t} to I^{e}

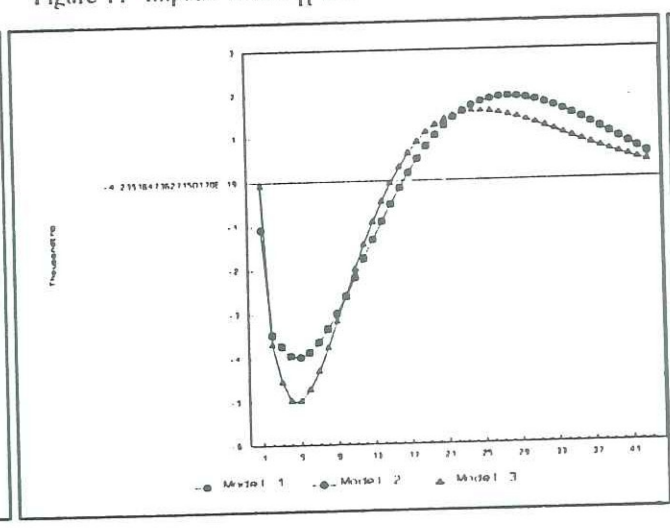


Figure 12 Impulse from ϵ^{λ}_{1t} to N

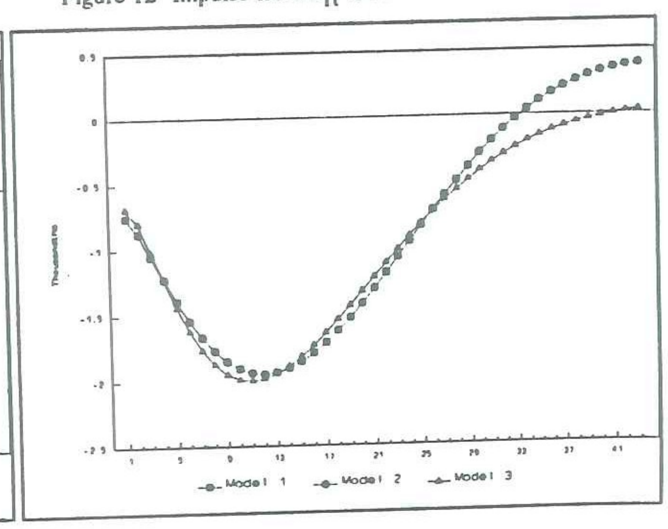


Figure 13 Impulse from ϵ^{λ}_{2t} to I^s

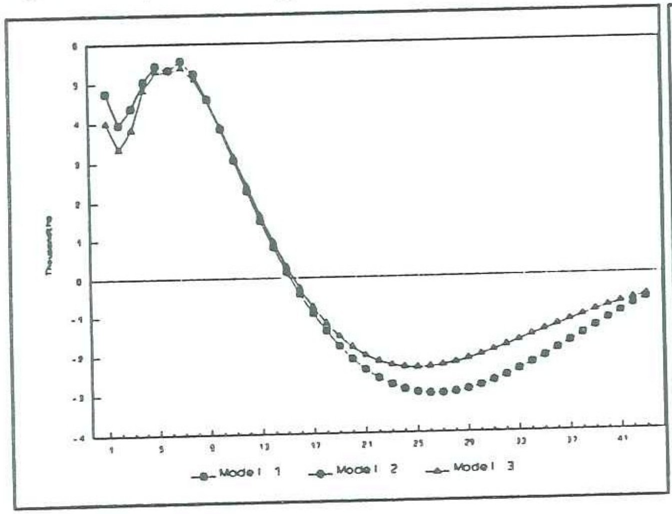


Figure 14 Impulse from ϵ^{λ}_{2t} to I^e

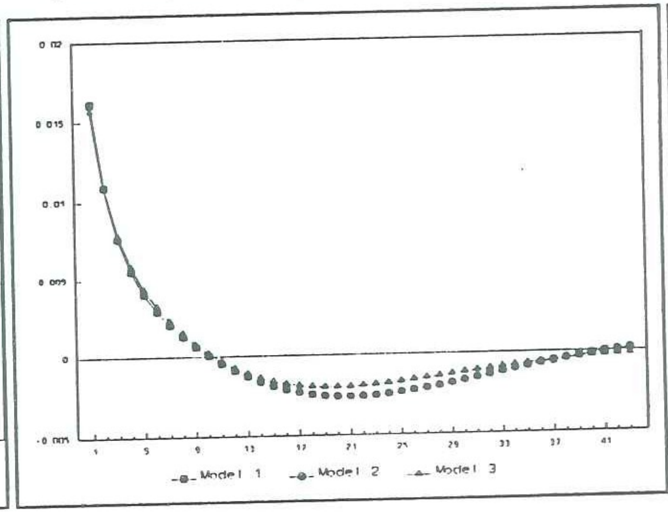


Figure 15 Impulse from ϵ^{λ}_{2t} to N

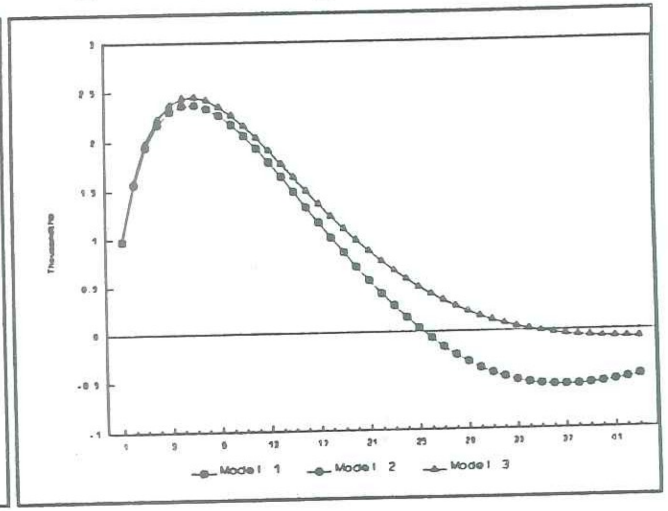


Figure 16 Impulse from ϵ^{λ}_{3t} to I^s

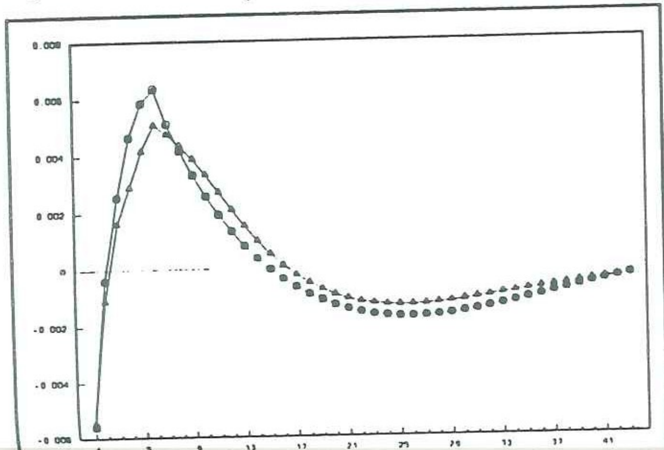


Figure 17 Impulse from ϵ^{λ}_{3t} to I^e

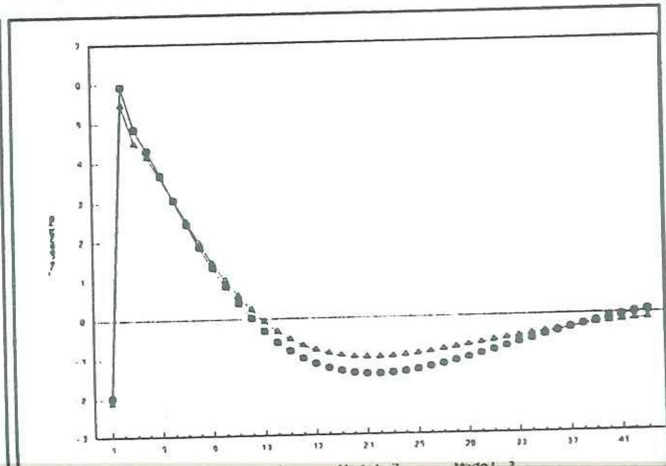
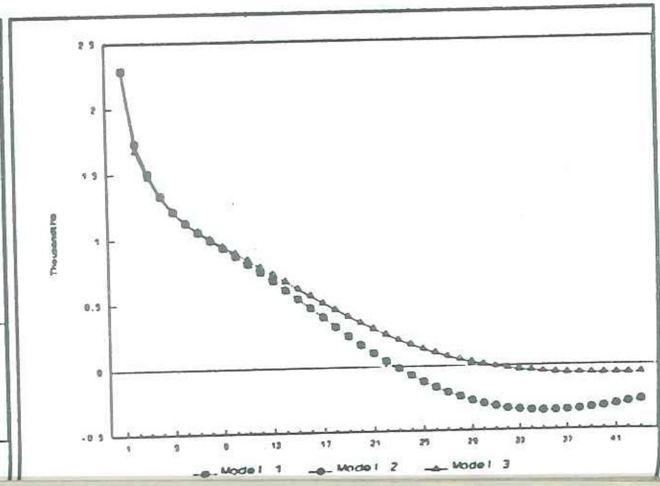


Figure 18 Impulse from ϵ^{λ}_{3t} to N



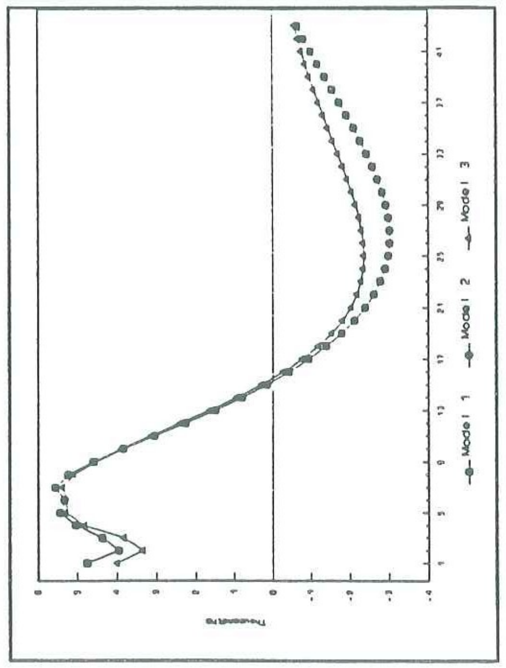


Figure 13 Impulse from ϵ^{λ}_{2t} to I^s

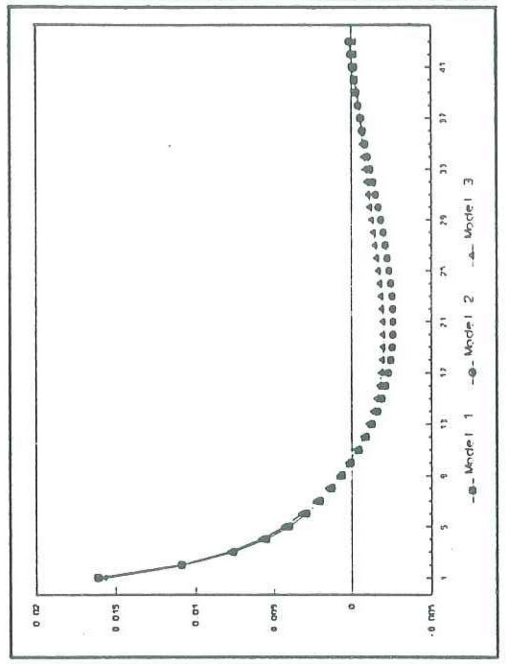


Figure 14 Impulse from ϵ^{λ}_{2t} to I^e

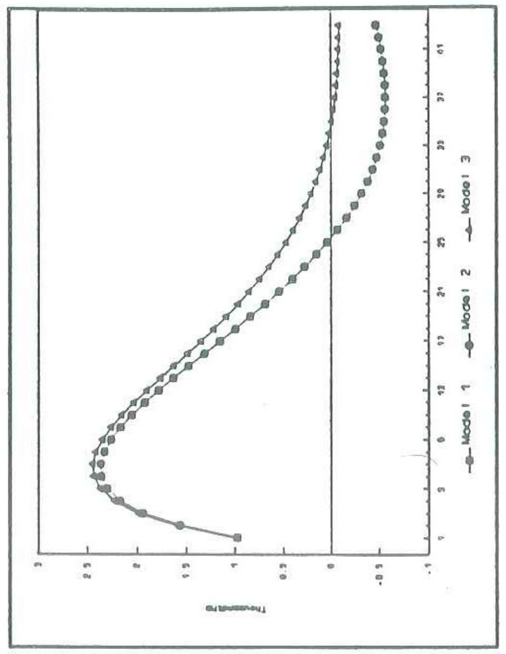


Figure 15 Impulse from ϵ^{λ}_{2t} to N

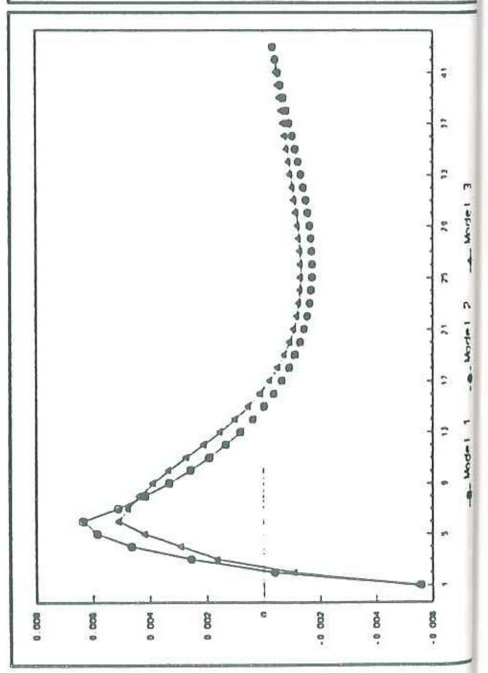


Figure 16 Impulse from ϵ^{λ}_{3t} to I^s

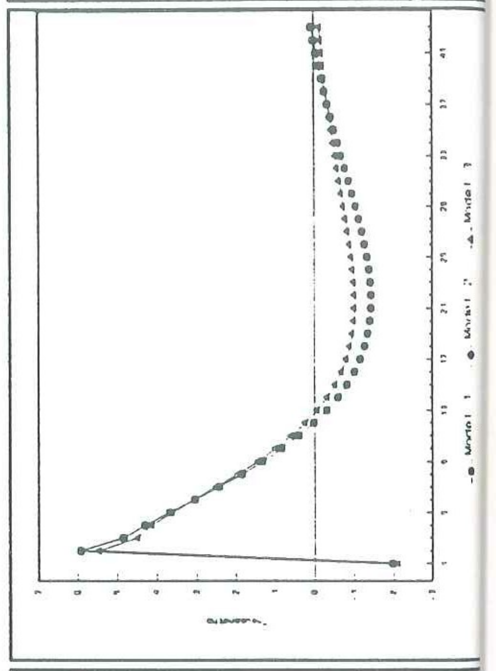


Figure 17 Impulse from ϵ^{λ}_{3t} to I^e

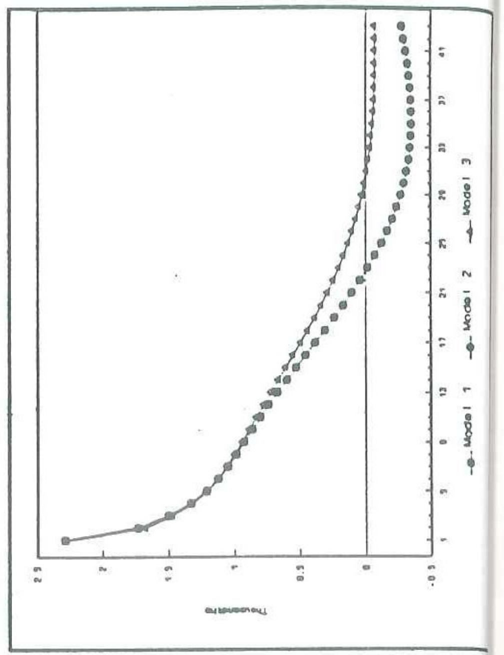


Figure 18 Impulse from ϵ^{λ}_{3t} to N

6. Conclusions

As large investment projects (like the building of plants) need a considerable time to be built, the incorporation of a multiperiod time-to-build in factor demand models for quarterly data seems realistic. The need for the inclusion of adjustment costs in addition to multiperiod time-to-build is however less evident a priori. This issue has been addressed in this paper.

A factor demand model for plants, equipment and labour was specified with adjustment costs for equipment and labour and a multiperiod time-to-build for plants. A closed form solution for the model was derived. The two different specifications for adjustment costs that prevail in the literature were analyzed together with the multi-period time-to-build assumption.

A model with interrelation between plants, equipment and labour was estimated with Dutch manufacturing industry data. In a model with gestation lags, the additional dynamics induced by adjustment costs are not significant. This is not surprising since the economic interpretation of adjustment costs on top of time-to-build is not obvious. Non-nested tests however, showed that the two specifications induce mutually exclusive time series properties, which are statistically important.

The econometric model adopted here could be extended by also taking into account more interrelation in the production function and/or interrelation in the adjustment cost function. Alternatively, the time-to-build specification could be specified in a more flexible way, like Park (1984) did.

The model could be further improved and simplified if productive physical capital stock data existed. The analyses here are inevitably carried out with gross investment data because existing and available capital stock data were not constructed in a way that is coherent with the multi-period time-to-build specification.

Further improvements could be achieved by gathering information about the form of time-to-build/gestation or delivery lags for equipment. Even a gestation time for labour, that is the period before labour becomes fully productive, could be investigated.

A final remark could be made concerning the multi-period time-to-build for structures only. In the manufacturing industry, the plants investments percentage in the Netherlands decreases from 31% in 1971 to 15% in 1990. These declines are mainly due to the big increases in the eighties of equipment investments. Therefore, the aggregation problem concerning the different time-to-build specifications in models that use aggregated physical capital stock and add both structures and equipment, should certainly deserve attention.

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APPENDIX

Data sources

MEI	*Main Economic Indicators*, Organisation for Economic Cooperation and Development (OECD), various issues, or databank DATASTREAM from the OECD
SOC	*Sociale maandstatistiek/Sociaal-economische maandstatistiek*, various issues, CBS.

Quarterly data for the Dutch manufacturing industry 1971.I - 1990.IV

The series L, I_c, I_k, P_y and W are from MEI.
Annual data on gross fixed capital formation for the manufacturing industry are disaggregated into structures (s) and equipment (e), I^i and I^i_c (i = s,e), expressed in current and constant (c) prices respectively. They are provided by the department Bedrijfstakkencoördinatie from the Central Planning Bureau (CPB) and include investments of small firms. Constant prices are of 1980. Structure investments include only plant investments and equal investments in non-residential buildings (CBS-code 2 for type of capital good). Equipment investments equal total gross manufacturing investments minus plant investments. The annual data are interpolated using the Ginsburgh method. To describe the quarterly fluctuations, the quarterly series I_c and I_k are divided in plants and equipment investments expressed in current and constant prices respectively. They are based on unpublished national quarterly data from the CBS for plants (type of capital good code 2) and equipment (type of capital good code 3, 4 and 6). As these unpublished data only exist from 1977 onwards, the distribution codes of 1977.I and 1971.I until 1977.I are assumed to be equal.
Real gross investment prices are calculated as $C^i = (I^i_c/I^i)/P_y$ (i = s,e), where P_y are producer prices of finished products (output of industry).

N denotes average weekly hours worked, that is $N = L * H$ where L and H are the number of all employees and of the weekly hours of work respectively.
H are biannual data from SOC up to 1985. Annual unpublished data from 1985 onwards were provided by the CBS. These series are interpolated into quarterly series using the Ginsburgh method.
W are hourly wage rates of the manufacturing industry deflated by P_y.

All series are seasonally unadjusted and indexed at 1985.II.