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This paper attempts to give a structural interpretation to the distributed lag of sales on investment at the two digit level in US manufacturing. It first presents a simple model which captures the various sources of lags and their respective implications. It then estimates the model, using both data on investment and sales as well as direct information on the sources of lags. The spirit of the paper is exploratory ; the model is used mainly as a vehicle to construct, present and interpret the data.

Lags in the response of investment expenditures to sales can be attributed to four main sources. The first is expectations. Investment depends on future sales, which themselves depend on current and past sales. The next two come from technology. One, costs of adjustment, is internal to the firm. The other, delivery lags, is external to the firm. Together, they imply that the firm is neither willing nor able to adjust its capital stock completely and instantaneously to movements in sales. The last source is financial. While the theory describes investment orders, data are about investment expenditures, which are related to orders by a distributed lag. Section 1 of the paper presents a model which incorporates these four sources explicitly and shows their respective implications.

Section 2 presents the basic investment and sales characteristics of each of the industries studied in the paper. It estimates a reduced form relation of investment on sales and the capital stock, showing common patterns and differences across industries.

Given the existence of data on orders and deliveries by sector of origin, one can construct direct estimates of delivery lags by type of good. Given information on the composition of capital by industry, one can construct estimates of delivery lags by sector of destination. These estimates are presented in Section 3.

Section 4 examines the stochastic behavior of sales in each industry. It shows substantial differences in univariate representations of sales across industries. There appears to be a relation between the degree of persistence of sales and the size of the effect of sales on investment, which supports the hypothesis that the stochastic behavior of sales is an important determinant of the distributed lag effect of sales on investment.

A more formal test of the theory is carried out in Section 5, through estimation of the structural model developed in section 1. The model is somewhat successful in explaining the distributed lag structures and the differences across industries through plausible structural parameters.

Section 6 reviews and assesses the main results of the paper.

Section I . A flexible accelerator model

We specify a flexible accelerator model. That is, we work under the maintained hypotheses that there is a causal relation from sales to investment, and that no factors other than sales affect investment[1]. While we do not believe that either of these two assumptions is correct, we see this shorcut as appropriate for a first look at the data[2]. We assume that investment behavior is characterized by :

$$(1)\quad I_t = \lambda\ (K^*_{t+n} - K_{t+n-1}) + \theta\ K_{t+n-1} + \xi_t\ ;\ 0 < \lambda < 1$$

$$(2)\quad K^*_{t+n} = \alpha(1-\sigma) \sum_{i=0}^{\infty} \sigma^i\ E(S_{t+n+i} | \Omega_t)\qquad ;\ 0 < \sigma < 1\ ;\ \alpha > 0$$

$$(3)\quad K_{t+n} = (1-\theta)K_{t+n-1} + I_t$$

$$(4)\quad X_t = \sum_{i=0}^{n} \omega_i I_{t-i} \qquad ; \omega_i \geq 0 \ \forall i, \sum_{i=0}^{n} \omega_i = 1$$

where :

K_t is the capital in place at the beginning of period t

K^*_{t+n} is the level of capital in place at the beginning of period t+n, desired as of time t

I_t is investment orders at time t, for delivery at the beginning of period t+n

X_t is investment expenditures in period t

S_t is sales in period t

ξ_t is a disturbance term

Ω_t is the information set at time t, which includes at least current and lagged sales.

Consider first the case where firms face costs of adjustment of capital but no delivery lags, so that n = 0. In this case, investment orders, expenditures and deliveries are identical. From equation (1), net investment is equal to a fraction λ of the gap between desired and actual capital, plus a disturbance term ; gross investment is equal to net investment plus replacement investment θK_{t-1}. Desired capital in turn depends on the sequence of expected future sales, with discount factor σ ; α is the steady state ratio of capital to sales.

Costs of adjustement give us two important parameters, a gap parameter λ and a discount parameter σ. These are not strictly speaking technological parameters, but rather functions of underlying technological parameters[3]. For example, an increase in the convexity of costs of adjustment reduces λ and increases σ : firms adjust more slowly and look at expected sales further in the future. We shall however treat them directly as structural parameters.

Consider now the case where firms also face delivery lags. Delivery lags are formalized in the simplest possible way, by assuming that capital is delivered and ready to use n periods after it is ordered[4]. This modifies all four equations. At time t, there is nothing the firm can do about its capital stock until time t+n (orders cannot be cancelled). Thus, in equation (1), orders close a fraction of the gap between the expected desired capital stock at time t+n and the actual capital stock at time t+n-1, which is known as of time t. Similarly replacement investment orders at time t are equal to θK_{t+n-1}. The expected desired capital stock at time t+n in equation (2) depends in turn on the sequence of sales from time t+n on, expected as of time t ; given the delivery lags, sales expected between t and t+n-1 have no effect on current investment decisions. Equation (3) is the modified accumulation equation. Equation (4) gives expenditures as a distributed lag on orders. The implicit assumption is that payment for capital goods is made partly on order, partly before delivery, with the remainder paid at delivery. Delivery lags introduce therefore a more complex dynamic relation both between orders and sales and between expenditures and orders.

To summarize, the dynamic relation between investment and sales depends on the characteristics of the sales process through expectations, on costs of adjustment through λ and σ, on delivery lags through n and on order-expenditure lags through $\{\omega_i\}$ $i=0,\ldots,n$. To see how they interact, we now consider a simple example.

Peristence of sales, costs of adjustment and delivery lags

Consider the case in which sales follow a stationary first order process. Ignoring constant terms for notational simplicity, let S follow :

$$S_t = \rho_s S_{t-1} + \varepsilon_{st} \; ; \; 0 \le \rho_s \le 1 \; , \; E(\varepsilon_{st} | \Omega_{t-1}) = 0, \; E(\varepsilon^2_{st} | \Omega_{t-1}) = \sigma^2_s$$

Solving for expectations in (2) and replacing in (1) gives :

$$I_t = \alpha[\lambda \; \rho_s^n \; (1-\sigma)/(1-\sigma\rho_s)] \; S_t + (\theta-\lambda)K_{t+n-1} + \xi_t$$

Thus, five coefficients affect the size of the effect of S on I, α, ρ_s, λ, σ and n. The first is the capital sales ratio and is non-dynamic. The next two, λ and σ, are functions of costs of adjustment. More convex costs of adjustment decrease λ, reducing the effect of any change in S. They also increase σ, leading firms to look over a longer horizon ; if ρ_s is less than one, this will also decrease the effect of S. Delivery lags are responsible for the term ρ_s^n. When ρ_s is less than one, this also decreases the effect of S on I.

If the effect of adjustment costs, delivery lags and persistence on the size of the effect of sales on investment is relatively straightforward, their effect on the dynamic, distributed lag relation is much less obvious. Indeed, in the above example, only current sales affect current orders. Only if sales follow a higher order process will investment orders depend on a distributed lag of sales. In that case, the lag of investment expenditures on sales will be a convolution of this lag and the order expenditure lag. Little can be said in general about this convolution ; if forecasts of future sales depend on a distributed lag of past sales with both positive and negative coefficients, some coefficients on lagged sales may well be negative.

Section 2. Basic characteristics of the data

We have selected all the 2 or 3 digit manufacturing sectors for which we had quarterly data on orders, shipments and investment expenditures, as well as associated price deflators. The result was the choice of thirteen sectors, eleven 2-digit sectors and two 3-digit sectors (motor vehicles and aircraft). Their names and mnemonics are given in the first two columns of Table 1. Orders, shipments and expenditures are directly available. Capital stock series, which are needed for estimation are constructed by accumulation of investment expenditures. Appendix A gives sources, methods of construction and other information on the data. One data problem must be mentioned in the text : shipments are collected on an establishment basis, while investment expenditures are collected on a company basis. This is not a major problem for most sectors except for Petroleum, in which a large proportion of investment expenditures by companies classified in petroleum takes place in activities largely unrelated to petroleum (see appendix A for details). The sample period is 1958-1 to 1979-3.

In examining the data, both informally here, or using econometric techniques later, we assume that investment and shipments have both a deterministic and a stochastic component. We assume the deterministic component to be the sum of an exponential time trend and seasonal dummies. Examining the data using the alternative assumption that there is no deterministic time trend would be useful but we have not done it in this paper.

The first six columns of numbers in table 1 give the estimated growth rates, the means and the standard deviations of the deviations from trend and seasonal, for investment and shipments for each sector. While we shall not focus on these deterministic components in what follows, it must be noted that there is both wide variation of growth rates among sectors, and between investment and shipments in a given sector ; this last fact is evidence of long run movements in the capital shipments ratio.

Table 1. Investment expenditures and shipments 1958-1 1979-3

	Mnemonics	Growth rates %		Means Billions 72$		Std deviations Billions 72$		α	R
		g_x	g_s	X	S	σ_x	σ_s	(K/S)	$(\sigma_x/X)/(\sigma_s/S)$
Food	FO	3.5	2.3	2.9	85.2	.3	1.6	.24	5.0
Textiles	TX	1.5	4.0	0.8	20.4	.2	1.6	.31	2.8
Paper	PA	6.0	3.6	1.8	21.6	.3	1.2	.50	3.0
Chemicals	CH	5.3	5.0	4.0	45.2	.6	3.6	.56	1.7
Petroleum	PET	3.7	3.0	5.8	22.8	.8	1.2	2.10	2.8
Rubber	RU	3.3	6.1	0.9	15.6	.2	1.2	.40	2.5
Stone, Clay and Glass	SCG	3.1	2.4	1.3	14.8	.2	0.8	.63	2.8
Primary Metals	PM	2.4	1.9	3.2	43.2	.7	4.8	.58	1.6
Fabricated Metals	FM	3.0	2.8	1.3	36.8	.2	3.6	.24	1.7
Non electrical Machinery	NEM	6.2	5.0	3.6	49.6	.6	4.0	.41	2.1
Electrical Machinery	EM	5.4	4.5	2.9	41.2	.7	4.0	.45	2.9
Motor vehicles	MV	3.5	4.4	3.2	46.4	.6	6.0	.45	1.5
Aircraft	AC	10.3	0.3	1.3	19.6	.5	3.2	.30	2.4

See appendix for definitions and construction
All variables at annual rate.

One of the reasons why investment may move more or less compared to shipments across sectors is simply the difference in their capital/shipments ratios, α. The next column gives mean capital/shipments ratios. For reasons explained above, the main outlier, petroleum, overestimates the true capital to shipments ratio, probably by a factor of 2. Otherwise, the capital/shipments ratio varies between .24 and .63.

Two sectors which are similar in all respects except in their mean capital shipments ratio, will have the same ratio of coefficient of variation of investment to the coefficient of variation of shipments. This ratio, denoted R, is given in the last column. Except for food where it is equal to 5, this ratio varies across sectors from 1.5 to 3.0.

Table 2 gives further evidence on the relation between investment and shipments, by giving, for each sector, estimates of the relation

$$X_t = b\, K_{t-1} + \sum_{i=0}^{6} c_i\, S_{t-i} + u_t \;;\; u_t = \rho\, u_{t-1} + \varepsilon_t \qquad (5)$$

We shall see in Section 5 that this equation is, under specific assumptions about the information set, the approximate reduced form of the structural model described in equations (1) to (4)[5]. The equation gives investment expenditures as depending on capital at the end of the previous quarter, on current and lagged values of shipments, up to 6 lags, and of a first order disturbance term. In addition to these variables, regressions include a constant, a deterministic exponential time trend and seasonal dummies

The coefficients on K(-1) and S to S(-6) are reported in the first seven columns. The next two columns give the sum of coefficients on shipments, Σ, and the sum divided by the mean capital shipment ratio, (Σ/α). If all sectors were the same,

Table 2. Reduced form. Investment and shipments 1959-2 to 1979-3

Sector	K(-1)	S[a]	S(-1)	S(-2)	S(-3)	S(-4)	S(-5)	S(-6)	Σ[b]	(Σ/α)[c]	L[d]	ρ	R^2[e]
FO	0.03	0.2	-1.1	0.3	-0.2	-0.3	1.9	-0.4	.00	.02	4	.87	-.04
TX	-0.18	1.7	2.2	0.1	-0.2	1.3	2.7	-0.2	.07	.24	12	.94	.05
PA	-0.18	3.0	4.7	5.1*	1.3	6.7	1.3	0.1	.22	.44	24*	.89	.24
CH	-0.21	-0.1	-2.2	5.3*	-0.6	0.4	2.8	-2.0	.04	.07	10	.94	.18
PET	-0.11	0.5	-1.7	11.6	-8.6	0.7	7.0	-3.2	.06	.03	12	.89	.05
RU	-0.00	3.0*	3.6*	2.9*	1.5	-0.7	0.1	-0.3	.10	.25	44*	.79	.41
SCG	-0.08	4.5*	4.1	3.0	5.1*	1.3	1.4	-0.0	.19	.31	16*	.91	.10
PM	-0.06	0.0	0.9	1.1	1.7*	1.6*	1.7*	0.8	.08	.13	12	.90	.05
FM	-0.12	1.5	0.5	1.4	1.2	1.6	-0.7	-0.5	.05	.20	24*	.53	.36
NEM	0.03	5.5*	3.6	2.0	5.6*	-3.5	-0.2	0.6	.13	.33	38*	.77	.36
EM	-0.03	1.5	2.9	2.3	1.7	2.9	0.7	-0.8	.11	.25	26*	.93	.21
MV	-0.03	0.8*	1.2*	2.5*	2.4*	1.9*	1.6*	0.6	.11	.24	54*	.83	.51
AC	-0.36	-0.1	2.5	4.1	1.2	0.3	2.5	2.6	.13	.43	14*	.99	.07

a : all coefficients on shipments are multiplied by 10^{-2}
b : sum of coefficients on shipments
c : sum of coefficients on shipments, divided by the capital/shipments ratio
d : value of the liklihood ratio test statistic, associated with the hypothesis that shipments do not affect investment
e : R^2 on ρ-transformed variables, after detrending and deseasonalisation
* : significant at the 5% level

except for their mean capital output ratio, (Σ/α) would be the same across sectors. The next column reports the value of the likelihood ratio test statistic, L, associated with the hypothesis that shipments play no role in explaining investment expenditures. The last two columns give the coefficient of serial correlation of the disturbance and the R^2 on the ρ-transformed variables, after taking out the deterministic trend and the seasonal component.

For four of the sectors (FO, CH, PET, PM) shipments have no significant effect on investment, and the cumulative effect (measured by Σ/α) is quantitatively small. For eight of the sectors, and for most of durable manufacturing (PA, RU and SCG in non durable manufacturing, and FM, NEM, EM, MV and AC in durable manufacturing), shipments have a very significant effect, with an average cumulative effect of .31. To get a feel for the size of this coefficient, suppose that shipments followed a random walk ; the cumulative effect of shipments as measured by Σ/α, would then be equal to λ. A coefficient of 4 [6] would then mean full adjustment of investment to the anticipated gap between desired capital and actual capital.

As we do not impose constraints on the distributed lag structure, multicollinearity implies that the shape of the lag structure is not estimated very tightly. The lag structure shows no definite pattern, and in particular no sign of smooth decay as the lag length increases ; in many sectors, coefficients on S(-1) to S(-3) are larger and more significant than the others.

In the rest of the paper, we try to explain the characteristics of these distributed lag structures and why they differ across sectors. But before we turn to this task, we must mention another characteristic of these reduced forms. For all sectors, even those where shipments are quantitatively and statistically significant, the disturbance term, which measures the effects of variables other than sales, is highly serially correlated and explains a good part of the movement in investment.

The adjusted R^2 is in most cases not very high ; its average value for the sectors in which shipments are significant is of .297. A large part of movements in investment is thus not due to shipments (This is true also when shipments are replaced by orders in (5)). Even if we were successful in explaining the effects of shipments on investment, there would be a lot left to be explained.

Section 3. Direct evidence on delivery lags

In this section, we construct direct estimates of delivery lags facing each of the sectors. We proceed in four steps. We first derive the capital composition of each sector, and then calculate the delivery lag associated with each type of equipment and structure. Next, we combine the information on capital composition and delivery lag by type of good to get average delivery lags by sector. Finally, we study whether the delivery lag associated with each type of good is approximately constant or, instead, varies cyclically with the output of the sector producing the type of capital goods.

Sectoral composition of capital

We construct a capital stock decomposition for each sector. We start from the capital flow tables, which give the amount of investment of each type for each sector, for both 1967 and 1972. We then go from these flows to stocks by using information about depreciation and growth rates for each type of good and each sector. The details of the computation are given in appendix B. The results are given in table 3.

Capital equipment comes nearly entirely from four sectors, mainly from non electrical machinery, with smaller amounts coming from fabricated metals, electrical machinery and motor vehicles. The ratio of capital equipment to structures is similar across sectors and close to unity, except for petroleum which has a much larger proportion of structures in capital.

Delivery lags by type of capital good

We use different approaches to the construction of delivery lags for structures and equipment.

Data on time to completion for different types of structures are directly available ; we therefore use them.

No such data exist on equipment and more work is needed. Of the four sectors producing equipment, only three have delivery lags ; motor vehicles may be assumed to be sold from stock. We have data on unfilled and new orders as well as on shipments for the remaining three sectors. If these sectors produced only capital goods, and if all goods were produced to order, then the ratio of unfilled orders to shipments would give a good estimate of the average delivery lag associated with these goods. These two assumptions are however strongly violated : the proportion in total sales of goods sold as capital goods is only of 4% for fabricated metals, 20% for electrical machinery and 43% for non electrical machinery. We use therefore the following approach. We assume that all capital goods are produced to order and that all sales by the producing sector to wholesalers and retailers, and only these sales, are from stock. We then estimate the mean delivery lag by

$V_i/(1-b_i)S_i$

Table 3. Composition of the capital stock by sector

Sector of origin :	FM	NEM	EM	MV	Structures
Sector of destination					
FO	.04	.34	.02	.06	.52
TX	.00	.51	.03	.03	.43
PA	.11	.41	.08	.03	.37
CH	.18	.27	.05	.03	.46
PET	.06	.08	.02	.02	.83
RU	.01	.55	.02	.02	.40
SCG	.01	.35	.04	.06	.53
PM	.06	.32	.09	.02	.50
FM	.00	.43	.05	.07	.46
NEM	.01	.44	.07	.04	.44
EM	.00	.36	.18	.03	.44
MV	.00	.53	.04	.03	.41
AC	.00	.40	.11	.05	.44

Table 4. Delivery/construction lags by type of good

	Average lag, in quarters
Fabricated metals	2
Non electrical machinery	2
Electrical machinery	3
Motor vehicles	0
Industrial structures	3-5
Commercial strctures	3-6
Other structures	4-8

Table 5. Average delivery lag, by sector of destination

	Average lag, in quarters
FO	3.4
TX	3.2
PA	3.2
CH	3.3
PET	5.3
RU	3.2
SCG	3.5
PM	3.5
FM	3.3
NEM	3.3
EM	3.5
MV	3.2
AC	3.3

where V_i, S_i and b_i are respectively mean unfilled orders, mean shipments and the proportion of shipments sold to wholesalers and retailers for sector i. (Details of construction are given in appendix B ; b_i varies between 42 and 46%). The results are given in table 4. Delivery lags appear similar across the different types of equipment ; this uniformity no doubt hides differences at a more disaggregated level. Not surprisingly, delivery lags are longer for structures than for equipment. It takes on average a year to build an industrial structure while it takes approximately six months to receive equipment.

Delivery lags by sector

All that is left to do is to combine results about sectoral composition with those about delivery lags by type of capital. Implied average delivery lags by sector of destination are given in Table 5. The main result, for our purposes, is that, except for petroleum, all sectors face very similar delivery lag structures ; the mean delivery lag varies between 3.2 and 3.5 quarters[8]. This is therefore not the source of the difference of the response of investment to shipments across sectors.

Cyclical behavior of delivery lags

Before leaving delivery lags, we return to a maintained assumption of our model, and indeed of all models which assumed a linear relation between demand and investment, namely that of constancy of delivery lags. We can use the time series on orders and shipments for the capital producing sectors to examine the validity of this assumption. If we assume that the proportion of production to order in total production is constant over the cycle, then if delivery lags are constant, the relation between orders and shipments should be constant through time. We therefore run the following regression :

Table 6. Cyclical behavior of delivery lags

	d	c	$D = \bar{D} - \sigma_D$		$D = \bar{D}$		$D = \bar{D} + \sigma_D$	
			d(D)	ML[a]	d(D)	ML	d(D)	ML
Sectors of origin :								
Fabricated metals	.29 (7.4)	$.38 \times 10^{-4}$ (4.7)	.11	.25	.29	.81	.47	1.77
Non electrical machinery	.30 (9.2)	$.12 \times 10^{-4}$ (2.9)	.23	.60	.30	.85	.37	1.17
Electrical machinery	.33	$.16 \times 10^{-4}$	.25	.66	.33	1.00	.41	1.38

Period of estimation 1958-3 to 1979-3

t statistics in parentheses

a: mean lag defined as (2d(D)/(1-d(D))

$$S_t = f \sum_{i=0}^{\infty} w_{it} O_{t-i} + e_t \; ; \; w_{it} = (1-d_t)^2 (i+1) d_t^{\,i}, \text{ where}$$

$$d_t = d + c(O_t - \overline{O}_t)$$

Under the null hypothesis of constant delivery lags, $c = 0$ so that d_t is constant and equal to d. The distributed lag of orders on shipments is taken to be a Pascal distribution, a parametrization which is convenient under both the null and the alternative hypothesis. The coefficient f is allowed to differ from one to reflect that some orders are cancelled and that not all shipments are in response to orders. The mean lag is given by $2d/(1-d)$.

Under the alternative hypothesis, c is positive and the mean lag is an increasing function of the level of demand, measured by the deviation of orders from an exponential deterministic trend and seasonals.

The relation between shipments and orders can be rewritten as :

$$S_t = 2d_t S_{t-1} - d_t^2 S_{t-2} + f(1-d_t)^2 O_t + e_t'$$

In the absence of good reasons to the contrary, we assume that e_t' , the disturbance term after transformation, is white, and estimate the above equation. Results are reported in Table 6. In addition to the estimates of d and c, we give estimates of the mean lag when deviations of orders from trend are respectively equal to plus and minus one standard deviation.

The results are quite clear and show delivery lags to be procyclical[9]. Having duly registered this result, we nevertheless proceed to estimate our model which is based on constant lags ; but these results make clear that the linear relation between investment and shipments is at best a rough approximation and that further research might uncover non-linearities.

Section 4. Dynamic behavior of sales

We have seen that whether or not an increase in current sales is expected to persist is an important determinant of the relation between investment expenditures and shipments, and that differences in processes for shipments across sectors have the potential to explain differences in the dynamic response of investment to shipments. In this section, we examine the characteristics of the univariate representation of shipments across sectors.

Table 7 presents the results of estimation of AR(4) processes for shipments. As discussed earlier, we maintain the assumption of a deterministic time trend and deterministic seasonality. Thus, we also include an exponential time trend and seasonal dummies ; their coefficients are not reported. An AR(4) representation is sufficient to capture the dynamics of the stochastic component of shipments (Q statistics are given in the table). In addition to the coefficients and their sum, table 6 presents the expected time between two successive downcrossings of the mean, which provides a measure of the length of the cycle in shipments.

Table 7 shows large variations in persistence across sectors. Food exhibits low persistence ; at the other end, textiles, fabricated metals, electrical and non electrical machinery, and aircraft exhibit high persistence. In two of these sectors (TX,AC), the hypothesis of non-stationarity cannot be rejected (using the distribution appropriate under the assumption of a unit root and the presence of a deterministic time trend in the regression). In many sectors, the degree of

Table 7. Univariate representations of shipments

	a_1	a_2	a_3	a_4	R^2	Q(27)[a]	Sum[b]	Cycle length[c]	Σ/α[d]
FO	.82	-.45	.20	-.07	.42	21.4	.50	6.6	.02
TX	1.22	-.14	-.38	.25	.90	21.0	.95	16.5	.24
PA	1.17	-.36	.07	-.07	.79	11.2	.81	12.0	.44*
CH	1.41	-.65	.09	.01	.86	18.9	.86	14.0	.07
PET	.91	-.21	.23	-.14	.64	7.6	.79	9.9	.03
RU	.94	.11	-.04	-.15	.82	14.2	.86	13.2	.25*
SCG	.88	-.30	.27	-.02	.63	33.4	.83	9.2	.31*
PM	.66	-.06	.25	-.08	.52	10.7	.77	7.8	.13
FM	1.15	-.26	.21	-.20	.89	9.6	.90	16.3	.20*
NEM	1.21	-.31	.03	-.04	.86	24.6	.89	15.4	.33*
EM	1.35	-.46	.01	.02	.91	10.6	.92	17.1	.25*
MV	.59	.11	.02	-.06	.81	9.1	.66	7.3	.24*
AC	.82	.35	-.14	-.09	.89	7.9	.94	17.9	.43*

Period of estimation 1958-4 to 1979-3

a : Q(27) is the Q statistic associated with the hypothesis that residuals are white. It is distributed $X^2(27)$. $X^2(27)$ = 40.1 at .05

b: Sum of coefficients on lagged shipments

c: Cycle length, defined as $360/\cos^{-1}(\rho)$, where ρ is the correlation between S and S(-1)

d: Normalised sum of coefficients on shipments in the investment equation, from table 2. A star indicates that the set of coefficients is significant at the 5% level.

persistence is such that, even with delivery lags of up to a year, we would expect substantial effects of current shipments on investment orders.

To see whether these differences in processes may help explain variations in the investment-shipments relation, the last column reports the normalised sum of coefficients on shipments in the investment equation, from table 2. One expects, ceteris paribus, a positive relation between persistence and the normalised sum of coefficients. There is indeed some relation between the two : the rank correlation between cycle length and the normalised sum is equal to .42, which is significant at the 10% level. The relation is however not tight ; motor vehicles for example has low persistence of shipments and a strong effect of shipments on investment. The next section provides a more formal assessment by estimating the structural investment equation implied by (1) to (4) given the sales process.

Section 5. Structural estimation

Derivation of the reduced form implied by (1) to (4)

The first step is to eliminate unobservable expectations. We assume that the information set includes only current and lagged investment expenditures and shipments, and that shipments are uncorrelated at all leads and lags with the disturbance ξ. This implies that expectations of shipments conditional on the information set are the same as forecasts of shipments using a univariate representation. This joint assumption is stronger than is needed for estimation, but allows a more intuitive interpretation of the relation between the characteristics of the shipments process presented in section 4 and the characteristics of the relation between investment and shipments[10]. Let the AR(4) process for shipments be given by :

$$S_t = a_1 S_{t-1} + a_2 S_{t-2} + a_3 S_{t-3} + a_4 S_{t-4} + \varepsilon_{st}$$

Rewriting it in companion form gives :

$$(6) \qquad Z_t = A\, Z_{t-1} + \Psi_t \;;\; Z_t' = [S_t \;\; S_{t-1} \;\; S_{t-2} \;\; S_{t-3}] \;,\; \Psi_t' = [\varepsilon_{st} \quad 0 \quad 0 \quad 0]$$

From the definition of Z_t, S_t is given by

$$S_t = \beta\, Z_t \qquad \text{where } \beta = [1 \quad 0 \quad 0 \quad 0]$$

The desired capital stock in equation (2) is then given by :

$$K^*_{t+n} = \alpha(1-\sigma)\beta\, A^n\, (I-\sigma A)^{-1}\, Z_t$$

Investment orders are given, from equation (1), by :

$$I_t = \lambda\alpha(1-\sigma)\beta\, A^n\, (I-\sigma A)^{-1}\, Z_t + (\theta-\lambda)K_{t+n-1} + \xi_t$$

Investment expenditures are given, from equation (4), by :

$$(7) \quad X_t = \lambda\alpha(1-\sigma)\beta A^n (I-\sigma A)^{-1} \sum_{i=0}^{n} \omega_i\, Z_{t-i} + (\theta-\lambda)\sum_{i=0}^{n} \omega_i K_{t+n-i-1} + \sum_{i=0}^{n} \omega_i \xi_{t-i}$$

Investment expenditures depend on three sets of terms. The first is a distributed lag of sales ; the second depends on capital from K_{t-1} to K_{t+n-1}, which determine past and current orders, and thus current expenditures ; the third depends on current and past disturbances.

Equation (7) is the equation to be estimated. Before we do so, we make two approximations :

The first follows from the fact that K_t is unobservable. We only observe expenditures, not deliveries of capital. Thus, the K series constructed by accumulation using expenditures includes capital paid for but not yet delivered. If capital goods were paid fully on order, our constructed K_t would measure the true

K_{t+n} and we could use our constructed $K_{t-n-1},\ldots,K_{t-1}$ in equation (7); if capital goods were instead paid fully on delivery, our constructed K_t would correctly measure the true K_t and we should use our constructed $K_t,\ldots,K_{t+n-1}$ in equation (7). Rather than to attempt to construct a two sided moving average of K to capture the second term in (7), we simply proxy $\Sigma\ \omega_i\ K_{t+n-i-1}$ by our constructed K_{t-1}. Given the slow movement of K compared to X, this is unlikely to be a source of major problems. It may however bias the coefficient on capital, an issue to which we shall return.

The second is in the specification of the process followed by the disturbance term in (7). If ξ_t followed an AR(1), the disturbance term would follow an ARMA(1,n). In general, the disturbance term in (7) is likely to have an MA component at least of order n. For computational convenience, we ignore this MA component and assume that the disturbance term follows an AR process. We have found that an AR(1) appears sufficient to yield white noise residuals.

With these two approximations, equation (7) becomes :

$$(8)\quad X_t = \lambda\alpha(1-\sigma)\beta A^n(I-\sigma A)^{-1} \sum_{i=0}^{n} \omega_i\ Z_{t-i} + (\theta-\lambda)K_{t-1} + u_t, \text{ where}$$

$$u_t = \rho\ u_{t-1} + \varepsilon_t$$

<u>Prior restrictions and identification</u>

The structural parameters in equation (7) are λ, σ, n, θ, α, $\{\omega_i\}_i$, ρ and the non-trivial elements of A (β is a vector of 1 and 0's). From the previous section, we have information on some of these elements, which we now use.

From section 3, we know that n, the average delivery lag is for all sectors -except petroleum- approximately equal to 3. Thus, we use n=3 in what follows[11].

In section 4, we have estimated the univariate representations of shipments. We use these estimated coefficients to construct the matrix A for each sector[12]. The combination of the assumption that n=3 and that S follows an AR(4) implies the presence of S to S(-6) in the investment equation.

This leaves the parameters λ, σ, α, θ and $\{\omega_i\}i=0,...,3$.

If the order-expenditure structure is left unconstrained, there are enough structural parameters to fit the reduced form exactly. Even if we impose that the ω_i be non negative, the model is in practice overparametrized and we are likely to end up explaining the reduced form distributed lag by a pseudo structural order expenditure lag structure. We therefore constrain the lag structure $\{\omega_i\}$ to obey :

ω_0 free

$\omega_i = (1-\omega_0)(1+\omega+\omega^2)^{-1}\omega^i$, for i = 1,2,3

Weights are exponentially declining if ω is less than unity, exponentially increasing if ω is greater than unity.

Under the above assumptions, all remaining structural parameters are identified. We have found however that our estimates of $(\lambda\alpha)$ and σ were highly correlated asymptotically. Thus, it is impossible to estimate precisely the discount parameter σ[13], and we are forced to assume rather than estimate the value of σ. This is unfortunate as σ, which measures the degree to which firms discount the future, is one of the most interesting parameters of the model. We choose a value of σ of .9 (values between .85 and .95 make little difference to the fit).

Finally, returning to equation (8), we see that we can estimate separately $(\lambda\alpha)$ and $(\lambda-\theta)$. Using the values of α and θ derived in sections 2 and 3 imposes an overidentifying restriction on λ ; using either α or θ just identifies λ. We decide to estimate $(\lambda\alpha)$ and $(\lambda-\theta)$ unconstrained. Given these estimates, we can by using the values of α and θ from the previous sections construct two estimates of λ, one from the reaction of investment to sales, and one from the effect of the past capital stock on investment.

Implied constrained reduced forms and estimated structural parameters.

Equation (8) is estimated by maximum likelihood[14]. The results of estimation of equation (8) are reported in tables 8 and 9. Table 8 reports the coefficients of the constrained reduced form and repeats for comparison the coefficients of the unconstrained reduced form already reported in table 2. Table 9 gives the values of the structural parameters.

We start with table 8. In addition to the coefficients, it gives the values ot two test statistics. The first one, L1, tests the constrained model against a model where all coefficients on shipments are equal to zero ; it shows therefore whether shipments play an important role in explaining investment in the structural model. The second one, L2, tests the constrained model, equation (8) against the unconstrained reduced form, eqúation (5) ; it shows therefore whether the constraints imposed by the structural model on the distributed lag on shipments are rejected by the data. Other things equal, high values of L1 and low values of L2 are good news for the structural model.

Table 8. Constrained and unconstrained reduced forms

Sector :		K(-1)	S[a]	S(-1)	S(-2)	S(-3)	S(-4)	S(-5)	S(-6)	ρ	L1[b]	L2[c]
FD	u	0.03	0.2	-1.1	0.3	-0.2	-0.3	1.9	-0.4	.87	.5	3.4
	c	-0.03	-0.6	-1.0	-0.5	-0.9	-0.2	0.2	-0.1	.89		
TX	u	-0.18	1.7	2.2	0.1	-0.2	1.3	2.7	-0.2	.94	7.5*	4.9
	c	-0.15	1.8	2.3	-0.1	0.2	0.6	0.2	0.1	.95		
PA	u	-0.18	3.0	4.7	5.1*	1.3	6.7	1.3	0.1	.89	1.3	24.0**
	c	-0.31	-0.4	3.3	1.2	1.1	-1.8	-0.4	0.3	.89		
CH	u	-0.21	-0.1	-2.2	5.3*	-0.6	0.4	2.8	-2.0	.94	0.2	10.5*
	c	-0.26	-0.1	0.4	0.6	1.7	-1.4	0.3	0.0	.95		
PET	u	-0.11	0.5	-1.7	11.6	-8.6	0.7	7.0	-3.2	.89	7.2*	5.2
	c	-0.11	-0.2	-8.4	10.1	-10.9	3.5	-2.0	1.6	.90		
RU	u	-0.00	3.0*	3.6*	2.9*	1.5	-0.7	0.1	-0.3	.79	34.6**	8.1
	c	0.11	2.7	3.6	2.6	1.7	-2.2	-1.6	-0.7	.82		
SCG	u	-0.08	4.5*	4.1	3.0	5.1*	1.3	1.4	-0.0	.91	14.8**	1.4
	c	-0.04	4.0	3.9	4.7	4.3	0.9	0.8	-0.1	.92		
PM	u	-0.06	0.0	0.9	1.1	1.7*	1.6*	1.7*	0.8	.90	12.0**	1.5
	c	-0.06	0.0	1.5	1.2	1.2	0.1	0.0	0.1	.94		
FM	u	-0.12	1.5	0.5	1.4	1.2	1.6	-0.7	-0.5	.53	13.0**	9.9*
	c	-0.00	1.5	0.8	1.5	1.9	-1.1	-0.5	-0.6	.55		
NEM	u	0.03	5.5*	3.6	2.0	5.6*	-3.5	-0.2	0.6	.77	32.0**	3.2
	c	0.04	5.2	2.8	4.0	4.6	-3.1	-0.4	-0.3	.79		
EM	u	-0.03	1.5	2.9	2.3	1.7	2.9	0.7	-0.8	.93	12.5**	13.6**
	c	-0.02	1.7	2.9	1.9	2.0	-1.5	0.2	0.1	.95		
MV	u	-0.03	0.8*	1.2*	2.5*	2.4*	1.9*	1.6*	0.6	.83	13.1**	40.3**
	c	-0.06	0.3	1.1	1.3	1.6	-0.2	-0.3	-0.2	.94		
AC	u	-0.36	-0.1	2.5	4.1	1.2	0.3	2.5	2.6	.99	3.7	11.1*
	c	-0.12	0.0	2.9	2.5	1.1	-0.6	-0.6	-0.2	.98		

Period of estimation 1959-2 to 1979-3
u : unconstrained, repeated from table 2
c : constrained
a : coefficients on shipments are multiplied by 10^{-2}
b : L1 is distributed $X^2(3)$
c : L2 is distributed $X^2(4)$
* : significant at the 5% level ; ** : significant at the 1% level

Examining first the values of L1 and L2 suggests the following conclusions. Overall the structural model performs well in approximately two thirds of the sectors. Looking at L1, the constrained model significantly outperforms (at the 5% level) a model with no role for shipments in 9 out of the 13 sectors. In 4 sectors (FO,PA,CH,AC), the constrained distributed lag on shipments does not help predict investment. Looking at L2, the restrictions imposed by the structural model are significantly rejected in 6 of the sectors at the 5% level, and in 3 of them (PA,EM, MV) at the 1% level.

Turning to the coefficients, the structural model is often successful at replicating the unconstrained distributed lag structure (SCG, NEM in particular). The model is able in most sectors to generate a flat, or slightly hump shaped distributed lag structure.

Being able to replicate approximately the reduced form is only good news if the underlying estimated structural parameters make sense. These are given in table 9.

Consider first the <u>order expenditure</u> lag structure implied by the estimates of ω_0 and ω. Apart from a few outliers, the results imply a relatively flat order expenditure structure, which corresponds well to the available qualitative evidence

From the estimates of $(\widehat{\lambda\alpha})$ and $(\widehat{\theta-\lambda})$, and the values of α from table 1 and of θ from table A, we construct two estimates of <u>the gap parameter λ</u>. The first one, λ_1 is obtained by dividing the estimated $(\widehat{\lambda\alpha})$ by α, and is therefore derived from the response of investment to movements in shipments. The second one, λ_2, is obtained by subtracting from θ the estimated $(\widehat{\theta-\lambda})$, and is therefore obtained from the effect of the lagged capital stock on investment. λ_1 and λ_2 are reported in the last two columns of table 9 (they are measured at annual rates. Thus, an estimated value of λ, λ, implies that investment responds within a quarter to close a proportion $(\lambda/4)$ of the gap between desired and actual capital.

Table 9. Structural parameters

	$\widehat{(\lambda\alpha)}$	$\widehat{(\theta-\lambda)}$	ω_0	ω	α^a	θ^b	λ_1^c	λ_2^d
Sector :								
FO[e]	0.072	-0.007	0.07	-0.42	0.24	0.110	0.300	0.117
TX	0.023	-0.037	0.30**	0.35*	0.31	0.112	0.074	0.149
PA	0.105	-0.077	-0.05	0.93*	0.50	0.110	0.210	0.187
CH	0.028	-0.065	-0.04	2.83*	0.56	0.106	0.050	0.171
PET	-0.125	-0.027	0.03	-1.03**	2.10	0.084	-0.059	0.111
RU	0.103**	0.027	0.19**	0.96**	0.40	0.114	0.257	0.087
SCG	0.172*	-0.010	0.27**	0.93**	0.63	0.110	0.273	0.120
PM	0.040*	-0.015	-0.33	0.68*	0.58	0.104	0.068	0.119
FM[e]	0.037	-0.001	0.20	1.53	0.24	0.119	0.154	0.120
NEM	0.141*	0.010	0.22**	1.22**	0.41	0.115	0.343	0.105
EM	0.058**	-0.005	0.13	0.99**	0.45	0.115	0.128	0.120
MV	0.141**	-0.015	0.08	1.27**	0.45	0.117	0.313	0.105
AC	0.027	-0.003	0.00	0.74**	0.30	0.116	0.090	0.119

a : capital to shipments ratio from table 1
b : depreciation rate, from table A in appendix
c : $\lambda_1 = \widehat{(\lambda\alpha)}/\alpha$
d : $\lambda_2 = \theta - \widehat{(\theta-\lambda)}$
e : Newton-Raphson not converged ; DFP results (no standard deviations reported)
* : significant at the 5% level ; ** :significant at the 1% level.

The estimated value λ_1 varies between -.05 and .35. The estimated value of λ_2 varies between .08 and .17. The average value of λ_1 is equal to .19 (so that approximately 5% of the gap is closed within the quarter) and is higher than the average value of λ_2, .12 . This result is interesting. One interpretation is that it captures the notion that investment overreacts to sales. Consider for example the case of motor vehicles : we have seen that the sales process is not very persistent but that the effect of shipments on investment is large. The structural model estiamtes therefore a large value of λ_1, consistent with low costs of adjustment. But, if costs of adjustment were low, the effect of the lagged capital stock on investment should be strongly negative and λ_2 should be large. Such is not the case ; in this sense investment appears to overreact to sales. But the result that λ_1 exceeds λ_2 can also be due to the use of a proxy for the correct capital stock series, which leads to a bias towards zero in its coefficient, and in turn to a downwards bias in λ_2

Section 6. Conclusion

We set out to give a structural interpretation to the distributed lag relation between investment and shipments at the 2 digit level. We have learned the following :

(1) Examination of the reduced form in section 2 reveals that there is no standard and robust accelerator relation between investment and shipments at that level of disaggregation. The relation between investment and shipments varies

substantially across sectors. In all sectors, a good part of investment is not explained by shipments ; indeed, in a few cases, there is no significant effect of shipments on investment.

When shipments affect investment, they do so through a long and rather flat, or hump shaped, distributed lag.

(2) Because the composition of capital is very similar across sectors, delivery lag structures facing each sector are also very similar. All industries except Petroleum face a mean delivery lag of approximately 3 quarters. Differences in delivery lags are therefore unlikely candidates to explain differences in the effects of shipments on investment across sectors.

A byproduct of our work on delivery lags is also to show that they appear procyclical. This suggests a non-linear specification of the effect of shipments on investment that we do not pursue further in this paper.

(3) Shipments follow very different processes across sectors. The processes differ significantly in their degree of persistence. There is a relation, although not a tight one, between the degree of persistence of shipments and the size of the effect of shipments on investment. This suggests that the distributed lag in the investment equation depends on the characteristics of the sales process in a way which is at least qualitatively consistent with the theory.

(4) The results of estimation of the structural model in section 5 suggest that the following model can generate roughly the distributed lag structure found in the data. Firms face delivery lags of 3 quarters. They also face adjustment costs, which imply : (1) they take all future expected sales, with discount factor .9, into consideration when constructing the desired capital stock ; and (2) they close 5% of the gap between desired and actual capital stock each quarter. They pay for orders at a constant rate between the time of order and the time of delivery.

(5) While this model can generate the long, flat or hump-shaped, distributed lag found in the data, the ability of the structural model to fit each sector and to give plausible explanations to differences across sectors is limited. The model performs poorly in some sectors. It does not attribute differences in distributed lags across sectors to any single main cause, such as differences in sales processes. In particular, it attributes these differences in part to differences in both costs of adjustment and in order expenditure lags. Although we do not have direct evidence on these costs of adjustment, it is not clear why -especially given that capital composition and delivery lags are so similar across sectors- costs of adjustment or order-expenditure lags should differ substantially across sectors. It would be interesting to examine formally how much of the differences across sectors could be explained by differences in any one element, for example differences in shipment processes with identical technologies (up to a capital shipment ratio) across sectors. We have not done it yet.

(6) We set up estimation of the structural model so as to get two separate estimates of the gap parameter. A comparison of these estimates shows the estimate obtained from the response to shipments often exceeds the one obtained from the response of investment to the lagged capital stock. The result may be explained by bias from the presence of errors in variables ; if not, it may indicate an overreaction of investment to shipments. While this result is suggestive, our model is too crude and ignores too many factors, and the difference between the two estimates often too small for us to push it too strongly.

Appendix A

1. Data Sources

For the construction of investment, orders and shipments time series :

[1] Plant and equipment expenditures, seasonally adjusted, quarterly, for manufacturing industries, constant 1972 $, 1947-1 to 1982-1, from the Bureau of Economic Analysis (tape)

[2] Manufacturers' shipments, inventories and orders, monthly, for manufacturing industries, current $, 1958-1 to 1980-12, from the Bureau of the Census M3-1-10 (tape)

[3] Implicit price deflators for shipments, monthly, 3-digit manufacturing, 1972=100, 1958-1 to 1980-12, from the Bureau of Labor Statistics (tape)

For the construction of delivery lag structures :

[4] New structures and equipment by using industries, 1972, detailed estimates and methodology, Bureau of Economic Analysis publication 035, September 1980

[5] Capital flow tables for 1967 and 1972, Survey of Current Business, September 1975 and July 1980

[6] Capital stock estimates for I/O industries : methods and data, Department of Labor, Bulletin 2034, 1979

[7] Census of Manufacturers, 1977, Volumes II and III, Industry Statistics

[8] Construction Reports, Department of Commerce, various issues (1-70, 12-70, 3-75, 12-78, 8-79, 8-80, 8-81)

2. Data Construction

SIC and I/O codes of the sectors

		SIC code	I/O code
Food	(FD)	20	14
Textiles	(TX)	22	16,17,19
Paper	(PA)	26	24,25
Chemicals	(CH)	28	27 to 30
Petroleum	(PET)	29	31
Rubber	(RU)	30	32
Stone, Clay, Glass	(SCG)	32	35,36
Primary metals	(PM)	33	37,38
Fabricated Metals	(FM)	34	39 to 42
Non electrical Machinery	(NEM)	35	43 to 52
Electrical Machinery	(EM)	36	53 to 58
Motor Vehicles	(MV)	371	59
Aircraft	(AC)	372	60

Discrepancies between establishment and company based data

Investment expenditures are collected on a company basis ; shipments and orders are collected on an establishment basis. A company may operate in sectors other than its main sector of activity. Information about activities of companies classified in a given sector can be obtained by computing the ratio of employees of these companies working in the sector to the total number of employees of these companies, using the Enterprise Statistics from the Department of Commerce and aggregating to the 2-digit level. This ratio is over 75% in all sectors except Petroleum (67%) and Motor Vehicles (59%). Employees in Motor Vehicles companies not working in the sector work however in sectors closely related to Motor Vehicles. Such is not the case for Petroleum.

Construction of Investment , Shipments and Orders

Investment series are directly obtained from [1]. Real shipments and orders series are obtained by deflation of series in [2] by price deflators constructed by aggregation of 3-digit deflators in [3], and by time aggregation from monthly to quarterly and transformation to annual rates.

Construction of the capital stock series

Time series for sectoral capital stocks are constructed using the following accumulation equation :

$$K_{it} = (1-\theta_i)K_{it-1} + X_{it}$$

where θ_i is the depreciation rate for capital of sector i. The construction of θ_i is described in appendix B.

The series is benchmarked so that the mean level of the capital stock is equal to the mean level of investment expenditures divided by the rate of growth of investment plus the rate of depreciation. This mean capital stock value is used in table 1 to compute the mean capital/shipments ratio, as the ratio of mean capital to mean shipments.

This crude computation of the mean level of capital can be compared to ratios using alternative establishment based measures of capital, such as those given in [6]. Columns 4 and 5 of table A below give respectively our estimated mean capital shipments ratio and the mean capital shipments ratio implied by [6](The two definitions of capital differ slightly and the results are not strictly comparable). The main discrepancy is for Petroleum, due to the establishment/company discrepancy discussed above.

Appendix B. Delivery lags

Construction of capital composition

Let i denote the sector, j denote the type of capital good, which may be either a type of equipment or a structure. Let θ_{ij}, g_{ij}, I_{ij}, K_{ij} be respectively the depreciation rate, the rate of growth of capital, the rate of investment and the level of capital of type j in sector i. For a given year, the following two identities hold :

$$I_{ij} = K_{ij} - (1-\theta_{ij})K_{ij}(-1)$$

$$K_{ij} = (1+g_{ij})K_{ij}(-1)$$

The above identities imply :

$$K_{ij}/K_i = ((1+g_{ij})/(g_{ij}+\theta_{ij}))I_{ij} \;/[\sum_j((1+g_{ij})/(g_i+\theta_j))I_{ij}]$$

This is the formula we use to compute capital composition. We compute the composition for two different years, 1967 and 1972 and then take the average.

Data for I_{ij} are obtained by aggregation of capital flow tables [5].

Rates of growth g_{ij} are assumed, for a given sector, to be the same across all types of equipment. Thus for each sector i, only two values of g_{ij} are computed, one for equipment and one for structures. These are computed using net capital measures from [6].

Rates of depreciation θ_{ij} for each type of equipment are assumed to be independent of the sector in which equipment is used. Thus, for equipment, $\theta_{ij} = \theta_j$ for all i. Depreciation rates for each type of capital equipment are obtained from average lives, L_j, from IRS Bulletin F lives (table 3 in [6]). These average lives are given in column 1 of table A. Depreciation rates θ_j are then constructed as $2/L_j$.

Rates of depreciation of structures are allowed to differ across sectors of destination. Average lives of structures for each sector, L_i, are computed using structure composition from [4] and lives by type of structure from table 3 in [6]. These average lives are given in column 2 of table A. Depreciation rates are computed as $2/L_i$

The implied sectoral capital compositions are reported in table 3 in the text.

Finally, the sector specific depreciation rates used to compute the time series for capital in each sector, θ_i, are computed as :

$$\theta_i = \sum_j (K_{ij}/K_i)\theta_{ij}$$

The constructed depreciation rates are given in column 3 of table A.

Construction of delivery lags by type of good

Delivery lags are computed using the formula $V_i/(1-b_i)S_i$, where V_i, b_i and S_i are respectively unfilled orders, shipments and the proportion of shipments sold to wholesalers and retailers. V_i and S_i are obtained from the [7] for 1977 and b_i is obtained from table 13a in [7]. The values of b_i are 46% for FM, 42% for NEM and 46% for EM. The implied delivery lags can be compared to estimates by the Department of Commerce (Survey of Current Business, July 1975) using a different approach ; they are very similar.

Footnotes

1. Even if we take as given that investment depends on demand, there are three possible candidates, production, orders and sales (shipments). Production data must be constructed using finished goods inventory data and are not of high quality. This leaves orders or shipments. Which one is appropriate depends on the technology. If the technology is a "referee report" technology in which orders are shelved until processed, capital requirements are more closely related to shipments. If the technology is a "pipeline" technology, in which production takes time and production starts upon receipt of orders, orders are more appropriate. Not knowing what technology is more appropriate, we have done estimation both using shipments and using orders. Because of space constraints, we only report results using shipments here ; results using orders are not qualitatively different.

2. To state more explicitly our position, we believe that the relation from shipments to investment is indeed largely causal (see Blanchard (1986)) ; we believe that the cost of capital affects investment, but our reading of empirical work is that leaving it out is unlikely to bias the coefficients on sales substantially.

3. If σ and λ are the parameters obtained from the standard quadratic cost of adjustment model, they depend on the rate at which the firm discounts profits ,β, and on the degree of convexity of the cost function and of costs of adjustment. They are related by the following : $\lambda = 1-(\sigma/\beta)$. We do not impose this relation in what follows

4. Jorgenson and Stephenson (1967) also assume that n periods elapse between the ordering of capital and the first arrival of capital. An extension would be to allow for different delivery lags. However, doing so is interesting only if capital is heterogenous. See Lucas (1965) for a discussion. This leads to too complex an empirical specification.

5. The use of "approximate" is due to the fact that, in going from the structural model to (5), two approximations are made. One is the use of K_{t-1} as an empirical counterpart to the variable implied by (1) to (4), which is unobservable. The other is in the approximation by an AR(1) of the process followed by the disturbance term. This is further discussed in Section 5.

6. Because α denotes the ratio of capital to annual shipments, λ is also expressed at annual rates. That is, for a given value λ, investment will close during a quarter $(\lambda/4)$ of the difference between desired and actual capital. This is why the number 4 rather than 1 appears in the text.

7. This result, which initially surprised us, is in fact consistent with previous studies at the sectoral level (see for example references in the surveys by Jorgenson (1971) and Uri(1982)). These studies usually report the R^2 on the original variables, which is obviously much higher. In our case for example, it always exceeds .9.

8. If we recognized explicitly the heterogeneity of capital in our model of investment and assumed for example the technology to be Leontief in the various types of capital, the longest delivery lag would be more relevant than the mean lag. Sectors would still look fairly similar.

9. Because we do not make any explicit correction for the fact that production is partly to stock, or equivalently that some of the orders are satisfied without lag from the shelf, the estimated mean lag is much shorter than the estimated delivery lag constructed earlier.

10. This joint assumption implies that investment should not help predict sales given past sales and is thus testable. It is rejected in three sectors at the 5% level, and in two (Petroleum, Aircraft) at the 1% level. Thus, for these two sectors, the results below are biased. For the other ten sectors, the assumption in the text is an acceptable first approximation.

11. We have also done estimation assuming n =4 and n=5 for Petroleum. The differences are not substantial.

12. Thus, rather than estimating (6) and (8) simultaneously, we first estimate (6) and replace A in (8) by its estimated counterpart. This procedure is much cheaper as the first estimation is linear but is less asymptotically efficient.

13. The difficulty of estimating precisely the discount rate in that type of estimation has often been documented.

14. The likelihood function is maximized using Davidon-Fletcher-Powell until convergence. Newton-Raphson is then used to obtain an estimate of the covariance matrix of the estimated parameters.

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