The Impacts of IT and EC Investments and Time Trends of the Speeds of Adjusting the Actual Toward the Maximum Pay upon CEO Compensation: An Extension

Winston T. Lin
University at Buffalo, The State University of New York

Yueh H. Chen
National Sun Yat-sen University

We analyze the impacts of information technology (IT) and e-commerce (EC) investments and time trends of the speeds of adjusting the observed (actual) toward the desired (maximum) pay upon chief executive officer (CEO) compensation in US firms, based on the adjustment model and its associated adjustment valuation (AV) approach, under the assumption of stochastic and dynamic adjustment speed (AS); and, then, we compare the new results to the findings of Lin and Chen (2024) based on the assumption of dynamic and variable AS. A comparative analysis strongly suggests that the new results are more realistic in a world full of uncertainty (Lin et al., 2019, pp. 769 and 777).

Keywords: stochastic (random) and dynamic adjustment speed (AS), the adjustment valuation (AV) approach, complementarity (COM) and substitutability (SUB), linearity and nonlinearity, average performance index

INTRODUCTION

In 1958, Nerlove proposed the one-equation theory of constant and fixed adjustment speed (AS). He argued that due to technological constraints and others, the AS must lie between 0 and 1. In other words, it is practically and technologically impossible that the AS is full and, hence, only partial. The theory of partial adjustment has been applied across various disciplines (e.g., Lin et al., 1987, for the demand for natural gas, electricity, and heating oil in the US; Flannery and Ragan, 2006, for partial adjustment toward target capital structure; etc.). Moreover, based on the one-equation theory of AS, Lin et al. (2010) have proposed an AS valuation (ASV) approach that offers at least two built-in performance metrics, namely, the firm's average performance index (API_i) and the average speed of adjustment (ASA_i). Nevertheless, the assumption of constant and fixed AS is neither useful nor appropriate for our research topic.

Subsequently, Lin (1988) and Lin and Kao (2014) have proposed the two-equation theory of dynamic and variable AS. Moreover, Lin and Kao (2014) also have offered an ASV approach which provides two performance metrics, namely, API_i and ASA_i. The two-equation theory of AS and the ASV approach under the assumption of dynamic and variable AS have been applied in Lin and Chen (2024).

Taking a step further, Lin et al. (2019) have developed a two-equation theory of stochastic (random) and dynamic AS, along with its associated ASV approach, which is composed of API_i and ASA_i performance metrics. These concepts form the theoretical foundation and research methodology for developing the research model in this study. Therefore, the details of this case will be given in Section 3 below. As such, the objective of the research is two-folds: one is to use the same data as employed in Lin and Chen (2024) to obtain the estimates of the research model, API_i , and ASA_i, under the two-equation theory of stochastic and dynamic AS; and, two is to undertake a comparative analysis to determine which AS assumption, dynamic and variable or stochastic and dynamic, is more realistic and appropriate.

The rest of the paper proceeds as follows. The second section mentions the review of literature. The third section focuses on the theoretical foundation, research model, and estimation method. The fourth section explains the panel data and data sources as used in Lin and Chen (2024). In the fifth section, we report and discuss the estimation results as well as conduct a comparative analysis. The final section concludes.

LITERATURE REVIEW

The detailed literature review and Table 1 presented in Lin and Chen (2024) remain highly relevant to, and valid for, this extended research. Hence, we decide to skip this section to save space.

THEORETICAL FOUNDATION, RESEARCH METHODOLOGY AND MODEL, AND ESTIMATION METHOD

This section outlines the theoretical foundation on which this extended research is based, the two built-in pay measures, the research model, and the estimation method.

An Adjustment Model of CEO Pay

Based on the two-equation theory of stochastic (random) and dynamic AS of Lin et al. (2019), we can set up the adjustment model composed of two random equations. To do this, let C_{it} be the actual (observed) CEO pay for firm *i* at time *t*, C_{it}^* be the desired (ideal or maximum) CEO pay for firm *i* at time *t*, and $C_{i,\,t-1}$ be the actual CEO pay for firm *i* and time *t-1*. Because C_{it}^* is unobserved, it is quantified by a function denoted by $f(\boldsymbol{X}_{it};\boldsymbol{\beta}_i)$ in which $\boldsymbol{X}_{it}$ is a vector to be specified and $\boldsymbol{\beta}_i$ is an unknown coefficient vector. Then, we have the adjustment model described below.

$$\tilde{C}_{it} = \tilde{\delta}_{it} f(\boldsymbol{X}_{it};\boldsymbol{\beta}_i) + \left(1-\tilde{\delta}_{it}\right)C_{i,t-1} + \tilde{u}_{it}, i = 1,\dots,m \; and \; t = 1,\dots,n \tag{1}$$

$$\tilde{\delta}_{it} = g(\boldsymbol{Z}_{it};\boldsymbol{\alpha}_i) \; + \tilde{\mathrm{v}}_{\mathrm{it}} \; i = 1,\dots,m \; and \; t = 1,\dots,n, \tag{2}$$

where a tilde (~) placed above a variable means that the variable is stochastic (random); $\tilde{u}_{it}$ is the traditional random error distributed according to *N(0,* σ_u^2*)*; $\tilde{v}_{it}$ is the random error contained in the random AS and is distributed as N(0, σ_v^2); and $g(\boldsymbol{Z}_{it};\boldsymbol{\alpha}_i)$ is also a function of variable vector $\boldsymbol{Z}_{it}$ with an unknown coefficient vector $\boldsymbol{\alpha}_i$.

Here, by the setting of Equation (2), the AS function is no longer just dynamic and variable as used in Lin and Chen (2024). Instead, the AS is now stochastic and dynamic in the presence of $\tilde{\mathrm{v}}_{\mathrm{it}}$ in Equation (2). In other words, as Lin et al. (2019) pointed out, the AS function is not only dynamic as reflected by the g function, but also stochastic as indicated by $\tilde{v}_{it}$, Thus, Equation (2) indicates that the AS function is constituted by two components, namely, a dynamic but deterministic component (represented by the g function) and a stochastic component (represented by $\tilde{v}_{it}$). The presence of $\tilde{u}_{it}$ and $\tilde{v}_{it}$ leads to the complexity of the AS model and the estimation of the unknown parameters ($\boldsymbol{\beta}_i, \boldsymbol{\alpha}_i, \sigma_u^2, and\; \sigma_v^2$). The complexity necessitates the application of a stepwise estimation method.

Two Built-in Pay Metrics

Based on the AS Valuation (ASV) approach under the stochastic and dynamic AS assumption as presented in Lin et al. (2019), we can construct two built-in pay metrics as follows.

The first built-in CEO pay metric is referred to as the average speed of adjustment for firm *i*, denoted by ASA_i. Assume that the estimate of $\boldsymbol{\alpha}_i$ is given by $\hat{\alpha}_i$, then the estimate of the stochastic and dynamic speed for firm *i* at time *t* is given by

$$\hat{\tilde{\delta}}_{it} = g(\boldsymbol{Z}_{\boldsymbol{it}}; \hat{\boldsymbol{\alpha}}_i), i = 1, \ldots, m \; and \; t = 1, \ldots, n, \tag{3}$$

then, the estimate of the average speed of adjustment for firm *i* can be computed as

$$ASA_i = \textstyle\sum_i g(\boldsymbol{Z}_{it}; \hat{\boldsymbol{\alpha}}_{\boldsymbol{i}})/n \geq 0 \tag{4}$$

and the grand average speed of adjustment for all *m* firms is given by

$$ASA = \textstyle\sum_i ASA_i/m \geq 0. \tag{5}$$

We interpret $ASA_i > 1.0$ as fast and $ASA_i < 1.0$ as slow for firm *i*, as suggested in Lin and Chen (2024).

A second built-in CEO pay metric for firm *i* is called the average pay index, denoted by $API_{i.}$. Once more, following Lin and Chen (2024), API_i can be constructed as given below.

- Step 1: Define $PV_{it} = g(\boldsymbol{Z}_{it}; \hat{\boldsymbol{\alpha}}_i)\, f(\boldsymbol{X}_{it}; \hat{\boldsymbol{\beta}})$, the product of g and *f*.
- Step 2: Define $PI_{it} = PV_{it}/\ln C_{it}$ as the CEO pay index for firm *i* at time *t*.
- Step 3: Define the average pay index for firm *i* as

$$API_i = \textstyle\sum_{t=1}^{n} PI_{it}/n \geq 0, i = 1, \ldots, m. \tag{6}$$

It follows that the grand (overall) pay index is given by

$$API = \textstyle\sum_{i=1}^{m} API_i/m \geq 0. \tag{7}$$

We interpret $API_i > 1.0$ as indicating that the CEO compensation in firm *i* for the period under consideration is excessive.

Research Model

Based on the theoretical foundation and research methodology as described in the preceding subsections, we are ready to construct a two-equation research model as follows. Let $\boldsymbol{X}_{\boldsymbol{it}} = (IT_{it}, EC_{it})$ and $\boldsymbol{Z}_{it} = (t, t^2)$, where *t* is the time trend variable. Then, we have the two-equation research model shown below.

$$\tilde{C}_{it} = \tilde{\delta}_{it} f(IT_{it}, EC_{it},; \boldsymbol{\beta}_i) + (1 - \tilde{\delta}_{it}) C_{i,t-1} + \tilde{u}_{it} \tag{8}$$

$$\tilde{\delta}_{it} = g(t, t^2; \boldsymbol{\alpha}_{\boldsymbol{i}}) + \tilde{v}_{it}, i = 1, \ldots, m \; and \; t = 1, \ldots, n. \tag{9}$$

Alternatively, Equations (8) and (9) may be combined into a single equation as follows.

$$\tilde{C}_{it} - C_{i,t-1} = g(\bullet) f(\bullet) - g(\bullet)\, C_{i,t-1} + \tilde{w}_{it}, i = 1, \ldots, m \; and \; t = 1, \ldots, n, \tag{10}$$

where $\tilde{w}_{it} = [f(\bullet) - C_{i,t-1}]\tilde{v}_{it} + \tilde{u}_{it}$ is a composite random error involving both $\tilde{u}_{it}$ and $\tilde{v}_{it}$ with $E(\tilde{w}_{it}) = 0 \; and \; V(\tilde{w}_{it}) = [f(\bullet) - C_{i,t-1}]^2 \sigma_v^2 + \sigma_u^2$ (see Lin et al., 2019, P.769). Note that in Equation (10), $g(\bullet) = g(t, t^2; \boldsymbol{\alpha}_{\boldsymbol{i}})$ and $f(\bullet) = f(IT_{it}, EC_{it},; \boldsymbol{\beta}_i)$.

Estimation

The presence of the composite random error ($\tilde{w}_{it}$) in Equation (10) complicates the estimation task of Equation (10). As such, we apply the modified four-step generalized least-squares (GLS) method, as detailed in Lin (1999), to carry out the estimation of Equation (10). In the stepwise method, Steps 1 and 2 are due to Theil (1971, PP. 622 – 627) and, in our estimation process, the $g(\bullet)$ function is quadratic form and the $f(\bullet)$ function is assumed linear.

PANEL DATA

The same set of annual data as employed in Lin and Chen (2024, PP.82-83) is used in order to facilitate a comparative analysis.

RESULTS AND DISCUSSION

Estimation Results (TABLES 1 to 4) and Discussion

To save space, the estimates of the research model are presented in an Appendix (8 pages, available upon request). The main results are summarized in TABLES 1 to 4.

First, our attention is paid to the percentage distributions of adjustment speeds presented in TABLE 1.

TABLE 1
PERCENTAGE DISTRIBUTIONS OF THE FIRMS WITH FAST AND SLOW ADJUSTMENT SPEEDS

Number (%) of Firms with $ASA_i < 1.0$ (Slow)	Number (%) of Firms with $ASA_i > 1.0$ (Fast)
Nos. 1, 2, 4, 5, 6, 7, 10, 11, 12, 15, 16, 18, 21, 24, 25, 26, 27, 28, 31, 33, 35 37, 38, 39, 42, 46, 47, 50, 51, 54, 60, 61, 65, 66, 67, 70, 71, 72, 73, 75, 76, 77, 78, 79, 82, 83, 85, 87, 89, 91, 93, 94, 96, 100, 101, 102, 103, 104, 105, 107, 109, 110, 111, 112, 117, 118, 120, 124, 127, 128, 129, 131, and 132 (73 firms or 59.35%)	Nos. 3, 9, 13, 14, 17, 20, 22, 23, 30, 32, 34, 40, 41, 43, 44, 45, 49, 52, 53, 55, 56, 57, 59, 62, 63, 64, 68, 69, 74, 81, 84, 86, 88, 90, 92, 95, 97, 99, 106, 108, 113, 114, 115, 119, 121, 122, 123, 126, 130, and 133 (50 firms or 40.65%)

(i) We consider firms Nos. 2 and 82. For firm No.2, its $ASA_2 = 0.8959 < 1.0$ and, for firm No.82, its $ASA_{82} = 0.3371 < 1.0$, thereby the adjustment speeds of both firms are slow.
(ii) We take firm Nos.3 and 81 as other examples. Because both $ASA_3 = 1.0690$ and $ASA_{81} = 1.1277$ are greater than 1.0, the adjustment speeds are said to be fast.
(iii) The percentage distribution of the firms with slow adjustment speeds (<1.0) is 59.35% (= 73/123 x 100), in comparison to the percentage distribution of the firms with fast adjustment speeds (>1.0) being equal to 40.65% (= 50/123 x100).
(iv) The overall (grand) ASA is 0.9229 which is less than 1.0.

Second, we proceed to Table 2, which examines the functional forms of adjustment speed (AS). A overwhelming number of 113 firms or 91.87% of the 123 firms understudy bears nonlinear AS functions; there are only 2 firms (Nos. 61 and 87 or 1.63%) with a linear function; and there are 8 firms (i.e., Nos. 26, 49, 52, 84, 86, 92, 102, and 109) whose AS functions can't be decided, that is there are 8 firms or 6.50% with neither linear nor nonlinear functions of AS.

TABLE 2
A SUMMARY OF FIRMS WITH LINEAR AND NONLINEAR FUNCTIONS OF ADJUSTMENT SPEED

Firms with significant linear function	**Firms with significant nonlinear Function**
Nos. 61 and 87 (2 firms or 1.63%)	Nos. 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23, 24, 25, 27, 28, 30, 31, 32, 33, 34, 35, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 50, 51, 53, 54, 55, 56, 57, 59, 60, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 81, 82, 83, 85, 88, 89, 90, 91, 93, 94, 95, 96, 97, 99, 100, 101, 103, 104, 105, 106, 107, 108, 110, 111, 112, 113, 114, 115, 117, 118, 119, 120, 121, 122, 123, 124, 126, 127, 128, 129, 130, 131, 132, and 133 (113 firms or 91.87%)

Notes: There are 8 firms or 6.5% with neither linear nor nonlinear functions

Third and final, we pay our attention to TABLES 3 and 4. TABLE 3 provides a summary of the estimates of API_i*'s* from the research model; and, then, TABLE 4 is established, based on TABLE 3, to classify the 123 firms into two groups, namely, one group is composed of the sample firms with API_i*'s* less than 1.0 and the other group involves the firms with API_i*'s* greater than 1.0. As such, TABLES 3 and 4 are interrelated.

TABLE 3
ESTIMATES OF API_i's

Firm No i	API_i Estimate	Firm No i	API_i Estimate	Firm No i	API_i Estimate	Firm No i	API_i Estimate
1	0.3662	37	0.8413	71	0.8978	105	0.5302
2	0.9028	38	0.4596	72	0.9369	106	1.0775
3	1.0741	39	0.4348	73	0.8959	107	0.7849
4	0.8140	40	1.1202	74	1.1124	108	1.0213
5	0.9769	41	1.1485	75	0.9542	109	0.9547
6	0.5230	42	0.9415	76	1.0009	110	0.5627
7	0.7612	43	1.3922	77	0.9571	111	0.8092
9	1.2194	44	1.0665	78	0.7797	112	0.5867
10	0.3925	45	1.5829	79	0.9426	113	1.8497
11	0.9173	46	0.8555	81	1.1329	114	1.5560
12	0.8777	47	0.7899	82	0.3410	115	1.0092
13	1.0989	49	1.1794	83	0.9995	117	1.0121
14	1.3428	50	0.4872	84	1.3944	118	0.6564
15	0.6537	51	0.7450	85	0.0693	119	1.0911
16	0.9548	52	1.4830	86	1.2648	120	0.7716
17	1.1274	53	1.3556	87	0.8329	121	1.4426
18	0.4073	54	0.7385	88	1.6658	122	1.3767
20	1.4268	55	1.2334	89	0.7913	123	1.0904
21	0.5725	56	1.2619	90	1.2554	124	0.9404
22	1.4943	57	1.1953	91	0.4980	126	1.0094
23	1.1493	59	1.5403	92	1.0118	127	0.9739
24	0.7208	60	0.8923	93	0.8371	128	0.3603

25	0.9267	61	0.5342	94	0.6293	129	0.3587
26	0.1134	62	1.4991	95	1.0736	130	1.0376
27	0.4100	63	1.1790	96	0.5147	131	0.2240
28	0.8460	64	1.4408	97	1.3695	132	0.8250
30	1.3143	65	0.2369	99	1.0707	133	1.1547
31	0.9567	66	0.6198	100	0.4573		
32	1.1151	67	0.8789	101	0.9918		
33	0.4369	68	1.3150	102	0.5317		
34	1.0806	69	1.6334	103	0.2880		
35	0.9743	70	0.4521	104	0.9254		

TABLE 4
FIRMS WITH APIi<1.0 AND FIRMS WITH APIi > 1.0

Firms with $API_i < 1.0$	Firms with $API_i > 1.0$
Nos. 1, 2, 4, 5, 6, 7, 10, 11, 12, 15, 16, 18, 21, 24, 25, 26, 27, 28, 31, 33, 35, 37, 38, 39, 42, 46, 47, 50, 51, 54, 60, 61, 65, 66, 67, 70, 71, 72, 73, 75, 77, 78, 79, 82, 83, 85, 87, 89, 91, 93, 94, 96, 100, 101, 102, 103, 104, 105, 107, 109, 110, 111, 112, 118, 120, 124, 127, 128, 129, 131, and 132	Nos. 3, 9, 13, 14, 17, 20, 22, 23, 30, 32, 34, 40, 41, 43, 44, 45, 49, 52, 53, 55, 56, 57, 59, 62, 63, 64, 68, 69, 74, 76, 81, 84, 86, 88, 90, 92, 95, 97, 99, 106, 108, 113, 114, 115, 117, 119, 121, 122, 123, 126, 130, and 133
Sub-total: 71 firms (57.72%)	Sub-total: 52 (42.28%)
Total = 71 + 52 = 123 firms (57.72% + 42.28%= 100%)	

(i) Take Firms Nos.1 and 74 from TABLE 3 as two examples. *The* API_1 of Firm No.1 is 0.3662 which is less than 1.0, while the API_{74} of firm No.74 is 1.1124 which is greater than 1.0. This means that during the sample period considered, the CEO of firm No.1 tends to underpay, while the CEO of firm No.74 tends to overpay.

(ii) The maximum API_i goes to firm No.113 and the minimum API_i to firm No.85.

(iii) The overall *API* of the sample firm studies is 0.9265 which is less than 1.0, meaning that overall, the CEO compensations are underpaid.

(iv) Among the 123 sample firms under consideration, the API_i*'s* of 71 firms (or 57.72%) of the sample firms were smaller than 1.0, whereas the API_i*'s* of 52 firms (or 42.28%) of the sample firms were larger than 1.0. The empirical evidence suggests that the US CEOs tend to underpay during the period studied.

A Comparative Analysis (TABLES 5 to 8)

Firstly, we compare the complementarity (COM) and substitutability (SUB) phenomena between IT and EC in Lin and Chen (2024) and this research, as shown in Table 5. Lin et al. (2015, PP.815-816) have stated: “When IT and EC are invested simultaneously, the presence of IT may enhance (reduce) EC value, hence, complementarity (substitutability), and vice versa.” Based on this definition of COM and SUB, we observe from TABLE 5 that under the stochastic and dynamic AS (This research), there were 8 COM firms, 18 SUB firms, and 97 Undecided firms and that under the dynamic and variable AS (Lin and Chen, 2024), there were only 3 COM firms, 12 SUB firms, and 108 Undecided firms.

TABLE 5
COMPARISON OF THE NUMBER (PERCENTAGE) OF THE FIRMS WITH COMPLEMENTARITY (COM) AND THE FIRMS WITH SUBSTITUTABILITY (SUB)

Under the dynamic and variable AS (Lin and Chen, 2024)			Under the stochastic and dynamic AS (This research))		
COM firms	SUB firms	Undecided	COM firms	SUB firms	Undecided
Nos. 4, 33, and 129	Nos. 16, 38, 44, 66, 75, 100, 107, 109, 110, 120, 128, and 130	Nos. 1, 2, 3, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 17, 18, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32, 34, 35, 37, 39, 40, 41, 42, 43, 45, 46, 47, 49, 50, 51, 52, 53, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 67, 68, 69, 70, 71, 72, 73, 74. 76, 77, 78, 79, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 99, 101, 102, 103, 104, 105, 106, 108, 111, 112, 113, 114, 115, 117, 118, 119, 121, 122, 123, 124, 126, 127, 131, 132, and 133	Nos. 16, 17, 33, 50, 60, 64, 72, and 97	Nos. 15, 44, 49, 62, 66, 73, 75, 77, 84, 85, 100, 103, 107, 110, 113, 122, 124, and 130	Nos. 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 18, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32, 34, 35, 37, 38, 39, 40, 41, 42, 43, 45, 46, 47, 51, 52, 53, 54, 55, 56, 57, 59, 61, 63, 65, 67, 68, 69, 70, 71, 74, 76, 78, 79, 81, 82, 83, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 99, 101, 102, 104, 105, 106, 108, 109, 111, 112, 114, 115, 117, 118, 119, 120, 121, 123, 126, 127, 128, 129, 131, 132, and 133
Subtotal = 3 (2.44%)	Subtotal = 12 (9.76%)	Subtotal = 108 (87.80%)	Subtotal = 8 (6.50%)	Subtotal = 18 (14.64%)	Subtotal = 97 (78.86%)
Total = 3 + 12 + 108 =123 (100%)			Total = 8 + 18 + 97 =123 (100%)		

Notes: AS means adjustment speed. A COM firm requires that both b_1 and b_2 be positively significant at the 1%, 5% or 10% level; a SUB firm requires that either b_1 be positively and b_2 negatively or b_1 be negatively and b_2 be positively significant; and Undecided because both b_1 and b_2 are insignificant, or both b_1 and b_2 are negative, or one significant and the other is insignificant.

In the second place, we undertake a comparison of the firms with $ASA_i > 1.0$ (fast) and those with $ASA_i < 1.0$ (slow) as reported in TABLE 6. Under the stochastic and dynamic AS assumption (This research), there were 50 firms (40.65%) with $ASA_i > 1.00$, 73firms (59.35%) with $ASA_i < 1.0$, and the overall (grant) ASA was 0.9229 < 1.0. In contrast, there were 69 firms (56.10%) with $ASA_i > 1.0$, 54 firms (43.90%) with $ASA_i < 1.0$, and the overall (grand) *ASA* was 1.0538, which is greater than 1.0. It appears that if the assumption of stochastic and dynamic AS is more realistic, then the results under the assumption of dynamic and variable AS tend to overstate the AS.

TABLE 6
COMPARISON OF THE FIRMS WITH $ASA_i > 1.0$ (FAST) AND THE FIRMS WITH $ASA_i < 1.0$ (SLOW)

Under the assumption of dynamic and variable AS (Lin and Chen 2024)	Under the assumption of stochastics and dynamic AS (This research)
69 firms (56.10%) with $ASA_i > 1.0$	50 firms (40.65%) with $ASA_i > 1.0$
54 firms (43.90%) with $ASA_i < 1.0$	73 firms (59.35%) with $ASA_i < 1.0$
The overall (grand) ASA is 1.0539>1.0	The overall (grand) ASA is 0.9229 <1.0

In the third place, we turn to TABLE 7 for a comparison of the numbers (percentages) of the firms with significant linear and nonlinear functions of AS. Under the assumption of stochastic and dynamic AS functions (This research), the AS functions for a considerably large number (113 firms or 91.87% of the 123 firms) are significantly nonlinear; and there are only 2 firms (1.63%) with significant linear functions and 8 firms (6.50%) undecided. In contrast, under the assumption of dynamic and variable AS (Lin and Chen, 2024) there are just 62 firms (50.41%) with significant nonlinear functions, 14 firms (11.38%) with significant linear functions, and the remaining 47 firms (38.21%) with AS functions undecided.

TABLE 7
COMPARISON OF THE NUMBERS (PERCENTAGES) OF THE FIRMS WITH SIGNIFICANT LINEAR AND NONLINEAR FUNCTIONS OF ADJUSTMENT SPEED (AS)

Under the assumption of dynamic and variable AS (Lin and Chen, 2024)	Under the assumption of stochastic and dynamic AS (This research)
14 firms (11.38%) with significant linear functions	2 firms (1.63%) with significant linear functions
62 firms (50.41%) with significant nonlinear functions	113 firms (91.87%) with significant nonlinear functions
47 firms (38.21%) undecided	8 firms (6.50%) undecided

In the fourth place, our attention is paid to TABLE 8 to compare the numbers (percentages) of the firms with API_i <1.0 and API_i >1.0.

TABLE 8
COMPARISON OF THE NUMBERS (PERCENTAGES) OF THE FIRMS WITH $API_i < 1.0$ AND $API_i > 1.0$

Under the assumption of dynamic and variable AS (Lin and Chen, 2024)	Under the assumption of stochastic and dynamic AS (This research)
69 firms (56.10%) with $API_i < 1.0$	71firms (57.72%) with $API_i < 1.0$
54 firms (43.90%) with $API_i > 1.0$	52 firms (42.28%) with $API_i > 1.0$
The sample average of the 123	The sample average of the 123
API_i 's $= \sum_{i=1}^{123} API_i/123 = API = 0.9418$	API_i 's $= \sum_{i=1}^{123} API_i/123 = API = 0.9265$
Maximum (API_i) = API_{10} = 2.1287	Maximum (API_i) = API_{113}= 1.8497
Minimum (API_i) = API_{70} =0.0192	Minimum (API_i) = API_{85} =0.0693
R = Range = 2.1095	R = Range = 1.8497 – 0.0693 = 1.7804

(i) There were 71 firms (57.72%) with $API_i < 1.0$ under the stochastic and dynamic AS assumption in comparison to 69 firms (56.10%) with $API_i < 1.0$ under the dynamic and variable AS assumption. The empirical evidence implies that the situation where the US CEOs tend to underpay appears to be more serious under the assumption of stochastic and dynamic AS than under the assumption of dynamic and variable AS.

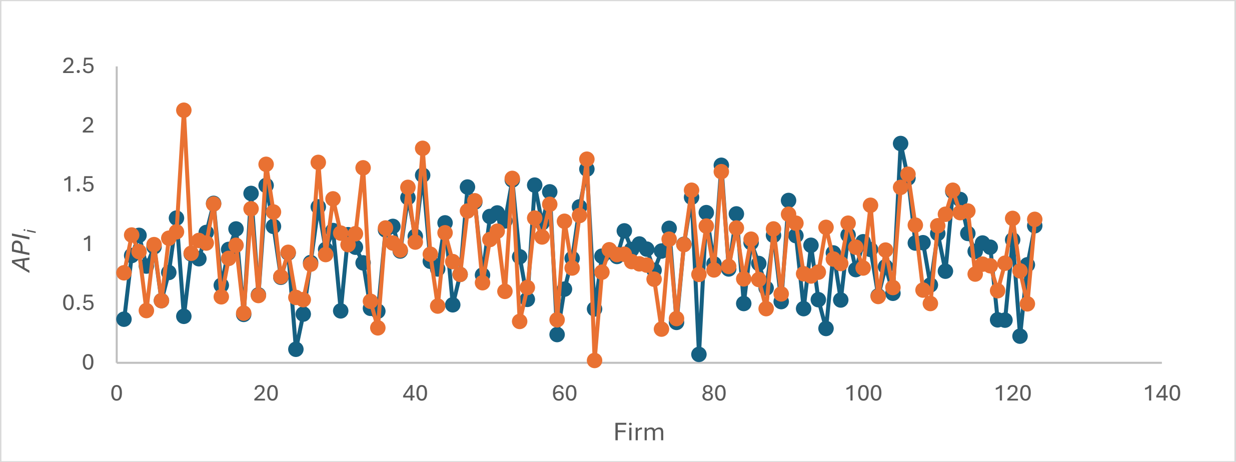
(ii) The same conclusion is reached based on the comparison of the sample average of the 123 API_i's = API = 0.9265 under the assumption of stochastic and dynamic AS to the sample average = 0.9418 under the assumption of dynamic and variable AS.

(iii) The Maximum (API_i) = API_{123} = 1.8497 and the Minimum (API_i) = API_{85} = 0.0693 under the assumption of stochastic and dynamic AS in sharp contrast with the Maximum (API_i) = API_{10} = 2.1287 and the Minimum (API_i) = API_{70} = 0.0192 under the assumption of dynamic and variable AS.

(iv) Consequently, the range of the API_i's is 1.77804 under the stochastic and dynamic AS assumption which is smaller than 2.1075 under the dynamic and variable AS assumption.

In the fifth and final place, it is worth presenting FIGURE 1 to facilitate an easier comparison of the 123 API_i's from the New Model in this research and their counterparts from the Lin and Chen (2024) Model.

FIGURE 1
COMPARISON OF THE API_i's FROM THE NEW MODEL (−) AND THE LIN AND CHEN (2024) MODEL IN JABE (−)



CONCLUDING REMARKS

In this paper, we have presented a new model under the assumption of stochastic and dynamic adjustment speed (AS) as an alternative to the model of Lin and Chen (2024) under the assumption of dynamic and variable to investigate and compare the effects of hi-tech (IT and EC) investments and the time trends of the speeds of adjusting the actual toward the maximum (desired) pay upon CEO compensation.

In particular, we have provided a detailed and comprehensive analysis comparing the estimation results obtained from the two different models developed under quite different assumptions of AS.

Since the real world is featured by a lot of uncertainty (Lin et al., 2019), the stochastic (random) and dynamic AS assumption may be in more conformity with realities in the globe. Of course, further research is called for as the updated data, especially the data on IT, become available.

ACKNOWLEDGEMENTS

We are indebted to the School of Management at the University at Buffalo, The State University of New York, for financial support (Grant No. 9107860600) and to the College of Management at National Sun Yat-sen University for grant support of No. 000C03031. We thank Li Ting Chiu, Yin-Chih. Sun, Y.H. Lin, L.S. Thummata, and Tanushree Agarwal for their excellent research assistance. The contents of this paper are solely our responsibilities.

REFERENCES

Flannery, M.J., & Ragan, K.P. (2006). Partial adjustment toward target capital structure. *Journal of Financial Economics*, *79*, 469–506.

Lin, W.T. (1986). Analysis of Lumber and Pulpwood production in a partial adjustment model with dynamic and variable speeds of adjustment. *Journal of Business & Economic Statistics*, *4*, 305–316.

Lin, W.T., Chen, Y.H., & Chatov, R. (1987). The Demand for Natural Gas, Electricity and Heating Oil in the United States. *Resources and Energy*, *9*, 233–258.

Lin, W.T. (1999). Dynamic and stochastic instability and the unbiased forward rate hypothesis: A variable mean response approach. *Multinational Finance Journal*, *3*, 173–221.

Lin, W.T., Chuang, C.H., & Choi, J.H. (2010). A partial adjustment approach to evaluating and measuring the business value of information technology. *International Journal of Production Economics*, *127*, 158–172.

Lin, W.T., & Kao, T.W. (2014). The partial adjustment valuation approach with dynamic and variable speeds of adjustment to evaluating and measuring the business value of information technology. *European Journal of Operational Research*, *238*, 208–220.

Lin, W.T., Chen, Y.H., & Shao, B.B.M. (2015). Assessing Business Values of Information Technology and E-Commerce Independently and Jointly. *European Journal of Operational Research*, *245*, 815–827.

Lin, W.T., Chen, Y.H., & Huang, T.S. (2019). A partial adjustment valuation approach with stochastic and dynamic speeds of partial adjustment to measuring and evaluating the business value of information technology. *European Journal of Operational Research*, *272*, 766–779.

Lin, W.T., & Chen, Y.H. (2024). Information Technology and Electronic Commerce Investments, Time Trends of the Speeds of Adjusting the Actual Toward the Maximum Pay, and Chief Executive Officer Compensation. *Journal of Applied Business and Economics*, *26*, 77–89.

Nerlove, M. (1958). Distribution lags and demand analysis for agricultural and other commodities. *DC Washington: Agricultural Handbook*, *141*. US Department of Agriculture.

Theil, H. (1971). *Principles of Econometrics*. New York, NY: Willey & Sons.