Title	LAGS IN INVESTMENT BEHAVIOR AND THE FIRM'S OPTIMIZATION
Sub Title	
Author	浜田, 文雅(HAMADA, Fumimasa)
Publisher	Keio Economic Society, Keio University
Publication year	1984
Jtitle	Keio economic studies Vol.21, No.2 (1984.) ,p.1- 15
JaLC DOI	
Abstract	This paper makes a survey of 28 articles of study in investment behavior with its emphasis on comparison of the average length of lags as a measure of the speed of adjustment of actual investment to the optimal level of investment. It was found that the average length of lags were too large to regard as the optimal speed of adjustment, and the more successfully the specification of investment function is done theoretically and statistically, the larger the average lags in investment behavior were. Some theoretical insights were also done.
Notes	
Genre	Journal Article
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=AA00260492-19840002-0001

LAGS IN INVESTMENT BEHAVIOR AND THE FIRM'S OPTIMIZATION

Fumimasa HAMADA*

Abstract: This paper makes a survey of 28 articles of study in investment behavior with its emphasis on comparison of the average length of lags as a measure of the speed of adjustment of actual investment to the optimal level of investment. It was found that the average length of lags were too large to regard as the optimal speed of adjustment, and the more successfully the specification of investment function is done theoretically and statistically, the larger the average lags in investment behavior were. Some theoretical insights were also done.

1. INTRODUCTION

Investment behavior has so far been analysed as to be the realization process of the firm's optimum in the long run. Most of studies along this line are based on the assumption that the firm is to maximize the sum of discounted profits expected to be earned, during the planning period, from investment in plants and equipments.

It should be emphasized that, in addition to this assumption, the firm is supposed to know, correctly, the optimal design of investment which is calculated, making use of all the informations about technological conditions that the firm actually can use, as well as about the state of the affairs to be expected in the future in the meanings as indicated by J. M. Keynes[1] more realistically. The realization process, therefore, is assumed to work as if the firm knows its optimal position exactly, at the beginning-of-period, and there is no gap between the optimal demand for the producers' durable goods that the firm knows and the true optimal demands based on the true technological conditions the firm faces on and it actually use in the production process.

Otherwise, the firm can not or may not estimate productivity of labor and capital respectively, mainly because of short of informations about the state of

* The author is grateful to Professor Lawrence R. Klein for his comments on this study on the earlier stage. He is also thankful to Professors Takatoshi Ito, Edward Foster, Craig Swan, and other faculty members of the Department of Economics, University of Minnesota for their discussions and comments, while he was staying as a visiting professor at University of Minnesota. R. Chida, Y. Maeda, and K. Kaneda assisted him to gather the articles for the survey, and to make calculation of statistics for this study.

This study was financially supported by the Grant-in-Aid for Scientific Research of the Ministry of Education [Type-A: 57330002], and by the funds from the Scholars Exchange Program of 1983 fiscal year between University of Minnesota and Keio University.

[1] Keynes (1936).

affairs at present and in the future.

If there takes place some sort of technological progress, particularly as developed within firm, or if the firm has a tendency or propensity to underestimate, in its nature, productivities of labor and capital, because of taking into account the risk and uncertainty in the commodity market, then another type of gap may be brought on through the firm's unintended or intended decisions.

This paper has two purposes. The first is to make a survey of the articles on study in investment behavior with its emphasis on comparison of the average length of lags as a measure of the speed of adjustment to the optimal level of investment of firm. The reason why to obtain average lags and to compare them with each other is to know whether or not the average lag has a length reasonable enough to regard as to show the optimal speed of adjustment, when the firm knows its optimal design of investment and it intends to make adjustment of the actual level of investment to its optimal. I will show the answer is no.[2] The second is to make a theoretical insight to an empirical evidence that the calculated values of the average length of lags extracted from those studies seem to be too long to understand as the speed of adjustment to the optimal investment which the firm is supposed to know correctly at its decision.

In Section 2, a rule for making comparison of studies in the articles under survey. In Section 3, a comparison of the average lags is made in those studies, and some considerations about the fact-findings are also made to summarize what they imply as a whole. Finally, in Section 4, I will make an attempt to present a theoretical insight about an empirical evidence extracted from this survey.

2. A RULE FOR COMPARISON OF THE LAG STRUCTURES

Since this study is concentrated on the comparison of the speed of adjustment of firm's investment, it seems that the average value of the lag-distribution is an appropriate measure for this purpose. Suppose, the investment behavior with the general form of distributed lags can be written as a following simple function:

$$I_t = W(L)y_t + V(L)Z_t + e_t\,, \tag{1}$$

where I_t is the volume of fixed investment; y_t, change in output; z_t, a vector of other determinants; e_t, a random disturbance at period t in real terms respectively. Needless to say, $E(e_t)=0$ and $E(e_t^2)=\text{const.}$, and $W(L)$ and $V(L)$ are lag functions respectively the form of which may be a rational or a polinomial type of some degree, and $W(1)$ and $V(1)$ are long-run coefficients of y_t and z_t respectively.

Define $T_m[W(L)]$ as the average value of the lag distribution $W(L)$, and $T_m[V(L)]$, as that of the lag distribution $V(L)$. Then these average values can be

[2] After I had finished this work, I found the same sort of survey article, Jorgenson (1971). But he just mentioned a large average lag is caused by using Koyck type lag distribution. In my study, I can show that this is not correct too.

written as below[3]:

$$(2) \qquad T_m[W(L)] = W'(1)/W(1) \quad \text{and} \quad T_m[V(L)] = V'(1)/V(1).$$

Now, it seems conceivable that the larger the average value of a lag distribution is, the more slowly the actual level of investment may be adjusted to its final target value by the firm. If this idea is correct as in an analysis of the lag distribution, a comparative analysis of investment behavior along this line may be appropriate, and the empirical results presented in the articles under survey can be classified on this criterion.

Needless to say, it may be necessary to take into account the differences of sample period, type of sample (cross section or time series), individual firms, industry or higher aggregates, and so forth. It is, however, very difficult to analyse the difference of sample periods, since we do not have information enough to do it. It may be rather easier to consider of the differences between the empirical results from cross section data and those from time series data, since the former reflect more long-run like aspects of investment behavior than the latter, so that the computed average value may turn out to be underbiased, because the marginal coefficient of each determinant variable may be estimated as a long-run estimate.[4]

3. COMPARISON OF THE AVERAGE LAGS

There are so many studies in investment behavior published on academic journals, that it may be almost difficult to cover all the studies. In this study, I have been obliged to confine myself to only four journals including Review of Economics and Statistics, Econometrica, American Economic Review, and Economic Studies Quarterly in principle. I also confined myself within doing a survey of the articles published since 1960.

As well known, there are many sorts of hypotheses so far adopted in studies on investment behavior. It seems, however, that they can be classified into four types in principle; that is, they are the flexible accelerator, "A", the accelerator-residual funds (or profits), "AP", the profit maximization, "PM", and the simple stock adjustment, "SA" respectively. The lag patterns adopted can also be classified into four types; that is, Koyck lag, the distributed lags without restriction, "NC", the polinomial function, "P", and the rational function, "R".

Using notations described above, twenty eight articles reporting estimates of the parameters of the lag distribution were kept under consideration. Tables 1–10 show a summary of the results of a comparison of the average length of lag distributions under the survey. The first column shows the authors and the years of publication of their articles, which can directly be referred to the reference in the

[3] See, for instance, Griliches (1967) or Maddala (1977).
[4] See Kuh (1963).

TABLE 1. COMPARISON OF THE AVERAGE LENGTH OF LAGS

Authors (years)	Type of model	Type of lag	Period & sample	Tm	RR
Eisner (1960)	A&P	NC (−3)	1955.C U.S. All firms	1.66	0.362
			Nonfinancial corporations	1.56	0.363
			All firms adjusted	1.29	0.304
			Food & Tobacco	−1.88	0.439
			Chemicals	1.41	0.191
			Petroleum	1.55	0.110
			Rubber et al.	1.24	0.659
			Machinery	0.92	0.383
			Electric Power & Gas	1.08	0.136
			Firms of high profits	1.40	0.470
			Firms of moderate profits	1.39	0.386
			Firms of low profits	1.26	0.343
			1954.C All firms	1.24	0.400
			1953.C All firms	1.28	0.305
		NC (−6)	1955.C All firms	2.03	0.293
			Large changes in sales	1.75	0.503
			Medium changes in sales	7.66	0.164
			Small changes in sales	3.44	0.197

TABLE 2. COMPARISON OF THE AVERAGE LENGTH OF LAGS

Authors (years)	Type of model	Type of lag	Period & sample	Tm	RR
Hamada (1962)	SA	Koyck	1952.L–1960.F, Japanese Industry		
			Textiles	0.18	0.507
			Chemicals	0.88	0.972
			Ferrous & Non-Ferrous	4.77	0.966
			Electric Machines & Tools	2.19	0.984
			Transportation Machines	1.63	0.943
Eisner (1962)	A	NC (−2)	1948.3–1960.4 U.S. Economy		
			Manufacturing Durables	0.62	0.379
			Manufacturing Non-Durables	0.44	0.659
			Utilities	0.39	0.537
			Commercial Businesses	0.21	0.719
			1957.C All firms	0.11	0.058
Big businesses				0.12	0.033
			1955.C Big businesses	0.09	0.238
Diamond (1962)	A	NC (−4)	1955.C U.S. All firms	0.82	0.381
			Nonfinancial corporations		
			High growth in fixed capital	0.75	0.465
			Medium growth	0.84	0.281

TABLE 3. COMPARISON OF THE AVERAGE LENGTH OF LAGS

Authors (years)	Type of model	Type of lag	Period & sample	Tm	RR
Diamond (1962)			1955.C Nonfinancial corporations		
			Low growth in fixed capital	0.56	0.151
			High depreciation rate	0.95	0.344
			Low depreciation rate	0.79	0.140
			Large increases in profits	0.96	0.466
			Medium increases	0.83	0.381
			Small increases	0.99	0.152
			1954.C All firms	0.82	0.361
			High growth in fixed capital	0.88	0.670
			Medium growth	0.96	0.690
			Low growth	0.87	0.670
			Large increases in profits	0.76	0.163
			Medium increases	0.99	0.689
			Small increases	0.99	0.256
			1953.C All firms	0.91	0.217
			1952.C All firms	0.88	0.254

TABLE 4. COMPARISON OF THE AVERAGE LENGTH OF LAGS

Authors (years)	Type of model	Type of lag	Period & sample	Tm	RR
Jorgenson (1963)	PM	R (−1/−2)	1948.1–1960.4 U.S. Manufacturing	1.39	0.890
		R (−2/−2)		1.03	0.943
			Fixed deterioration rate		
		R (−1/−2)		1.42	0.890
		R (−2/−2)		1.11	0.942
Resek (1966)	A		1953.1–1962.4 U.S. Manufacturing		
		Pln (−7)	Food	1.05	—
		Pln (−6)	Textiles	0.92	—
		Pln (−9)	Papers	1.07	—
		Pln (−9)	Chemicals	1.22	—
		Pln (−5)	Peroleum	0.62	—
		Pln (−5)	Rubber	1.13	—
		Pln (−9)	Cement, Clay & Stones	1.12	—
		Pln (−8)	Iron & Steel	1.35	—
		Pln (−10)	Non-Ferrous	1.23	—
		Pln (−8)	General Machines & Tools	0.99	—
		Pln (−10)	Electric Machines & Tools	1.21	—

last pages. To make the tables simplified, the names of some authors were written in their initials; that is, J & S implies Jorgenson & Stephenson; R & C, Rayner & Cowling; C & H, Coen & Hickman; G & M & M, Gandet & May & McFetridge.

The second column is the expression of the type of hypothesis on the optimal

TABLE 5. COMPARISON OF THE AVERAGE LENGTH OF LAGS

Authors (years)	Type of model	Type of lag	Period & sample	Tm	RR
Resek (1966)	A		1953.1–1962.4 U.S. Manufacturing		
		Pln (−8)	Automobiles	1.01	—
		Pln (−8)	Other Transport. Machines	1.01	—
		Pln (−8)	All manufacturing	1.06	—
J & S (1967)	PM	R (−6/−2)	1949.1–1960.4 U.S. Manufacturing		
			All manufacturing	2.13	—
			Durables	2.73	—
			Iron & Steel	2.27	—
			Non-Ferrous	2.06	—
			Electric Machines & Tools	1.76	—
			General Machines & Tools	1.77	—
			Automobiles	2.68	—
			Other Transport. Machines	2.20	—
			Cement, Clay & Stones	1.95	—
			Other Durables	1.69	—
			Non-Durables	1.94	—
			Foods	2.19	—

TABLE 6. COMPARISON OF THE AVERAGE LENGTH OF LAGS

Authors (years)	Type of model	Type of lag	Period & sample	Tm	RR
J & S (1967)	PM		1949.1–1960.4 U.S. Manufacturing		
		R (−6/−2)	Textiles	2.06	—
			Paper & Products	2.17	—
			Chemicals	2.82	—
			Petroleum & Coal Products	1.77	—
			Rubber	1.93	—
			Other Non-Durables	1.50	—
Evans (1967)	SA	DD	1949.1–1963.4 U.S. Manufacturing	1.38	—
Satlzman (1967)	SA	Koyck	? A firm	0.15	0.738
R & C (1967)	SA	Koyck	1948–1960 U.K. demand for tractor	3.46	0.992
Eisner (1967)	AP	NC (−6)	1955–1962.C U.S. Manufacturing	2.07	0.162
			Pooled	2.19	0.248
			Industry-time series	2.47	0.240
			Industry-cross section	1.88	0.629
			Industry-overall	1.83	0.643
	P		Firm-time series	2.04	0.055
	P		Industry-time series	2.42	0.648

level of investment or stock of the four types such as "A", "AP", "PM", and "SA" on which have already been described above, where CD implies Cobb-Douglas, and CES, the constant elasticity of substitution production function, respectively. The third column shows the form of lag function, in which some abridgements in

TABLE 7. Comparison of the Average Length of Lags

Authors (years)	Type of model	Type of lag	Period & sample	Tm	RR
H & J (1967)	PM	R (−1/−1)	1931–41, 1950–63 U.S. Eqp of mnf	2.07	0.722
			Cnst of mnf	3.84	0.848
			Eqp of non-mnf	1.26	0.690
			Cnst of non-mnf	7.49	0.983
J & S (1968)	A	R (−2/−1)	1949–1963 General Motors	1.92	0.620
			with liquidity var.	1.28	0.610
	P			0.42	0.640
	PM			1.01	0.700
	PM			2.03	0.890
Neal (1969)	A	R (−1/−1)	1897–1914 U.S. Railway	5.57	0.900
	PM			−5.64	0.700
Thurow (1969)	DEQ	P (−7)	1954.2–68.3 U.S. Industry eqp.	0.60	0.980
		P (−11)	cnst.	1.22	0.900
Bischoff (1969)	PM	R (−8/−2)	1951.3–65.4 U.S. Manufacturing		
			Cost of capital services	4.05	1.000
			Output	4.46	1.000

TABLE 8. Comparison of the Average Length of Lags

Authors (years)	Type of model	Type of lag	Period & sample	Tm	RR
Eisner (1969)	A	NC (−6)	1955–66.C U.S. Manufacturing		
			Firms of cross section	6.54	0.187
			Industry-cross section	1.93	0.628
Coen (1969)	PM	R (−1/−1)	1951–63 U.S. Manufacturing		
			Equipments	0.50	0.212
			Constructions	1.00	0.116
			Total	1.30	0.381
Rowley (1970)	PM-CD	R (−4/−1)	1958.1–65.4 U.K. Economy	1.27	0.918
	CES			1.03	0.936
	CD	NC (−4)		0.88	0.821
	CES			0.87	0.914
C & H (1970)	PM	Koyck	1924–40, 49–65 U.S. Industry		
	SMT		Labor non-restricted	0.29	0.889
			Capital non-restricted	8.96	0.948
			Capital restricted	5.20	0.624
			Combined labor	0.34	0.903
			Combined capital	5.20	0.545
Mayer (1971)	A	Koyck	1947–67 U.S. Economy		
			Agriculture	1.93	0.700

expression were also done; that is, Koyck is the Koyck lag distribution; NC($-i$), lag distribution with no restriction and maximum lag of the ith period behind; P(k, $-i$), the polinomials of the kth degree and with maximum lags of the ith

TABLE 9. COMPARISON OF THE AVERAGE LENGTH OF LAGS

Authors (years)	Type of model	Type of lag	Period & sample	Tm	RR
Mayer (1971)	A	Koyck	1947–67 U.S. Economy		
			Mining	1.69	0.700
			Petroleum & Gas	1.80	0.800
			Construction	1.16	0.570
			Textiles	1.07	0.810
			Rubber	1.75	0.960
			Printing & Publishing	1.04	0.840
			Basic Chemicals	2.11	0.900
			Plastics	2.03	0.900
			Petroleum Refining	2.36	0.510
			Iron & Steel	1.85	0.620
			Non-Ferrous	2.37	0.730
			OA Machinery	1.55	0.940
			Electric Machines & Tools	0.70	0.910
			Automobiles	1.86	0.650
			Transportation	0.83	0.830
			Communications	0.98	0.980

TABLE 10. COMPARISON OF THE AVERAGE LENGTH OF LAGS

Authors (years)	Type of model	Type of lag	Period & sample	Tm	RR
Mayer (1971)	A	Koyck	1947–67 U.S. Economy		
			Commercial Businesses	1.38	0.770
			Financial institutions	1.53	0.830
Morgan (1971)	SA	Koyck	1897–1914 U.S. Railway	0.33	0.902
			1897–1907	0.23	0.954
			1907–1914	0.38	0.904
Loranger (1976)	PM	P (2, −14)	1947.1–64.4 Canada Manufacturing	1.75	—
G & M & M (1976)	PM	P (2, −2)	1952–73 Canada Manufacturing		
			Capital cost for Machines	4.25	0.997
			— for output	3.25	
			— for buildings	1.96	0.998
			— for output	1.96	
			— for construction	5.44	0.997
			— for output	1.44	
Faurot (1978)	PM	Koyck	1953.1–69.4 U.S. Manufacturing		
	SMT		Durables	21.49	0.510
			Non-Durables	37.06	0.350
			Total	48.87	0.380
Kinoshita (1982)	SA	Koyck	1955–70 U.S. Steel Industry	2.35	0.929

period behind; $R(-i/-j)$, the rational distribution with the numerator's maximum lag of the ith period and the denominator's that of the jth period behind respectively.

The fourth column shows the observation periods and the brief explanation of the samples in estimation, where C implies that estimation is done by using cross-section data. The fifth column is the computed values of the average length of lag distribution, "T_m" in terms of the number of years which was already defined in equation (2). The last column is the coefficients of determination adjusted by the degree of freedom, in each estimation of investment function.

Now, looking at a glance on the whole tables, the value of average lag appears much different from each other; they are spreading widely from less than one year to even 49 years! To sum up the whole aspects of the figures in Tables 1–10 seems to be rather difficult, but a listing of what makes them remarkable is perhaps easier. For this purpose, Tables 1–10 are summarized in Table 11, where the average lags estimated from the articles under survey are classified into 29 items which almost correspond to individual industries of two digit classification or their aggregates, and the average lag estimates are shown from studies using time series data.

Cross-section estimates seem to be considerably smaller than those from time series, and it should be emphasized that the coefficients of factors influencing investment level can be regarded as to handle the long-run effects of those factors, when those coefficients are estimated from cross-section data. Eisner (1962) and Diamond (1962) are the typical cases, but Eisner (1967) and (1969) reported somewhat different aspects of cross-section estimates which may have been caused by revision of specification of investment equation like the so-called "Permanent Income Theory for Investment". It could, therefore, be possible to include estimates from Eisner (1967) and (1969) in Table 11.

In Table 11, Faurot's estimates appear remarkably high; that is, they are 48.87 years for all manufacturing, 21.49 years for manufacturing durables, and 37.06 years for manufacturing nondurables, respectively. Aside from those estimates, it may be still easy to list up the following points: Firstly, the average lag estimates appear to be considerably large in general. Figures in Table 11 are shown in order from the older through the newer in their publication. So, secondly, the newer estimates for the average lag seem to be larger in their values. To make this point clearer, the mean value of the estimates for the average lag was computed for each item. They are shown in Table 12, where the over-all average, the average of the last five or less to obtain the latest features, the average of the average lags based on hypothesis of the profit maximization, "PM", and that of the last five or less were computed respectively. Figures in all the items except for Ferrous & Non-Ferrous industry are not smaller of the second column than those of the first column.

Thirdly, the average lag estimates in this table seem to be larger for the estimates which are obtained from investment functions based on the profit maximization

TABLE 11. A SUMMARY OF TABLES 1–10

Items	The average lags (years)
All firms	1.66; 1.29; 1.38; 1.27; 1.03; 0.88; 0.87; 8.96; 5.20; 5.20
Nonfinancial corporations	1.56
Financial institutions	1.26; 1.53
Mining	1.69
Manufacturing	1.39; 1.03; 1.42; 1.11; 1.06; 2.13; 4.46; 1.30; 1.75; 3.25; 48.87
Manufacturing durables	0.62; 2.73; 1.69; 0.50; 21.49
Manufacturing nondurables	0.44; 1.94; 1.50; 37.06
Manufacturing equipment	2.07
Food & Tobacco	−1.88; 1.05; 2.19
Textiles	0.18; 0.92; 2.06; 1.07
Paper & Products	1.07; 2.17
Rubber et al.	1.24; 1.13; 1.93; 1.75
Chemicals	1.41; 0.88; 1.22; 2.82; 2.11; 2.03; 2.36
Cement, Clay & Stones	1.12; 1.95

TABLE 11. A SUMMARY OF TABLES 1–10 (to be continued)

Items	The average lags (years)
Ferrous & Non-ferrous	4.77; 1.35; 1.23; 2.27; 2.06; 1.85; 2.37; 2.35
Petroleum	1.55; 0.62; 1.77; 1.80
Machinery	0.92
General machines & Tools	0.99; 1.77; 1.55
Electric machines & Tools	2.19; 1.21; 1.76
Transportation machines	1.63; 1.01; 1.01; 2.68; 2.20; 3.46; 1.92; 1.86
Constructions	3.84; 7.49; 1.00; 1.16
Printing & Publishing	1.04
Electric power & Gas	1.08; 0.70
Utilities	0.39; 5.57
Communications	0.98
Commercial businesses	0.21; 1.38
Firms of high profits	1.40
Firms of moderate profits	1.39
Firms of low profits	1.26

hypothesis than for those from investment functions based on the hypotheses such as flexible accelerator, accelerator-residual funds (or profits), stock adjustment and so forth.

The last point is very important from the view-point of specification of investment functions. As to be represented by Faurot's estimates, the more satisfactorily and the more successfully theorizing the firm's rational behavior of investment be done, the larger the estimates of average lag are, almost in every item as shown in Table 12.[5]

[5] Another good example may be Coen & Hickman (1970).

TABLE 12. MEAN VALUES OF THE AVERAGE LAGS (YEARS)

Items	All	Last 5 or less	PM	PM (last 5 or less)
All firms	2.77	4.22	3.34	4.22
Nonfinancial corporations	1.56	1.56	—	—
Financial institutions	1.40	1.40	—	—
Mining	1.69	1.69		
Manufacturing	6.16 (1.89)	11.93	6.67 (1.98)	11.93
Manufacturing durables	5.41 (1.39)	5.41 (1.39)	8.64 (2.21)	8.64 (2.21)
Manufacturing nondurables	10.24 (1.29)	10.24 (1.29)	13.50 (1.72)	13.50 (1.72)
Manufacturing equipment	2.07	2.07	2.07	2.07
Food & Tobacco	1.62	1.62	2.19	2.19
Textiles	1.06	1.06	2.06	2.06
Paper & Products	1.62	1.62	2.17	2.17
Chemicals	1.83	2.11	2.82	2.82
Cement, Clay & Stones	1.54	1.54	1.95	1.95

TABLE 12. MEAN VALUES OF THE AVERAGE LAGS (YEARS)

Items	All	Last 5 or less	PM	PM (last 5 or less)
Ferrous & Non-ferrous	2.28	2.28	2.17	2.17
Petroleum	1.44	1.44	1.77	1.77
Machinery	0.92	0.92	—	—
General machines & Tools	1.44	1.44	1.77	1.77
Electric machines & Tools	1.72	1.72	1.76	1.76
Transportation machines	1.97	2.42	2.44	2.44
Constructions	3.37	3.37	—	—
Printing & Publishing	1.04	1.04	—	—
Electric power & Gas	0.89	0.89	—	—
Utilities	2.98	2.98	—	—
Communications	0.98	0.98	—	—
Commercial businesses	0.80	0.80	—	—
Firms of high profits	1.40	1.40	—	—
Firms of moderate profits	1.39	1.39	—	—
Firms of low profits	1.26	1.26	—	—

Note: Figures in parentheses are the average values when computed by dropping the Faurot's. — is not to be applicable.

And finally, the average lag estimates as shown in Table 12 and as just seen in the last two columns in this table, seem to be remarkably large. It seems too large to interprete them as the speed of adjustment of actual investment toward the optimal or desired investment level. If the firm knows its optimal investment level at the beginning of the current period correctly, it will not waste so long time to adjust it for the final target level. It seems rather difficult to understand that the firm is to adjust its current investment to the optimal level during the period of more than 2 years or even 5 years on the average as the optimal speed of adjustment. Even though the adjustment costs of two years is minimum for the realization of the optimal investment, there is nothing sure that is optimal two years later, even if it is optimal at present and in the near future.

In Faurot's case where theoretical specification of level of optimal investment seems to be most elaborate as well as econometric estimation procedures, the average lag estimates are in the range from 21 years to 49 years which are unbelievably long periods.

Those empirical findings seem to suggest that some other interpretations and theoretical insights are needed, which should be accepted more flexibly and widely by economists, orthodox or eclectic in the field of theoretical economics as well as empirical or applied economics. The next section will discuss some theoretical implications consistent with the empirical findings stated above, and attempt to make some further theoretical insights as concluding remarks.

4. CONCLUDING REMARKS

The statistical evidence drawn from many articles in this survey tells us that the speed of adjustment of actual investment to the optimal level which is supposed to be different depending on the expected market conditions during the planning horizon is too slow to regard as the optimal or the intended speed. It is because the speed of adjustment is supposed to be optimal that the average length of lag is questioned as to be so large.

Even if the lag in the firm's decision making, the lag in design of an investment plan, the lag in order, and the lag in deliveries and installment are all convoluted in an actual investment behavior of the firm, the average lag may be at least one year or less.[6] It should be noted that the average lag in this study is considered to be caused in the realization process of investment to be optimal in the current period.

Traditional or neoclassical theory of capital accumulation assumes that the firm knows all the information which is necessary for it to make an investment decision at the beginning of the current period, and it designs the optimal time path of the level of investment during the planning horizon.[7] And so, the firm determines the optimal level of investment for each period of the planning horizon, which is implicitly supposed to be equal to the true optimal level of investment for each period.

It is, however, a very strong assumption that the firm's "subjective" optimal level of investment for each planning period is exactly equal to the true or the "objective" optimal level of investment for each planning period. The volume of information available to the firm is not necessarily perfect, but perhaps be limitted

[6] Taka Ito suggested that the expected demand or other factors influencing the optimal investment could be dependent on the lag distribution of those variables, and the firm could learn from those lagged informations. But, I think that the firm may weigh much the latest informations on the economic circumstances as well as market conditions, when it makes an investment decision.

[7] For instance, see Jorgenson (1963).

partially, and this may bring about some expost gap between the firm's subjective optimal and the true optimal, which should not necessarily be regarded as stochastic but, in part, systematic, by reviewing the statistical evidence already discussed in the previous section.

If the gap between the firm's optimal level of investment and the true optimal investment were simply stochastic, it may be difficult to explain why the average lag is so large in investment realization process. If the gap between the firm's optimal level of investment and the true optimal investment were systematic, then it is only because the firm could not know, in exante, that there would be brought about the gap stated above.

This does not imply that the firm behaves by the so-called "Rule of Thum" principle. The firm certainly does make an optimal decision on investment planning, but it can use only the limitted informations such as market conditions, technological efficiency, and so forth. It could even be assumed that the firm is, in principle, to underestimate the rate of return on investment or marginal productivity of capital, taking into account the risk and uncertainty, which do not reflect on market discount rates.

Suppose that the firm makes the adjustments or the realizations of investment so as to give chase to the true optimal level of investment, period after period. If the production efficiency produced within the firm were increasing in a rapid pace, say 5 or 6 per cent of productivity growth a year, the speed of adjustment of the firm for the true optimal level of investment, period after period, could not be so high, which can be called the "Gradual Adjustment Process" or "GAP". The GAP theory of investment behavior is to explain the firm's chasing behavior of investment just described above. GAP theory may be applicable to other economic behavior such as consumer behavior, bank's financial behavior, money market behavior, and so forth.

An attempt to develop a study on production and changes in industrial structure in the long-run was written by the author himself recently. He also tried to estimate the gap between the actual level of investment and the computed optimal level of investment by industry for the Japanese industries.[8]

To contrast GAP theory with the traditional theory, I will call the latter the cost of adjustment lag: "CAL" or the lag adjustment process: "LAP" theory. The significant difference between the CAL or the LAP theory and the GAP theory depends on whether to think that the length of the average lags computed from the articles under survey be too large to adjust the actual level of investment to the firm's optimal level of investment or not, and also, whether to think that the firm's subjective optimal level of investment is exactly equal to the true or the objective level of investment except for a stochastic disturbance or not. It should again be notified that Table 12 states the more successfully the specification of investment function is done theoretically and statistically, the larger the average lags in

[8] See Hamada (1980). More about the GAP theory can be referred in Hamada (1984) and (1983).

investment behavior are.

Keio University

REFERENCES

Bischoff, C. W. (1969), "Hypothesis Testing and the Demand for Capital Goods," *R.E.S.*, Vol. 51, No. 3, pp. 354–368.

Coen, R. M. (1969), "Tax Policy and Investment Behavior: Comment," *A.R.E.*, Vol. 59, No. 3, pp. 370–401.

——— and B. G. Hickman (1970), "Constrained Joint Estimation of Factor Demand and Production Function," *R.E.S.*, Vol. 52, No. 3, pp. 287–300.

Diamond, J. J. (1962), "Further Development of a Distributed Lag," *Econometrica*, Vol. 30, No. 4, pp. 788–800.

Eisner, R. (1960), "A Distributed Lag Investment Function," *Econometrica*, Vol. 28, No. 1, pp. 1–30.

——— (1962), "Studies in Business Behavior-Investment Plans and Realizations," *A.E.R.*, Vol. 52, No. 2, pp. 190–203.

——— (1967), "A Permanent Income Theory for Investment: Some Empirical Exploration," *A.E.R.*, Vol. 57, No. 3, pp. 363–390.

——— (1969), "Investment and the Frustrations of Econometricianc," *A.E.R.*, Vol. 59, No. 2, pp. 50–64.

Evans, M. K. (1967), "A Study of Industry Investment Decisions," *R.E.S.*, Vol. 49, No. 2, pp. 151–164.

Faurot, D. J. (1978), "Interrelated Demand for Capital and Labor in a Globally Optimal Flexible Accelerator," *R.E.S.*, Vol. 60, No. 1, pp. 25–32.

Gandet, G. O., J. D. May and D. G. McFetridge (1976), "Optimal Capital Accumulation: The Neoclassical Framework in a Canadian Context," *R.E.S.*, Vol. 58, No. 3, pp. 269–273.

Griliches, Z. (1967), "Distributed Lags: A Sruvey," *Econometrica*, Vol. 35, No. 1, pp. 16–49.

Gupta, Y. P. (1971), *Statistical Estimation of Linear Economic Relationships*, Rotterdam University Press, Groningen, pp. 17–25.

Hall, R. E. and D. W. Jorgenson (1967), "Tax Policy and Investment Behavior," *R.E.S.*, Vol. 49, No. 3, pp. 391–414.

Hamada, F. (1962), "An Econometric Analysis of Investment Behavior in the Japanese Economy," (in Japanese) *The Economic Studies Quarterly*, Vol. 13, No. 1, pp. 15–23.

——— (1964), "A Study in Investment Behavior by Industry," Management and Labor Studies, English Series No. 10, reprinted from Hamada (1962).

——— (1967), "Growth in Capital Stock in th Postwar Japanese Manufacturing Industries," *Review of Economics and Statistics*, Vol. 49, No. 4.

——— (1980), "Differentials of the Rate of Return on Investments by Industry: The Japanese Case," *Keio Economic Studies*, Vol. 17, No. 1.

——— (1981), "Know-How, Experiences and Production Efficiency: *An Econometric Study*," Paper presented at The International Roundtable Congress, The 50th Anniversary of the Japan Statistical Society, October 14–16, 1981, Tokyo.

——— (1984), "An Empirical Study of Production: Facts and Theoretical Insights," Mimeo.

——— and R. Chida (1983), "Direct Estimation of Production Function by Industry," *Keio Economic Studies*, Vol. 22, No. 1.

Jorgenson, D. W. (1963), "Capital Theory and Investment Behavior," *A.E.R.*, Vol. 53, No. 2, pp. 247–259.

——— (1967), "Investment Behavior in US Manufacturing, 1947–1960," *Econometrica*, Vol. 35, No. 2, pp. 169–220.

——— and C. D. Siebert (1968), "A Comparison of Alternative Theories of Corporate Investment," *A.E.R.*, Vol. 58, No. 4, pp. 681–713.

——— and J. A. Stephenson (1967), "The Time Structure of Investment Behavior in United States Manufacturing, 1947–1960," *R.E.S.*, Vol. 49, No. 1, pp. 16–27.

Keynes, J. M. (1936), *The General Theory of Employment, Interest and Money*, MacMillan Press Ltd., London.

Kinoshita, S. (1982), *The Economic Behaviors in the Postwar Japan*, (in Japanese), Yuhikaku, Tokyo.

Klein, L. R. (1974), "Issues in Econometric Studies of Investment Behavior," *Journal of Economic Literature*, Vol. 12, No. 1, pp. 43–50.

Kuh, E. (1963), *Capital Stock Growth: A Micro-Econometric Approach*, North-Holland, Amsterdam, Chapt. 5.

Loranger, J. G. (1976), "Problems of Identification and Estimation of the Demand for Capital," *R.E.S.*, Vol. 58, No. 2, pp. 173–180.

Lucas, R. E., Jr. (1967), "Adjustment Costs and the Theory of Supply," *Journal of Political Economy*, Vol. 75, No.

Maddala, G. S. (1977), *Econometrics*, McGraw-Hill Book Company, New York, Chapt. 16–7.

Mayer, T. H. (1971), "Equipment Expenditure by Input-Output Industries," *R.E.S.*, Vol. 53, No. 1, pp. 26–36.

Morgan, W. D. (1971), "Investment Behavior by American Railroad: 1897–1914, A. Comment," *R.E.S.*, Vol. 53, No. 3, pp. 294–300.

Nelson, R. R. (1981), "Research on Productivity Growth and Productivity Differences: Dead Ends and New Departures," *Journal of Economic Literature*, Vol. 19, No. 3.

Rayner, A. J. and K. Cowling (1967), "Demand for a Durable Input: An Analysis of the United Kingdom Market for Farm Tractor," *R.E.S.*, Vol. 49, No. 4, pp. 590–598.

Resek, R. W. (1966), "Investment by Manufacturing Firm: A Quarterly Time Series Analysis of Industry Data," *R.E.S.*, Vol. 48, No. 3, pp. 322–347.

Rowley, J. C. R. (1970), "Investment Functions: Which Production?," *A.E.R.*, Vol. 60, No. 5, pp. 1008–1012.

Saltzman, S. (1967), "An Econometric Model of a Firm," *R.E.S.*, Vol. 49, No. 3, pp. 332–342.

Thurow, L. C. (1969), "A Disequilibrium Neoclassical Investment Function," *R.E.S.*, Vol. 51, No. 4, pp. 431–435.

Tobin, J. (1969), "A General Equilibrium Approach to Monetary Theory," *Journal of Money, Credit and Banking*, Vol. 1, No. 1, pp. 15–29.