# Information Technology and Electronic Commerce Investments, Time Trends of the Speeds of Adjusting the Actual Toward the Maximum Pay, and Chief Executive Officer Compensation

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*This research analyzes the effects of information technology (IT) and e-commerce (EC) investments and trends of the speeds of adjusting the observed toward the desired CEO pay in US firms, based on the adjustment model and its associated adjustment valuation (AV) approach, where the adjustment speeds are assumed dynamic and variable. The findings include: the speeds of adjusting the observed toward the unobserved compensation are fast; either IT or EC appearing alone or jointly impacts CEO compensation; the trends of adjustment speeds are nonlinear and nonstationary; and overall, the US CEOs tend to underpay during the period under study; among others.*

*Keywords: dynamic and variable speeds of adjustment, the adjustment valuation (AV) approach, nonlinear and nonstationary time trends of the adjustment speeds, the CEO pay paradox*

## INTRODUCTION

The objective of this paper is twofold. One focuses on the issue of how the decisions made on the information technology (IT) and electronic commerce (EC) investments by the chief executive officers (CEOs) of US firms affect their pay because hi-technology (IT-EC) investments have rapidly increased through time since 1944 (Lin et al., 2015). Two explores the issue of whether the time trends of the speeds of adjusting the actual (observed) toward the maximum (unobserved, desired or expected) CEO pay are nonlinear and/or nonstationary. The two-equation theory of adjustment under the dynamic and variable speeds of adjustment assumption, equipped with an adjustment valuation (AV) approach (Lin, 1986; Lin and Kao, 2014), will be applied to fulfill the objectives.

More importantly, the AV approach provides two useful metrics related to CEO compensation: the firm i's average speed of adjustment (*ASAi*) and average pay index of the firm (*APIi*). The former measures the speed of adjusting the observed (actual) toward the unobserved (expected, desired, or maximum) CEO pay. In contrast, the latter gauges the firm's average CEO pay index over the time considered.

CEO compensation has been a highly controversial problem. Abundant research (e.g., Kostiuk 1990; Brookman and Thistle 2013, Lin and Shi, 2020; Shi et al., 2021; among many others) have sought justifications of CEO pays (see Table 1). But a careful review of the related literature strongly suggests that the literature still has failed to address the two highly important and relevant research issues in this high-tech era as described above. The issues represent a significant research gap that needs to be bridged.

Here, we transform the objective into the answers to four research questions to achieve the research objective. A careful literature review suggests that these four questions' answers, Q1, Q2, Q3, and Q4, are in urgent demand. The research questions are described as follows.

***Q1:*** *How fast does the actual (observed) CEO pay adjust to the target (unobserved, desired or maximum) CEO pay, if the adjustment speeds are dynamic and variable over time? In other words, what are the speeds of adjustment of the actual (observed) compensation toward the maximum (unobserved) compensation when the speeds of adjustment are assumed dynamic and variable? In resolving this question, we seek to find out whether the adjustment speeds are fast (e.g., greater than 1.0) or slow (e.g., smaller than 1.0).*

***Q2:*** *In the high-tech era, do the decisions made by CEOs on EC and IT investments influence the expected (desired or maximum) CEO pay?*

***Q3:*** *Is the pattern of the adjustment speeds of the actual (observed) toward the maximum (unobserved or desired) CEO pay linear (stationary) or nonlinear (nonstationary) over time?*

***Q4:*** *Does the firm i's average pay index (APIi) is greater than or less than one over the time period considered?*

The remainder of the paper is organized as follows. Section 2 offers a review of the relevant literature. Section 3 describes the theoretical foundation, research methodology, research model, two built-in pay metrics, and estimation method. Section 4 presents the panel data used and data sources. Section 5 reports and discusses the empirical results. Section 6 is devoted to the implications to the practice of management. Finally, Section 7 concludes.

## LITERATURE REVIEW

CEO pay has become a highly controversial topic and has attracted much attention in the academic and business world during the past half-century. In the academic community, a great number of research papers are devoted to the debates over, and interpretations or justifications of, how and why CEO compensations have increased rapidly over time. In theory, there are two competing schools (Lin and Shi, 2020; Shi et al., 2021), namely, optimal contracting (OC) (e.g., Kaplan, 2008) and managerial entrenchment (ME) (e.g., Jensen and Mecking, 1976; Shleifer and Vishny, 1989) school. The former theorizes that CEO pay determined by firm performance (measured by net income, return on asset or ROA, earnings, sales, market value, stock returns, etc.) and competitive labor markets. The latter contends that CEOs employ managerial power (e.g., age, CEO talent, and skill, ownership, and tenure) as well as legitimizing factors (e.g., firm size and market risk) to control and manipulate their pay. The list of managerial power and legitimizing factors is lengthy, including CEO power, corporate risk, compensation peer groups, pay design, the importance of the CEO, firm behavior, compensation targets or goals, CEO attributes/turnover threat/risk-taking behavior, corporate governance, technological innovation, taxes (taxation), pension benefit manipulation, etc.

The authors of previous research on the issue of CEO pay may be classified into three groups. The first group belongs to the OC school. Examples in this category include, but are not limited to, Smirnova and Zavertiaeva (2017), Bebchuk et al. (2011), Bennett et al. (2017), and Page (2018). The literature review suggests that OC is a minority group. The complexity of the CEO pay has forced the authors interested in CEO compensations to construct research models mixed by OC and ME (see the third group below).

The second group consists of those authors who own the membership of the ME school. These authors include Faulkender and Yang (2010), Albuquerque et al. (2013), Chen and Ebrahim (2018), Gormley et al.

(2013), Hill et al. (2016), Frydman and Molloy (2011), and Kostiuk (1990). ME has a significant number of authors.

The third group features by hybridism which is a mixture of OC and ME researchers, such as Core et al. (1999), Gabaix and Landier (2008), Gao and Li (2015), Bebchuk et al. (2011), Brookman and Thistle (2013), Smirnova and Zavertiaeva (2017), Page (2018), Lin and Shi (2020), and Shi et al. (2021), among others. The hybridism group is certainly the biggest one. The present study is a member of the third group.

Nevertheless, none of these studies has ever considered the impacts of hi-tech investments (IT and EC) on CEO pay. This is a research gap to be bridged. Moreover, the literature review indicates that the absence of research on the adjustment patterns and speeds of CEO pay over time represents another research gap to fill.

In terms of methodology, most authors have used causal-effect regressions (e.g., Faulkender and Yang, 2010; Albuquerque et al. 2013; Chen and Ebrahim, 2018; among many others). Gabaix and Landier (2008) have proposed a simple mathematical equilibrium model of the CEO pay. In a recent study, Smirnova and Zavertiaeva (SZ, 2017) have constructed a mutual influence of CEO pay and firm performance model estimated by the two-stage least squares (2SLS) method (Pages, 668-670), instead of the three-stage least squares (3SLS) method. According to Shi et al. (2021), the SZ model involves some problems if it is a simultaneous equations system (SES): Is it truly a SES model? Does the identification problem exist (that is, is the model identified? If no, how can 2SLS be applied? How can 2SLS handle their panel data? Because 3SLS is more efficient than 2SLS (Zellner and Theil, 1962; Kmenta, 1997), why do SZ fail to apply 3SLS?

One recent publication of Lin and Shi (2020) has applied a seemingly unrelated regression (known as SUR) approach to analyzing CEO pays for 21 Dow Jones firms. One step further, Shi et al. (2021) have constructed a SES model of CEO pays. In this research, we apply the adjustment valuation (AV) approach based on the two-equation theory of adjustment with dynamic and variable adjustment speeds (Lin and Kao, 2014; Lin 1986).

To position the paper more strongly to articulate its incremental contributions to the literature, we prepare Table 1, a literature review table summarizing the major existing research on CEO compensations. The last row represents the present research. It focuses on the influence of hi-tech (IT-EC) investments and time trends of adjustment speeds upon CEO compensations. In other words, this study aims to analyze the relationships of CEO pays with hi-tech investments and time trends of adjusting the actual (observed) toward the desired (unobserved, expected, or maximum) pay.

**TABLE 1**
**A LITERATURE REVIEW TABLE SUMMARIZING THE MAJOR EXISTING RESEARCH ON CEO COMPENSATION**

| Author(s) (Year) | Influential Factors Considered |
|---|---|
| Child (1974) | Managerial and organizational factors |
| Jensen and Meckling (1976) | Managerial behavior, agency costs, and ownership structure |
| Finkelstein and Hambrick (1988) | A synthesis and reconciliation |
| Shleifer and Vishny (1989) | Management entrenchment: The case of manager-specific investments |
| Boyd (1990) | Corporate linkages and organizational environment |
| Kostiuk (1990) | Firm size |
| Gomez-Mejia and Wiseman (1997) | An assessment and outlook |
| Core et al. (1999) | Corporate governance and firm performance |

| | |
|---|---|
| Attaway (2000) | Relationship between company performance and CEO compensation |
| Tosi et al. (2000) | A meta-analysis of CEO pay and performance |
| Anderson and Bizjak (2003) | The role of the CEO in the firm's compensation committee |
| Henderson et al. (2006) | Industry dynamism, CEO tenure, and company performance |
| Devers et al. (2007) | A multidisciplinary analysis |
| Kaplan (2008) | Firm performance measured by net income, sales, ROA, etc. |
| Frydman and Molloy (2011) | Tax policy |
| Gormley et al. (2013) | Corporate risk |
| Brookman and Thistle (2013) | Luck, skill, or labor markets |
| Quigley and Hambrick (2015) | CEO effect shifts over time |
| Hill et al. (2016) | Firm size and managerial power |
| Bennett et al. (2017) | Pay goals and firm performance |
| Page (2018) | Four CEO attributes |
| Frydman and Papanikolaou (2018) | Technological innovation using traditional labor (L) and capital (K) |
| Song and Wan (2019) | Managerial ability or managerial power |
| Guay et al. (2019) | Performance sensitivities |
| Göx and Homomer (2020) | Managerial power |
| Lin and Shi (2020) | Strategic coopetition and firm performance |
| Shi, Lin, and Pham (2021) | Managerial discretion and firm performance |
| Sheikh (2022) | CEO power |
| Lin and Chen (2024, this manuscript) | Hi-tech (IT-EC) investments and time trends (nonlinearity and/or nonstationarity) of the speeds of adjusting the actual (observed) toward desired (expected, maximum) pay |

As mentioned above, the importance and novelty of the paper lies in the theoretical foundation and methodology, namely, the application of the two-equation theory of adjustment under the assumption of dynamic and variable adjustment speeds, alongside the firm's average pay index (*APIi*) derived from the AV approach.

To sum up, this research compares favorably to the existing literature of CEO compensations in a number of aspects: (i) the theoretical foundation is strong and sound, (ii) the research methodology and model are novel, (iii) the data used are neither just cross-sectional (*i*) nor just time-series over time (*t*), but a panel set (*i, t*) combining *i* and *t*, (iv) unlike the common practice of using sales, *ROA*, and others, to measure firm performance, we employ the metrics (such as *ASAi* and *APIi*) built-in the research approach, derived from two-equation theory of PA, (v) this research links the CEO compensation to two hi-tech variables (IT and EC) for the first time, and (vi) it is also new to explore the trend of the CEO pay adjustment speed through time.

## THEORETICAL FOUNDATION, RESEARCH METHODOLOGY AND MODEL, AND ESTIMATION METHOD

This section outlines the theoretical foundation upon which this research is based, research methodology (approach), built-in pay metrics and estimation method.

### The Two-Equation Theory of Adjustment With Dynamic and Variable Speeds

The one-equation theory of adjustment under the assumption of constant and fixed speeds was originated by Nerlove (1958). Here, in terms of the CEO pay, the Ner love's theory of PA with constant and fixed speeds of adjustment can be stated as follows:

$C_{it} - C_{i,t-1} = \delta_i \left(C^*_{it} - C_{i,t-1}\right) + u_{it},\ i = 1,2,\ldots,m\ and\ t = 1,2,\ldots,n,$ where where $u_{it}$ is a random error, $C_{it}$ is the actual (observed) CEO compensation for firm *i* at time t, $C_{i,t-1}$ is the actual CEO compensation at time *t-1*, $C^*_{it}$ is the desired (maximum or ideal) CEO compensation at time t, and $\delta_i$ is the constant speed for firm *i*. Alternatively, the equation can be rewritten as $C_{it} = \delta_i C^*_{it} + (1-\delta_i)C_{i,t-1} + u_{it},\ i = 1,2,\ldots,m\ and\ t = 1,2,\ldots,n,$ which means that the actual CEO pay is a weighted average of the current period's desired and the previous period's CEO pay, with constant weights equal to $\delta_i$ and $(1-\delta_i)$, respectively. Subsequently, Lin et al. (2010) have proposed an adjustment valuation (AV) approach under the constant and fixed assumption.

Lin (1986) and Lin and Kao (2014) proposed the two-equation theory of adjustment with dynamic and variable speeds. Here, $\delta_i$ is replaced by $\delta_{it}$ and $\delta_{it}$ is expressd as a *g* function of vector $\boldsymbol{Z}_{it}$. Then, we have an adjustment model consisting of two equations as described below:

$$C_{it} = \delta_{it} f\left(\boldsymbol{X}_{it}; \boldsymbol{\beta}_i\right) + (1-\delta_{it})C_{i,t-1} + u_{it}, i = 1,\ldots,m\ and\ t = 1,\ldots,n \quad (1)$$

$$\delta_{it} = \text{g}(\boldsymbol{Z}_{it}; \boldsymbol{\alpha}_i),\quad \delta_{it} \geq 0,\ i = 1,\ldots,m\ and\ t = 1,\ldots,n. \quad (2)$$

Note that $C^*_{it}$ above is now quantified by a function of variable vector $\boldsymbol{X}_{it}$ with unknown coefficient vector $\boldsymbol{\beta}_i$. Equation (1) is the stochastic adjustment equation of the CEO compensation and Equation (2) is the function of dynamic and variable adjustment speeds, or a function of variable vector $\boldsymbol{Z}_{it}$ with unknown coefficient vector $\boldsymbol{\alpha}_i$. As such, the adjustment speeds are no longer fixed and constant. Equations (1) and (2) may be combined into a single regression model.

The second component of the adjustment value (AV) approach under the assumption of dynamic and variable speeds is composed of Equations (1) and (2) and the pay metrics which are described in Subsection 3.2 below.

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### Two Built-In Pay Metrics

One of the built-in pay metrics, called the average speed of adjustment ($ASA_i$) is particularly useful for this research on CEO compensation. Here, we describe it in detail.

Given the estimates of $\boldsymbol{\alpha}_i$, denoted by $\widehat{\boldsymbol{\alpha}}_i$, then using Equation (2), we can obtain the estimates of the dynamic and variable speeds over time for firm *i* at time *t* as described by

$$\widehat{\delta}_{it} = \text{g}(\boldsymbol{Z}_{it}; \widehat{\boldsymbol{\alpha}}_i),\ i = 1,\ldots m\ and\ t = 1,\ldots,n. \quad (3)$$

Then, the estimated average speed of adjustment for firm *i* ($ASA_i$)can be calculated via

$$ASA_i = \sum_i g(\boldsymbol{Z}_{it}, \widehat{\boldsymbol{\alpha}}_i)/n, \quad ASA_i \geq 0. \tag{4}$$

We interpret $ASA_i$ >1.0 as fast and $ASA_i$ <1 as slow for firm *i*. Thus, the grand average speed of adjustment for all m firms is given by

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

A second built-in CEO pay index can be constructed as follows. Step1: Define $PV_{it} = g(\boldsymbol{Z}_{it}, \widehat{\boldsymbol{\alpha}}_i) f(\boldsymbol{X}_{it}; \widehat{\boldsymbol{\beta}}_i)$, the product of *g* and *f*. Step 2: Define $PI_{it} = PV_{it}/lnC_{it}$ as the *i*th firm's CEO pay index at time *t*. Step 3: Define the average pay index ($API_i$) of the *i*th firm as

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

We interpret $API_i$>1.0 as the indication that the CEO compensation is excessive in firm *i* for the time period under study. It follows that the grand (overall) pay index can be expressed as

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

**Research Model**

Based on the research methodology as outlined in the preceding Subsections, we can readily construct the following research model in order to answer the four research questions as identified in the Introduction Section. Using Equations (1) and (2), we can construct a two-equation research model as follows.

Let $\boldsymbol{X}_{it} = (IT_{it}, EC_{it})$ and $\boldsymbol{Z}_{it} = (t, t^2)$ with *t* being the time trend variable. Then, we have the research model described by:

$$C_{it} = \delta_{it} f\left(IT_{it}, EC_{it}; \boldsymbol{\beta}_i\right) + (1 - \delta_{it}) C_{i,t-1} + u_{it}, \tag{8}$$

$$\delta_{it} = g(t, t^2; \boldsymbol{\alpha}_i), \;\; \delta_{it} \geq 0, \tag{9}$$

where $E(u_{it}) = 0$ for all *i* and *t* and $V(u_i) = \sigma_{ui}^2$. Alternatively, Equations (8) and (9) may be combined into a single equation as follows:

$$C_{it} = f(\cdot) g(\cdot) + \left(1 - g(\cdot)\right) C_{i,t-1} + u_{it}. \tag{10}$$

Note that in Equations (10), $f(\cdot)=f(IT_{it}, EC_{it}; \boldsymbol{\beta}_i)$ and $g(\cdot) = g(t, t^2; \boldsymbol{\alpha}_i)$.

**Estimation**

The research model under the assumption of dynamic and variable adjustment speeds is estimated by the nonlinear maximum likelihood (NML) method (Lin and Kao, 2014). It is noted that in our estimation work, the $g(\cdot)$ function is, by assumption, a quadratic form, while the $f(\cdot)$ is assumed linear.

## PANEL DATA

The annual data used involve 123 U.S. firms from 1999 to 2012, collected from different data sources. Consequently, the panel sample is composed of 1,722 observations. Originally, we secured a sample of 133 firms, but ten firms were deleted because the estimation processes for these ten firms fail to converge. These ten firms are firm Nos. 8, 19, 29, 36, 48, 58, 80, 98, 116, and 125. The availability of the data on IT constrains the ending year of the time period.

The total Execucomp Annual compensation ($C_{it}$) and EC investments ($EC_{it}$) were collected from the COMPUSTAT database using the Wharton Research Data Services (WRDS); and IT investment ($IT_{it}$) was obtained from Information Week 500 (IW500). The total compensation is the sum of salary, bonus, restricted stock grants, LTIP payouts, value of option grants, and all others. The sum is usually referred to as Type 2 compensation. Time t ant t2 data are generated as follows: $t$=1 for 1999, 2 for 2000, …, 14 for 2012; then $t^2=1^2=1$ for 1999, $2^2=4$ for 2000, …, $14^2=196$ for 2012. Note that both the time period considered, and the sample firms chosen were constrained by the availability of the data on IT and that all the data on $C_{it}$, $IT_{it}$, and $EC_{it}$are expressed in terms of millions of 2005 US dollars.

## RESULTS AND DISCUSSION

### Estimation Results

In the interest of space, the estimates of the research model are presented in Appendix A (6 pages) as a supplement (available upon request), because the main results of the table are shown in Tables 2, 3, 4, and 5. Here, we simply present a summary of Appendix A as follows. The empirical results reported in Appendix A include coefficient estimates and their t-statistics, $ASA_i$ via Equation (4), $ASA$ via Equation (5), $API_i$ from Equation (6), and API from Equation (7). A careful review of the results reveals that: (i) IT and EC have varying effects upon the desired (maximum or expected) pay ($C^*_{it}$), (ii) the time trend patterns (linear or stationary and nonlinear or nonstationary) of the functions of the speeds of adjusting the actual toward the desired compensation differ from firm to firm (see the detailed discussion undertaken in the next subsection below), and (iii) overall, the average of 123 $R^2$s is, 0.6568.

We now turn to discussing the results to answer the four critical research questions posed to be resolved at the very outset.

### Discussion

First, we attempt to analyze the answer to the first question **(Q1)**, namely, *Are the speeds of the adjustment of the observed (actual) CEO pay toward the unobserved (target or desired) CEO pay fast (greater than 1.0) or slow (smaller than 1.0), under the assumption that the adjustment speeds are dynamic and variable over time?* To answer this question, we refer to the *ASA*i estimates. Based on the estimates of *ASA*i, we construct Table 2 to show the percentage distributions of the firms with fast (*ASA*i>1.0) and slow (*ASA*i<1.0) adjustment speeds. We observe the following points of interest from the percentage distributions shown in Table 2.

**TABLE 2**
**PERCENTAGE DISTRIBUTIONS OF THE FIRMS WITH FAST AND SLOW ADJUSTMENT SPEEDS**

| % (number) of Firms with $ASA_i$>1.0 (fast) | % (number) of Firms with $ASA_i$<1.0 (slow) |
|---|---|
| Nos. 3, 7, 9, 10, 12, 13, 14, 16, 17, 20, 22, 23, 30, 32, 33, 34, 35, 37, 40, 41, 42, 43, 44, 45, 46, 49, 52, 53, 55, 56, 57, 59, 62, 63, 64, 66, 67, 68, 69, 71, 72, 74, 76, 81, 84, 85, 86, 88, 90, 92, 95, 97, 99, 103, 106, 107, 108, 109, 111, 113, 114, 119, 120, 121, 122, 123, 124, 130, and 133 (69 firms or 56.10%) | Nos. 1, 2, 4, 5, 6, 11, 15, 18, 21, 24, 25, 26, 27, 28, 31, 38, 39, 47, 50, 51, 54, 60, 61, 65, 70, 73, 75, 77, 78, 79, 82, 83, 87, 89, 91, 93, 94, 96, 100, 101, 102, 104, 105, 110, 112, 115, 117, 118, 126, 127, 128, 129, 131, and 132 (54 firms or 43.90%) |

(i) We take firm Nos. 2 and 82 as illustrative examples. For firm No.2, ASA1=0.4868<1.0 (slow), while for firm No.82, *ASA*82=0.3135<1.0 (slow). In other words, the adjustment speed of firm No.2 is small than 1.0 and the adjustment speeds of firm No.82 is also less than 1.0.

(ii) As shown in Table 2, the percentage distribution of the firms with fast (>1.0) adjustment speeds is 56.10% (=69/123*100). In other words, the percentage distribution of those firms with slow speeds (<1.0) of adjustment is 43.90% (=54/123*100).

(iii) The overall (grand) $ASA$ is equal to 1.0539 which is slightly greater than, but very close to 1.0.

Second, we address the second question **(Q2)** with respect to whether IT and EC impact the desired (expected or maximum) CEO pay. This Q2 is divided into three sub-questions: in the joint presence of IT and EC investments,

***Q2-1:*** *Does IT alone have significant effects upon the desired CEO pay at the 10%, 5%, or 1% level of significance?*

***Q2-2:*** *Does EC alone have power to significantly influence the desired CEO pay at the same levels of significance?*

***Q2-3:*** *Do IT and EC jointly affect significantly the desired CEO pay at the same three levels of significance?*

To answer Q2-2, we must check the significance of the estimates of the coefficient $\beta_{2i}$ of EC: Yes, for firm Nos. 6, 7, 8, 14,15, 22, 27, 28, 30, 32, 35, 41, 49, 62, 79, 89, 90, 91, 92, 97, 101, 101, 102, 103, 108, 115, 124, 129, and 133, meaning that 28 firms or 28/123=22.76% of the sample firms have earned a positive answer.

In contrast with the conclusions reached for Q2-1, we find that the number of firms where EC has significantly affected the desired CEO pay has been more than double than IT.

To answer Q2-3, it is necessary for us to examine the significance (at the 10%, 5% and 1% levels) of the estimates of both $\beta_{1i}$ and $\beta_{2i}$ for IT and EC simultaneously as follows.

Yes is given to firm Nos. 4, 16, 33, 38, 44, 55, 66, 75, 85, 100, 107, 109, 110, 120, 128, and 130, or only 16 (16/123=13.01% of the 123) business organizations have secured a Yes answer.

A comparison of the answers to Q2-3 with their counterparts of Q2-2 suggests that the number of firms, where the joint presence of IT and EC has significantly impacted their desired CEO pays, has declined.

Third, we turn to research Q3, Are the adjustment speeds function linear (stationary) or nonlinear (and hence nonstationary)? The question can be answered by observing the statistical significance of $\hat{\alpha}_{1i}$ (the coefficient of t) and $\hat{\alpha}_{2i}$ (the coefficient of $t^2$). If $\hat{\alpha}_{1i}$ is significant but $\hat{\alpha}_{2i}$ is insignificant, at the 10%, 5% or 1% level, then the function is linear; and if only $\hat{\alpha}_{2i}$ or both $\hat{\alpha}_{1i}$ and $\hat{\alpha}_{2i}$ are significant, at the 10%, 5%, or 1% level, then the function is nonlinear (and nonstationary). Note that Q3 is highly relevant. To answer this question, we set up Table 3 to summarize the firms with linear or nonlinear (nonstationary) adjustment speeds functions.

**TABLE 3**
**A SUMMARY OF FIRMS WITH LINEAR AND NONLINEAR FUNCTIONS OF ADJUSTMENT SPEEDS**

| Firms with significant linear function | Firms with significant nonlinear Function |
|---|---|
| Nos. 2, 15 20, 21, 25, 27, 49, 52, 61, 67, 92, 106, 123, and 132 (14 firms or 11.38%) | Nos. 1, 3, 4, 5, 6, 7, 9, 12, 16, 23, 24, 28, 30, 31, 32, 33, 38, 42, 44, 45, 50, 53, 55, 56, 60, 62, 63, 64, 65, 66, 68, 69, 70, 71, 72, 75, 77, 78, 81, 82, 85, 91, 100, 101, 103, 105, 107, 110, 111, 113, 115, 117, 118, 120, 122, 124, 126, 128, 129, 130, 131, and 133 (62 firms or 50.41%) |

The summary of Table 3 clearly indicates that 62 firms or 50.41% of the 123 sample firms require a nonlinear function of adjustment speeds in comparison with only 14 (or 11.38% out of 123) firms whose adjustment speeds functions are linear. The nonlinearity of the adjustment speeds for a significant majority of the sample firms suggests that the adjustment speeds are nonstationary. Such nonstationarity has important consequences for $\delta_{it}$ according to Box and Jenkins (1976).

Fourth, we employ Tables 4 and 5 to answer Q4. Table 4 summaries the $API_i$'s from the research model. Then, based on Table 4, Table 5 is set up to classify the123 firms into two groups: one group contains the sample firms with $API_i$'s less than 1 and the other group is composed of the sample firms with $API_i$'s greater than 1.

**TABLE 4**
**COMPARISONS 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 | 0.7581 | 37 | 1.6426 | 71 | 0.7637 | 105 | 0.8374 |
| 2 | 1.0770 | 38 | 0.5185 | 72 | 0.9521 | 106 | 1.1776 |
| 3 | 0.9363 | 39 | 0.2937 | 73 | 0.9130 | 107 | 0.9730 |
| 4 | 0.4404 | 40 | 1.1355 | 74 | 0.9161 | 108 | 0.7984 |
| 5 | 0.9969 | 41 | 1.0103 | 75 | 0.8537 | 109 | 1.3270 |
| 6 | 0.5236 | 42 | 0.9495 | 76 | 0.8336 | 110 | 0.5599 |
| 7 | 1.0506 | 43 | 1.4792 | 77 | 0.8245 | 111 | 0.9492 |
| 9 | 1.1043 | 44 | 1.0181 | 78 | 0.7031 | 112 | 0.6330 |
| 10 | 2.1287 | 45 | 1.8071 | 79 | 0.2834 | 113 | 1.4792 |
| 11 | 0.9241 | 46 | 0.9141 | 81 | 1.0411 | 114 | 1.5899 |
| 12 | 1.0303 | 47 | 0.4779 | 82 | 0.3719 | 115 | 1.1604 |
| 13 | 1.0107 | 49 | 1.0952 | 83 | 0.9957 | 117 | 0.6137 |
| 14 | 1.3384 | 50 | 0.8521 | 84 | 1.4554 | 118 | 0.4995 |
| 15 | 0.5562 | 51 | 0.7456 | 85 | 0.7444 | 119 | 1.1551 |
| 16 | 0.8799 | 52 | 1.2782 | 86 | 1.1513 | 120 | 1.2535 |
| 17 | 0.9892 | 53 | 1.3655 | 87 | 0.7839 | 121 | 1.4538 |
| 18 | 0.4173 | 54 | 0.6752 | 88 | 1.6104 | 122 | 1.2648 |
| 20 | 1.2977 | 55 | 1.0379 | 89 | 0.8136 | 123 | 1.2803 |
| 21 | 0.5654 | 56 | 1.1085 | 90 | 1.1358 | 124 | 0.7464 |
| 22 | 1.6721 | 57 | 0.6007 | 91 | 0.7061 | 126 | 0.8307 |
| 23 | 1.2713 | 59 | 1.5552 | 92 | 1.0429 | 127 | 0.8170 |
| 24 | 0.7258 | 60 | 0.3477 | 93 | 0.7028 | 128 | 0.6075 |
| 25 | 0.9311 | 61 | 0.6341 | 94 | 0.4570 | 129 | 0.8391 |
| 26 | 0.5499 | 62 | 1.2196 | 95 | 1.1282 | 130 | 1.2161 |
| 27 | 0.5309 | 63 | 1.0603 | 96 | 0.5793 | 131 | 0.7757 |
| 28 | 0.8305 | 64 | 1.3356 | 97 | 1.2536 | 132 | 0.4967 |
| 30 | 1.6897 | 65 | 0.3604 | 99 | 1.1775 | 133 | 1.2079 |
| 31 | 0.9110 | 66 | 1.1923 | 100 | 0.7490 | | |
| 32 | 1.3826 | 67 | 0.7982 | 101 | 0.7323 | | |
| 33 | 1.0924 | 68 | 1.2423 | 102 | 0.7649 | | |
| 34 | 0.9966 | 69 | 1.7169 | 103 | 1.1410 | | |
| 35 | 1.0886 | 70 | 0.0192 | 104 | 0.8732 | | |

**TABLE 5**
**FIRMS WITH $API_i$ <1 AND FIRMS WITH $API_i$> 1**

| Firms with $API_i$ <1 | Firms with $API_i$ >1 |
|---|---|
| Nos. 1, 3, 4, 5, 6, 11, 15, 16, 17, 18, 21, 24, 25, 26, 27, 28, 31, 34, 38, 39, 42, 46, 47, 50, 51, 54, 57, ,60, 61, 65, 67, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 82, 83, 85, 87, 89, 91, 93, 94, 96, 100, 101, 102, 104, 105, 107, 108, 110, 111, 112, 117, 118, 124, 126, 127, 128, 129, 131, 132 | Nos. 2, 7, 9, 10, 12, 13, 14, 20, 22, 23, 30, 32, 33, 35, 37, 40, 41, 43, 44, 45, 49, 52, 53, 55, 56, 59, 62, 63, 64, 66, 68, 69, 81, 84, 86, 88, 90, 92, 95, 97, 99, 103, 106, 109, 113, 114, 115, 119, 120,, 121, 122, 123, 130, 133 |
| Sub-total: 69 (56.1%) | Sub-total: 54 (43.90%) |
| Total = 69 + 54 = 123 | |

We can observe the following points of interest from Table 4 and 5.

(i) The maximum *APIi* goes to Firm No.10, that is, *API10* =2.1287, while the minimum *APIi* belongs to Firm No. 79, namely, *API79* =0.2834, thereby, the range (R) being 1.8453.

(ii) The overall *API* of the sample firms is 0.9418 which is less than 1.

(iii) The *APIi* of 69 firms or 56.10% of the sample firms were less than 1 and the APIi's of 54 firms or 43.90% of the sample firms were greater than 1. It is noted that the *APIi's* of three firms (2.44% of the sample firms), namely, Firm Nos. 5, 34, and 83 were 0.9969, 0.9966, and 0.9957, respectively, which are very close to 1.

**Important Implications to the Practice of Management**

There are differences in numbers and estimates and, therefore, managerial implications can be derived from different numbers and estimates.

In the first place, the answer to Q1 implies that the overall speed (1.0539) of adjusting the observed (actual) toward the unobserved (maximum or desired) CEO pay is nearly normal and is not excessive during the period under study.

In the second place, the answers to Q2-1 and Q2-2 imply that IT is less important than EC as revealed by comparing 16 firms from the answer to Q2-1 with 28 firms from the answer to Q2-2. Moreover, the answer to Q2-3 implies that IT and EC are complementary because, in the joint presence of IT and EC, the number of firms with significant estimation coefficients of $\beta_{1i}$ (of IT) and of $\beta_{2i}$ (of EC) is just 16. This finding supports the conclusion of Lin et al. (2015) that in the joint presence of IT and EC investments, the presence of EC may enhance (reduce) IT value, thereby complementarity (substitutability), and vice versa. Since these phenomena are related to CEO pays, we call these phenomena as the CEO compensation paradox.

In the third place, the answers to Q3 imply that the number of firms facing a nonlinear and nonstationary function of adjustment speeds is 62 firms or 50.41% of the sample firms. In particular, the finding that the adjustment speed function is characterized by nonlinearity (and hence nonstationarity) also implies that the CEO pay is a complex matter and may simply be accelerated by the nonlinear trend over time. In particular, the nonstationary trend is an important finding that means a lasting imprint on CEO pay which can't be possibly and/or accurately explained by managerial behavior (Jenkins and Meckling,1976), firm size (Kostiuk, 1990; Hill et al., 2016), managerial power (Song and Wan, 2019), firm performance (Attaway, 2000; Handerson et al., 2006), CEO attributes (Page, 2018), CEO power (Sheikh, 2022), strategic coopetition (Lin and Shi, 2020), managerial discretion (Shi et al., 2021), etc.

In the fourth place, the results of Tables 4 and 5 and the overall *API* of 0.9418 (which is less than 1) imply that during the period under consideration, the CEOs were underpaid. The results shown in Tables 4 and 5 further imply that CEO compensation is hard to measure by CEO performance and the factors mentioned in the third place above, such as firm size, company performance, CEO power, etc.

## CONCLUSION

The objective of this research is twofold: one is to assess the influence of high-tech (IT and/or EC) investments on CEO compensation, and, two is to identify the time patterns of the functions of adjustment speeds, that is, the function of the speeds of adjusting the actual (observed) CEO pay toward the desired (unobserved) CEO pay, using the AV approach based on the theory of adjustment under the assumption of dynamic and variable speeds.

The achievement of the objective has been made possible using the theory of adjustment accompanied by the adjustment valuation (AV) approach. The adjustment theory provides the theoretical foundation, and the AV approach (based on the adjustment theory) offers the pay metrics (*APIi* and *ASA*i). A novel theoretical foundation is needed for an empirical work such as this research.

Our empirical results from 123 US companies suggest that the adjustment speeds of a significant majority of the firms considered are fast (>1.0), that the impacts of high-tech investments upon CEO compensation vary with whether IT and EC are present alone or jointly, and that the functions of adjustment speeds are found nonlinear (and nonstationary) for 62 out of 123 firms under the dynamic and variable adjustment speeds assumption. Consequently, the empirical evidence implies that CEO compensation in US firms seems difficult to assess using such factors as ownership structure, firm size, CEO tenure, company performance, CEO attributes, managerial power, managerial discretion, etc. In conclusion, we raise two research questions related to CEO compensation for future research. First, can CEO compensation be justified by select economic factors and CEO ages? Second, do CEO compensation, IT, and EC impact firm performance? To answer the second question, the research models may be developed to equip with the Box-Tidwell (1962) transformation production function (cf. Lin et al., 2023).

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**Highlights**

1. The adjustment valuation approach based on the theory of adjustment under the dynamic and variable speeds assumption is applied and the results are analyzed and compared.
2. The speeds of adjusting the actual toward the expected CEO pay are fast (greater than 1.0) for 56.10% of the sample firms in comparison to 43.9% of the sample firms with slow speeds (less than 1.0).
3. The results imply that either EC or IT alone or the joint presence of EC and IT impacts CEO compensation differently.
4. The time trends of adjustment speeds are nonlinear and nonstationary for a significant majority of the sample firms.
5. Among others, one practical implication is that the CEOs in US firms tend to underpay during the time period considered.

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